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The Rising Hope of Our Land

Proceedings

Southern Region
No-Till Conference
July 16-17, 1985
Griffin, Georgia

Proceedings

of the

1985
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Edited by

W. L. Hargrove and F. C. Boswell

Agronomy Department, Georgia Agricultural Experiment Station,
Experiment, GA 30212

and

G. W. Langdale

USDA-ARS, Southern Piedmont Conservation Research Center,
Watkinsville, GA 30677

Contributors

Field Programs Branch, Tennessee Valley Authority
Environmental Protection Agency
Georgia Commodity Commission for Soybeans

Preface

The objective of the Southern Region No-Tillage Conference is to promote no-tillage production systems by providing a means of communication between research, extension, conservation, and industry personnel and agricultural producers from the thirteen states in the Southern region. "The Rising Hope of Our Land" is from the preamble to the charter of the University of Georgia written by Abraham Baldwin in 1785. In this year of the Bicentennial of the University, it is a fitting theme for this Conference. Not only does it verbally symbolize the College of Agriculture and its resources in teaching, research, and service, but it expresses the hope of success in soil conservation and productivity offered by no-tillage production methods - hope for our land, for our farmers, for our future.

The first no-tillage conference was held among seven southeastern states in 1978 and was hosted by the Georgia Station. This year marks a new beginning with an expanded conference, which includes all thirteen states in the Southern region. The Georgia Station is honored to be the site of the 1985 conference. It is our hope that this publication will be effective in accomplishing the objective of the conference.

W. L. Hargrove
W. L. Hargrove
Associate Professor, UGA

F. C. Boswell
F. C. Boswell
Professor, UGA

G. W. Langdale
G. W. Langdale
Soil Scientist
USDA-ARS

1785-1985

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Conservation Tillage Equipment

Equipment for No-Tillage Crop Production

Fred D. Tompkins

Agricultural Engineering Department, University of Tennessee

The first planter system designed specifically for no-tillage farming was introduced in the commercial market almost two decades ago (Agrichemical Age, 1982). Since then, an impressive variety of machines and component options have been developed and manufactured. Illustrating this extensive evolution is the fact that there are currently commercially available more than 4,000 different combinations of coulters, openers, covering disks, presswheels, and other components for row planters alone (Successful Farming, 1983b). In spite of this proliferation of available machinery, many of the perceived problems associated with no-tillage production are equipment related. In a survey conducted by Pioneer Hi-Bred International, the three most important reasons farmers gave for opposing conservation tillage were (1) inadequate weed control, (2) high chemical costs, and (3) lack of proper equipment (Agrichemical Age, 1983). Better equipment was listed by 34 percent of the respondents to that same survey as a technological factor that could influence farmers to increase conservation tillage practices.

A 1982 survey of 509 West Tennessee farmers was conducted to identify the crop producers' views of the advantages and disadvantages of no-tillage production techniques (Leuthold and Hart, 1984). Farmer response to eight listed disadvantages are summarized by user category in Table 1. Note that several of the major disadvantages of no-tillage as perceived by farmers are either directly or indirectly related to machinery.

Table 1. Proportion of West Tennessee farmer survey respondents who perceived various problems of no-tillage as major disadvantages

Disadvantages of No-tillage	All Farmers (N-509)	User Category Former Users (N-54)	Nonusers (N-156)	Continued Users (N-223)
	percentage			
1. Increased chemical costs	60.5	64.8	57.1	57.9
2. Weed control problems	49.5	59.3	60.3	40.4
3. Cost of no-till equipment	37.5	42.6	48.7	27.4
4. More difficult to manage	29.9	35.2	37.2	25.1
5. More precise planting needed	19.3	27.8	18.6	17.4
6. Necessity of also keeping conventional planters	19.3	27.8	27.6	13.5
7. Spray residues	13.6	24.1	20.5	7.6
8. Yield variability	13.0	22.2	18.0	6.7

Long regarded as vital to the success of any no–tillage crop production system is the ability to (1) establish adequate plant stands and (2) effectively control the crop pests, most notably weeds. Neither of these tasks is easily accomplished in a practical sense without proper equipment and good machinery management. Consequently, both researchers and manufacturers have continually sought to develop more effective planting and chemical application equipment and to identify widely reliable operating procedures for that equipment. In the past few years, considerable attention has been given to developing fertilizer application equipment to meet the unique requirements of no–tillage cultural practices. An overview of the available equipment and recommended operating procedures in the general areas of planting, spraying, and fertilizer application for no–tillage is presented below.

PLANTING EQUIPMENT

No–tillage planters generally feature more rugged construction, have more soil–contacting components or assemblies, and consequently cost 15 to 25 percent more than conventional planters (Mowitz, 1985). The principal functions of a no–tillage planter are to prepare a seed zone in previously untilled soil and to place crop seeds such that an adequate stand of plants in an acceptable pattern is established. General preparation of the seed zone is the function of the primary furrow opener which may be a passive rolling coulter, a powered coulter, a powered tiller, a rigid blade or shank, or some combination of these. Passive rolling coulters (smooth, serrated, ripple, or fluted) are by far the most widely used primary furrow openers. The coulter should cleanly cut through surface residue without pushing portions of the residue down into the opened slot. Studies have indicated that plant residue pressed into the furrow results in reduced seedling emergence because the residue prevents the seed–soil contact necessary for germination (Sanford, 1982). Thus, coulter edges should be kept sharp. Some research suggests that clearing the residue from a narrow strip in front of the furrow opener can be advantageous in enhancing germination (Mangold, 1985). Attachments featuring tines or disks designed for clearing away residue in the path of the furrow opener are widely available but may be more useful in reduced tillage planting than in no–tillage environments.

The coulter should uniformly penetrate the soil to a depth somewhat greater than the depth of desired seed placement. When the soil is especially hard, achieving this penetration may require the addition of a substantial quantity of ballast, perhaps 400 to 500 pounds per row.

Debate over which type of coulter is best for a particular planting situation continues. Smooth coulters require less force to cut heavy residue and to penetrate hard, dry soil than do wider ripple and fluted coulters (Erbach and Choi, 1983). Smooth coulters, on the other hand, open a very narrow slot and perform little tillage within the slot. Wider fluted and ripple coulters perform more tillage and produce more loose soil but tend to be more speed sensitive than smooth coulters. At high operating speeds and with certain soil moisture conditions, wider coulters tend to throw soil out of the furrow. This soil displacement is undesirable for at least two reasons: (1) loose soil needed to cover the seed is effectively lost, and (2) soil thrown out of the furrow makes maintaining a uniform seeding depth more difficult. The general trend is toward the narrower coulter design (smooth, ripple, or fluted) because research indicates that a narrow slot results in more precision in seed placement and that the narrow coulters function better over a wider range of planting conditions (Successful Farming, 1983b). Multiple coulters are sometimes used for opening and conditioning the furrow. In the usual scheme, a smooth coulter in front cuts the residue and creates a slot in the soil while a following ripple or fluted coulter provides additionial tillage within the slot. The overall distance from the leading furrow opening device to the rear–most soil–contacting component on the planter should be as short as possible to insure proper tracking when planting on the contour.

The primary furrow opening assembly may include a shank to provide deep tillage directly under the crop row. Studies have shown that in–row subsoiling may be necessary to obtain no–till crop yields comparable to conventional tillage yields in soils particularly susceptible to compaction and plow pan formation (Touchton arid Johnson, 1982). A smooth coulter is usually mounted in front of the shank to cut the surface residue, initiate slot formation, and prevent collection of trash on the shank. Attachments behind the shank are necessary to insure that the deep slot is completely refilled with moderately compacted soil; otherwise, uniformity of seeding depth is likely to be difficult to achieve.

Disk–type planter openers are typically used on no–tillage units, although runner openers are successfully employed on some models. Double–disk planter openers are generally preferred behind rolling coulters because they disturb relatively little soil and cut through the residue well. At least one commercial planter model employs an offset double–disk opener designed to penetrate the untilled soil directly without benefit of a leading coulter for opening a slot. Depth control at the planter opener is important in assuring uniformity in the depth of seed placement. Best results are obtained when depth' is controlled for each planter unit independently and when the depth control device is located very near the planter opener.

Furrow closing devices and press wheels are used to insure that the deposited seed are covered with soil and that the soil is brought firmly in contact with the seed. The difficulty in closing the furrow behind the planter opener depends upon the characteristics of the soil, especially the moisture content. To vividly illustrate the importance of the operating conditions, consider the results of Tennessee tests evaluating commercial no–tillage planter performance in seeding soybeans in wheat stubble. A planter equipped with a pneumatic center–rib press wheel operated in Calloway silt loam at 21 percent moisture (db) failed to adequately close the furrows leaving an average of 28 percent of the seeds exposed while a similarly equipped planter operated in Memphis silt loam at 20 percent moisture achieved complete furrow closure and excellent seed coverage. In these same tests, aggressive covering devices (multiple press wheels and furrow closure disks) tended to cover a greater percentage of metered seed under dry soil conditions than a single press wheel design (Bell, 1984). The press wheel should assure that the soil is firmed around the seed to establish seed–soil contact without excessively compacting the soil through which the seedling must emerge.

SPRAYING EQUIPMENT

Herbicide formulations applied for no-tillage planting should be delivered so as to accomplish two things: (1) thorough coverage of the foliage of existing vegetation to effect post emergence control and (2) uniform penetration of surface residue enroute to the soil surface to establish preemergence weed control. Specific studies with metribuzin and atrazine indicated that less than 50 percent of the chemicals penetrated the straw and stubble and reached the soil surface (Ghadiri et al., 1984; Banks and Robinson, 1982). Results of a study examining straw and stubble penetration using flat fan nozzles to apply 10 to 30 gallons per acre showed that the percentage of chemical reaching the soil increased as application rate increased (Gerling and Solie, 1984). While the operating pressure did not affect the percentage penetration, the quantity of surface residue did have a pronounced effect. Some sources suggest application rates as high as 60 gallons per acre where vegetation is heavy or growth is rank (Successful Farming, 1983a). Yet there is tremendous interest in and considerable research related to the use of relatively low volume application in no-tillage. Centrifugal-type droplet forming devices known as controlled droplet applicators (CDA), which generate small droplets relatively uniform in size, are currently being widely marketed as low volume applicators. Several studies, including one in Tennessee, where soybeans were no-till seeded in wheat stubble, showed that weed control obtained with 4 gallons per acre was equal to that obtained with applications of 20 gallons per acre. Furthermore, low volume applications with flat fan nozzles were just as effective as those made with CDA. Among the disadvantages cited by critics of CDA are poor canopy or stubble penetration and enhanced drift potential naturally associated with small droplets. Perhaps Gordon Berg (1985) in a recent article summarized the question of CDA versus conventional spray application best by noting that "the jury is still out."

Experimental air-assist nozzles which employ a stream of compressed air to aid in formation and delivery of droplets to the target surface have been introduced as low volume application units. The droplets are delivered from a modified flood tip in a tapered edge flat spray pattern for broadcast application. Design modifications to the prototype nozzles continue to be made based upon the results of field and laboratory tests.

Renewed interest has been shown in postemergence directed sprayers for use in no-tillage crops. While effective over-the-top postemergence herbicides have been made widely available, postemergent directed spraying may still offer an economically attractive alternative from the standpoint of total cost of herbicides required to produce a crop. However, many row crops currently grown no-tillage are seeded in rows spaced 20 inches or less. In a Tennessee study, six commercial and experimental directed spray applicators were evaluated for effectiveness of operation in soybeans planted with 20-inch row spacing. Each of the sprayers featured devices for shielding the soybean plants from the spray being applied between the crop rows. Recommended nozzle tips ranged from flood-type to flat fan and even spray. Study results indicated that with careful management directed spraying is a feasible alternative in 20-inch rows and that a good selection of appropriate equipment is commercially available.

New equipment for injecting chemical concentrate into the fluid circuit near the point of spray discharge from the machine is being introduced in the marketplace. The overwhelming advantage of this technology is that an operator can put a bulk container of chemical on the sprayer and inject the material right in the field, eliminating the necessity for tank mixing and disposal of excess liquid. Some experts suggest that there remain several problems to resolve before direct chemical injection systems become commomplace. However, most agree that such systems offer tremendous potential for increasing the efficiency and safety of chemical application generally.

While there are presently available radar speed detectors, sprayer monitors, and electronic control systems designed to enhance the precision of chemical application, a recent study in Nebraska revealed that 60 percent of the applicators surveyed missed their estimated application rate by more than 10 percent. About a third overapplied by more than 10 percent with an average error of 30 percent (Agrichemical Age, 1985). While farmers must stay abreast of changes in technology, this and similar studies indicate that attention should be given to maintaining chemical application equipment in good working condition and to proper calibration and operation of the equipment.

FERTILIZER APPLICATION EQUIPMENT

Fertilizer application on the soil surface has been the general practice in no-tillage historically. Certain nitrogenous fertilizers were not used because of the significant nutrient loss due to volatilization. There was also the suggestion that the presence of crop residues on the soil surface made the nitrogen less available for crop use. Some studies indicate that nutrients can become stratified in the soil if the soil is continuously no-tilled and not stirred and mixed through tillage. Considerable research suggests potential performance advantages associated with injecting fertilizer materials into the soil at a particular time in the plant growth cycle or in a strategic location relative to the plant. Fertilizer injection units used in conventional cultivation generally consisted of a shank or blade with a fertilizer delivery tube on the back side. Such a device was not directly applicable to no-tillage cropping practices. But with the addition of a smooth coulter in front of the blade to cut the residue and to start forming the slit in the soil, the device worked quite well in no-tillage environments. Consequently, several brands of such liquid or dry fertilizer injectors are currently available commercially. They are designed as either planter toolbar attachments or for use with separate fertilizer applicators. Use of a depth control device for the coulter is generally recommended so that fertilizer placement can be maintained at the desired depth.

A new machine which uses high pressure to force a stream of liquid fertilizer through crop stubble and into the soil has been developed specifically for no-tillage applications (Richardson, 1984). Fertilizer at pressures of up to 2,000 psi flows through a solid stream nozzle mounted on a shoe which slides over the ground surface. Depth of fertilizer penetration depends on the soil condition including moisture content, the height of the nozzle relative to the ground surface, and the liquid pressure. Application rate depends upon the orifice size selected.

A CLOSING COMMENT

The survey mentioned near the beginning of this paper suggested that several of the perceived problems associated with conservation tillage were related to the production equipment used (Agrichemical Age, 1983). However, 96 percent of the conservation tillage practioners surveyed in that study indicated at least a moderate level of satisfaction with the practice and the results obtained. Continued innovative developments in equipment and operational methodology for no-tillage will farther alleviate perceived shortcomings of the practice. At a 1984 national conference on conservation tillage, industry representatives indicated that they were anxious and ready to design, manufacture, and market new equipment for conservation farming (Lindemann et al., 1984).

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Construction and Use of a Simple No-Till Post Direct Sprayer

Dr. Carl H. Hovermale

South Mississippi Branch Experiment Station, Poplarville, MS

Weed control is one of the most important and probably most difficult aspects of row crop production. There are two times to control weeds -- before they emerge from the ground and after emergence. The purpose of this paper is to describe the construction and use of a simple post-direct sprayer.

Herbicides are normally applied prior to crop emergence to kill germinating weed seeds or emerging seedlings. These preemergence herbicides do not give season long control of weed species but are normally effective only for four to six weeks after application. During this period of time, the crop has become established, grown, and hardened to some extent while the later emerging weeds are still young, succulent, and more succeptible to mechanical or chemical injury. A height differential between the crop and weed is also established.

A crop planted no-till can be mechanically cultivated for weed control but it is a difficult task and also breaks the existing herbicide layer. As a result, post emergence chemical weed control is the preferred method. Post emergence herbicide application can be accomplished by two methods: (1) by spraying non selective herbicides to the base of the crop plant with complete coverage of the weed plants between the rows, or (2) by spraying over the top of the crop a very selective herbicide that kills specific weeds but has a minimal effect on the crop.

The over-the-top treatment has the advantage of ease and speed of application but in many instances is inefficient and expensive. Over-the-top materials are normally very effective but also very selective in the seed species that they will control and dependent on the stage of growth of the weed. Some of the newer materials have restrictions limiting other chemicals with which they can be mixed. Some mixtures inactivate or inhibit activity of one or both of the components or the combination will adversely affect the crop. The expense of over-the-top materials (approximately $20 per acre) is another major consideration. Post directed spraying is advantegious because non-selective herbicides can be used. It is relatively inexpensive and does little or no damage to the growing crop and, if applied correctly it will control all small weeds between the rows. The major disadvantage is that post directed spraying is considerably slower than spraying over the top materials.

Post directing of herbicide is done with many types of machines ranging from expensive models with shielded spray and other refinements made by manufacturing companies to home built rigs with nozzles attached to old cultivator frames. Most of these machines and modifications are very effective but some are expensive and others cumbersome and hard to calibrate.

Having used commercial sprayers for a number of years the author sought an easier, more efficient and cheaper way to post direct no-tillage planted crops.

Sprayer Description

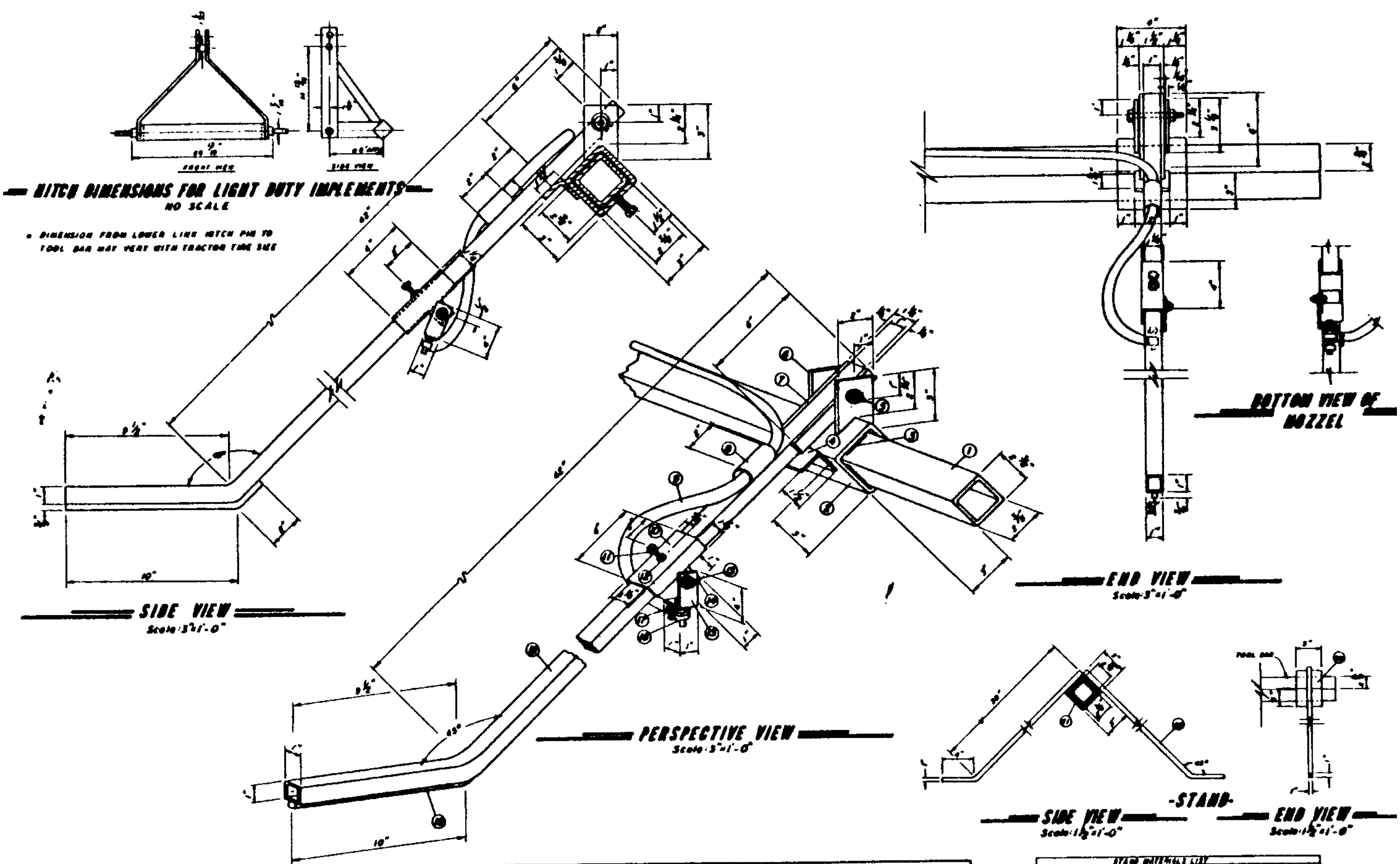
Construction is of relatively light square steel tubing mounted on a hollow three inch diamond tool bar. It was built with five "legs" to cover four crop rows. For best results, this sprayer should be constructed to cover the same number of rows as the planter. Each leg is constructed as a separate unit *so* each can be moved along the tool bar for various row widths. A diagram of the sprayer is included, details of construction can be obtained from the author.

This design is very flexible, and these specifications can be used as a guide for fitting legs on any toolbar. Pipe can also be used for the framework and legs, but rotation of the parts can make adjustments difficult.

The main advantages of this design are low cost and efficiency. The smoothly rounded drag shoe with wear bar does not drag up residue. Placing the nozzle above the residue protects it from fouling by vegetation. The spray pattern may be slightly disrupted by residue such as high wheat stubble, but this does not appear to affect weed kill. Locating the nozzle in the center of the row reduces the likelihood that the nozzle will contact the plants in the row.

For wider rows (30"-40") flood type nozzles are used, but as rows narrow to 20" or less flat fan nozzles may be mounted to give a narrower band and still stay above the residue. The outer leg on either side should use a 1/2 rate nozzle. This reduces the amount of herbicide applied on each pass and prevents doubling the recommended rates on outside rows.

Nozzle height can be adjusted by two methods: (1) height of the tool bar, and (2) the nozzle height adjustment on the leg (part no. 10). A height is selected for the toolbar which allows the legs to flex up and down freely but is high enough to clear the crop. The nozzle mount is then slipped up or down the leg to obtain the desired spray coverage. This gives a base spray coverage; however, the toolbar can be lowered while spraying an area where the crop is shorter than average to reduce the width of the spray band and keep herbicide off the smaller plants.



HITCH DIMENSIONS FOR LIGHT DUTY IMPLEMENTS

NO SCALE

* DIMENSION FROM LOWER LINK HITCH PIN TO TOOL BAR MAY VARY WITH TRACTOR TIRE SIZE

SIDE VIEW

Scale: 3"=1'-0"

PERSPECTIVE VIEW

Scale: 3"=1'-0"

END VIEW

Scale: 3"=1'-0"

BOTTOM VIEW OF NOZZEL

-STAND-

SIDE VIEW

Scale: 1½"=1'-0"

END VIEW

Scale: 1½"=1'-0"

MATERIALS LIST

PART NO.	SIZE	DESCRIPTION	FOUR ROW	SIX ROW	EIGHT ROW	PART NO.	SIZE	DESCRIPTION	FOUR ROW	SIX ROW	EIGHT ROW
1	2½"×2½"×3/16"	TUBULAR STEEL TOOL BAR	14FT	20FT	30FT	11	3/8" DIA ×1"L	BOLT	5	7	9
2	3"×3"×3/16"	TUBULAR STEEL	5	7	9	12	3/8" DIA	NUT WELDED TO PART NO. 10	5	7	9
3	6"×6"×1/4"	FLAT BAR FOR BUSHING PLATES	10	14	18	13	3/8" DIA ×1"L	BOLT W/WASHERS & NUTS	5	7	9
4	1½"×1½"×3/16"	ANGLE IRON 6" LONG	5	7	9	14	1"×1"×1/8"	ANGLE IRON 1" LONG	5	7	9
5	3/8" DIA ×6"L	BOLT W/WASHERS & NUTS	5	7	9	15	1"×1"×1/8"	ANGLE IRON 6" LONG OR 6"×6"	5	7	9
6	2"×3½"×3/16"	TWO EACH ROW	10	14	18	16	-	SPRAYER NOZZEL, FLOODING OR WIDE ANGLE FLAT FAN TIP	5	7	9
7	1"×6"×1/4"	TWO EACH ROW	10	14	18	17	-	SPRAYER HOSE CLAMP	5	7	9
8	3/4" DIA ×6"	PIPE SIZED TO FIT SPRAYER HOSE (HOLDER)	5	7	9	18	1"×1"×1/8"	TUBULAR STEEL 32" LONG	5	7	9
9	-	SPRAYER HOSE (SIZE TO FIT)	-	-	-	19	3/8" DIA ×12"L	BAR STEEL OR ROD FOR GROUND GUIDE	5	7	9
10	1½"×1½"×3/16"	TUBULAR STEEL 4" LONG	5	7	9						

STAND MATERIALS LIST			
PART NO.	SIZE	DESCRIPTION	NO. REQD.
20	2"×2"×1/4"	TUBULAR STEEL	5
21	4"×3"×1/4"	FLAT BAR FOR BUSHING PLATES	4
22	1"×1"×1/8"	TUBULAR STEEL 30" LONG	4

PL. NO. 6200-

SIDE NOZZLE MOUNT FOR POST DIRECT SPRAYIN

DESIGN BY CARL HOVERMALE & HERB WILCUTT

DRAWN BY JERRY BINGHAM

DATE SEPT. 21, 1984

SHEET 1 OF 1

Energy Considerations

Energy Requirements in Conservation Tillage

W. W. Frye

Department of Agronomy, University of Kentucky, Lexington, KY 40546

Several years have past with little being said about an energy crisis. Yet the world has less energy today than it had at the height of the energy crisis. More reserves of fossil energy have been found and some of these reserves have been developed; however, in ways we may have potential less energy now than we did then. Nuclear fission has grown in disfavor as a source of energy, construction of breeder-reactor plants has been halted, and, at times, the country has appeared to be on the brink of restricting the use of high sulfur coal. Energy consumption in the U.S. has been far below the projections of a few years ago.

ROLE OF ENERGY CONSERVATION

What accounted for the rapid transition from crisis shortage to a glutenous oversupply? There were a number of contributing factors, but first and foremost was energy conservation. Americans in general adopted an energy conservation attitude during the years of the energy crisis, and it still affects our lifestyles in many ways. It is apparent in the smaller, more fuel-efficient cars we drive, increased carpooling, and use of mass transit, thermostat settings that are lower in winter and higher in summer, greater use of solar energy and wood to conserve fossil fuels, and better home insulation.

Although it appears there is no energy shortage at this time, an energy crisis will very likely emerge again in the near future. Our society is highly dependent upon fossil fuels. The world's supply of these fuels is finite and is diminishing rapidly with use. Currently, recovery of fossil fuels meets or exceeds the demand and new discoveries will ensure a supply for several years in the future. However, most energy experts agree that the inevitable is the eventual depletion of fossil fuels to a level so low that their recovery will no longer be economically feasible (Pollard, 1976). If plentiful, safe alternative energy sources are not developed, a very serious energy crisis will occur long before that time. In addition to actual shortages, we may encounter politically motivated, government imposed, or industry inflicted artificial shortages. Continuation of conservation efforts will delay the time of run-out of fossil fuels and help prevent or ease future energy crises, but they are not likely to prevent crises.

Probably only a small portion of energy conservation can be attributed to a conscious effort to conserve fossil fuels as natural resources. More likely, the major motivation for adopting conservation measures is to save money. The same has been said about the adoption of conservation tillage by farmers. Conservation tillage reduces soil erosion, saves labor, conserves soil water, decreases tractor fuel requirement, and often increases crop yields. As a result, profits increase, thus providing the momentum for the rapid adoption of the practice. Improving energy use-efficiency will continue to play an important role in American agriculture, as well as in all other sectors of our economy, as long as energy prices remain relatively high.

ENERGY USED IN PRODUCTION AGRICULTURE

Production agriculture uses only about 3% of the U.S. energy demand, and the amount of energy used in tillage is only a portion of that. Therefore, energy conservation through tillage systems has little affect on total energy use, but it can save a substantial amount of production costs for individual farmers.

The greatest amount of energy used in nonirrigated crop production in the U.S. is for tillage and nitrogen fertilizers (Table 1). Therefore, the greatest effects can be obtained from energy conservation efforts in these areas. This paper compares the energy requirements of no-tillage and conventional tillage and points out crop production practices that will conserve energy and reduce production costs.

Table 1. Distribution of energy used in production agriculture. (American Chemical Society, 1974).

Input	Distribution of energy used in production agriculture
	%
Fuel	32
Fertilizers	23
Methods and Machinery	20
Electricity	14
Pesticides and other chemicals	6
Feeds and other uses	5

ENERGY REQUIREMENTS FOR FIELD OPERATIONS

Energy requirements for various management inputs and field operations vary greatly among references in the literature. The values shown in Table 2 are intermediate values based on several sources and are rather well supported by research measurements on energy use. Table 2 can be used to analyze the energy requirement of any cropping system. A list of production inputs and field operations is all that is needed.

Tillage

Tillage, where used, is one of the more energy-intensive inputs in crop production. When the same amount of N fertilizer is used, the energy requirement for producing a particular crop is generally proportional to the amount of tillage (Frye and Phillips, 1980). The conventional tillage system usually involves moldboard plowing followed by at least one disking as secondary tillage. No-tillage has much lower fuel requirement because it eliminates both the primary and secondary tillage operations.

Planting

Except in sandy soils, no-tillage planting would be expected to require slightly more energy than conventional tillage. Host studies have shown that the bulk density of no-tillage soil at planting time is usually greater than conventional tillage soil. Therefore, pulling the planter through the firmer soil at the proper depth requires more energy. No-tillage planting in sandy soils may require less energy because of excessive looseness under conventional tillage.

Weed Control

Chemical herbicides are used for weed control in all tillage systems; economics dictate it. As tillage is decreased, the need for herbicides increases. It is a fairly commonly accepted estimate that no-tillage requires about 1.5 times more herbicides than conventional tillage. This greater energy requirement offsets some, but not all of the energy saved by less tillage.

Some herbicides are formulated with petroleum or petroleum derivatives as the carrier. Thus, both the active ingredients and their carriers represent energy. The energy represented by other herbicides is due largely to manufacturing. Therefore, the amount of energy represented by herbicides varies considerably. Because herbicides make up such a small part of the total energy used in crop production, a convincing argument can be made for adopting a single energy value to represent most of the herbicides for the purpose of making energy estimates. With the exception of paraquat which is estimated to represent about 1.2 gal diesel fuel equivalent (DFE) per pound of active ingredient (a.i.), an energy value of about 0.5 gal DFE per pound a.i. is thought to be a fairly representative value for most of the commonly used herbicides (Frye, 1985).

Research in Minnesota (Nalewaja, 1974) on weed control methods for corn showed that use of herbicides compared very favorably with cultivation and

Table 2. Estimated average energy requirements of crop production inputs and operations (adapted from Frye, 1984).

Management input or operation	Unit	DFE[1] (gal/unit)
Machinery manufacture and repair	100 lb machinery	24
Primary tillage		
Moldboard plow (8 inches depth)	ac	1.82
Chisel plow (8 inches depth)	ac	1.18
Disk (once)	ac	0.64
Secondary tillage		
Disk	ac	0.64
Spike-tooth harrow	ac	0.32
Field cultivator	ac	0.64
Subsoiler (14 inches depth)	ac	2.14
Plant (36 inches)		
Conventional and reduced tillage	ac	0.43
No-tillage	ac	0.53
Weed control		
Herbicides	lb a.i.	0.48
Spray herbicides	ac	0.11
Apply herbicides and disk second time	ac	0.75
Cultivate (each time)	ac	0.43
Fertilizer		
Nitrogen	lb N	0.17
Phosphorus	lb P_2O_5	0.02
Potassium	lb K_2O	0.01
Broadcast granular fertilizer	ac	0.21
Spray liquid fertilizer	ac	0.21
Apply anhydrous ammonia (no-tillage)	ac	1.18
Apply anhydrous ammonia (plowed soil)	ac	0.75
Irrigation	ac	30.91
Harvest		
Corn picker-sheller	ac	1.39
Combine	ac	1.60
Miscellaneous		
Shred cornstalks	ac	0.75
Disk cornstalks	ac	0.43
Grain drill	ac	0.53
Seed	lb	0.05

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[1] Diesel fuel equivalent (155 MJ/gal).

hand labor in terms of both energy requirement and profit due to weed control. Net profits due to weed control were about $61, $78, and $-66 per acre, respectively, for cultivation, herbicides, and hand labor. Thus, economics excludes hand labor as a viable alternative weed control method.

Field Machinery

The use of large tractors and field machinery has contributed greatly in making agriculture energy-intensive and energy-dependent. At the same time, it has been mainly responsible for the rapid increase in production output per farm worker. Today, on the average, one farm worker produces enough food for 60 persons.

Since the time-consuming practice of tilling the soil is eliminated in no-tillage, the need for large, time-efficient equipment is greatly reduced, allowing selection of optimum-sized equipment to obtain greater energy efficiency. Also, less machinery is need for no-tillage than for conventional tillage. Phillips et al. (1980) estimated that no-tillage requires about 18% less energy for manufacturing and maintaining machinery than does conventional tillage.

Seeding Rates

Generally, it is recommended that seeding rates be about 20% higher for no-tillage than conventional tillage. It is estimated that this increases the energy requirement for no-tillage corn by slightly less than 0.1 gal DFE/acre, a rather insignificant amount.

FERTILIZER MANAGEMENT FOR ENERGY EFFICIENCY

Of the energy used in fertilizer manufacture, about 83 percent is for nitrogen, 11 percent for phosphorus, and 6 percent for potassium (Nelson, 1975). A pound of fertilizer nitrogen represents about 0.17 gal DFE. Therefore, any appreciable effect on energy conservation through improved efficiency in the management of fertilizers on the farm must be in nitrogen fertilizers. When irrigation or crop drying are not used, nitrogen fertilizer is usually by far the largest single fossil energy input into grain production (Phillips et al., 1980). Energy conservation through nitrogen fertilizers can be attained by improving nitrogen fertilizer efficiency in the field, using legume crops in the cropping system to provide a portion of the nitrogen needs of nonlegume crops, and using waste materials, e.g., animal manure or industrial wastes, as sources of nitrogen. This paper will emphasize nitrogen-use efficiency and legume cover crops as energy conservation measures.

Nitrogen fertilizer efficiency can be improved significantly by proper timing and placement of the application and nitrogen efficiency has been shown to be greater under no-tillage corn than conventional tillage corn.

No-Tillage vs Conventional Tillage

Several researchers have shown that nitrogen fertilizer is used more efficiently in no-tillage than conventional tillage, when based on the increase in grain yield per increment of fertilizer N (Frye et al., 1981; Moschler and Martens, 1975; Phillips et al., 1980; Wells, 1984). One can calculate an energy output:input ratio (Energy O/I) for nitrogen fertilizer using the following relationship outlined by Frye (1984):

$$\text{Energy O/I} = \frac{(Y_{m+1} - Y_m)(E^P)}{(N_{m+1} - N_m)(E^N)} \qquad [1]$$

where

Y_m (bu/acre) = yield with mth increment of applied fertilizer N, $m = 0, 1, 2, 3, \ldots$

E^P (gal DFE/bu) = estimated amount of energy per bu of crop produced

N_m (lb/acre) = amount of mth increment of fertilizer N applied

E^N (gal DFE/lb) = estimated amount of energy represented by pound of fertilizer N.

Based on results from corn tillage studies on four soils in Kentucky, Frye calculated Energy O/I values (gal DFE in grain/gal DFE in N fertilizer) as 4.7 for conventional tillage and 9.3 for no-tillage with the first increment of 75 lb/acre fertilizer N. The second 75-lb/acre increment of N resulted in energy output:input ratios of 0 for conventional tillage and 4.1 for no-tillage. The latter ratio arises from the commonly observed phenomenon in which corn grain yields peak at higher rates of N in no-tillage than in conventional tillage (Phillips et al., 1980; Wells, 1984). This has been attributed to more efficient use of fertilizer N by no-tillage corn due to more available soil water.

Although more nitrogen fertilizer, thus more energy, is usually required to obtain peak corn yields with no-tillage than with conventional tillage, the nitrogen (and energy) is used more efficiently, because it increases yield and produces more biological energy. Occasionally writers discuss the greater need for nitrogen fertilizer as a disadvantage of no-tillage, when in fact it is usually both economically sound and energy efficient.

Time of Application

A well-known principle of crop production is that nitrogen fertilizer is more efficient if most of it is applied just before the start of rapid uptake by the crop. For corn that is about 30 to 40 days. The University of Kentucky recommends that the fertilizer nitrogen application be decreased by 35 lb/acre for no-tillage corn on moderately well drained soil or for conventional tillage corn on moderately well or poorly drained soil, if as much as two-thirds of the nitrogen is applied 4 to 6 weeks after planting the corn. The lower nitrogen requirement associated with delayed application results from improved use-efficiency of the nitrogen fertilizer. Apparently the increase in efficiency is a result of less nitrogen loss by leaching and denitrification (which is potentially large under the drainage conditions described above) and less immobilization of nitrogen, especially in no-tillage. Delayed application of nitrogen fertilizer is usually more advantageous under no-tillage than conventional tillage.

The nitrogen fertilizer saved when farmers follow the above recommendation represents about 6 gal DFE/acre. It is estimated that delayed application is practiced on at least 100,000 acres annually of corn in Kentucky (K.L. Wells, personal communication). That amounts to a potential energy savings of 600,000 gal DFE/year by Kentucky farmers alone.

Significant responses to starter fertilizers have been shown by research in certain areas. Touchton and Rickerl (1985) reported a 32-bu/acre yield increase attributable to 22 lb/acre of each N and P_2O_5 starter fertilizer. In terms of energy output:input, an additional 4 gal DFE/acre resulted in output of 83 gal DFE/acre of biological energy. The response to in-row subsoiling averaged 77 bu/acre in their study, amounting to a return of about 200 gal DFE/acre biological energy for an investment of only about 2.14 gal DFE/acre fossil fuel. This illustrates how fossil energy can be used efficiently to produce additional biological energy.

Fertilizer Placement

Subsurface banding of nitrogen fertilizer increases its efficiency compared to surface broadcast application, in both conventional tillage and no-tillage (Wells, 1984). This is especially true with urea-ammonium nitrate solutions or dry urea, since a substantial amount of nitrogen may be lost by ammonia volatilization from surface-applied urea (Fox and Hoffman, 1981; Murdock and Frye, 1985). In addition to potential volatilization losses, efficiency of nitrogen fertilizer is lost through immobilization in no-tillage (Smith and Rice, 1984). Recent work in several states indicates a significant advantage of subsurface application of nitrogen fertilizer for no-tillage corn, which presumably avoids the immobilization problem. In a 3-year no-tillage corn study in Kentucky (1982-84), Earles (1985) obtained yield advantages averaging 12 and 8 bu/acre for subsurface banding compared to surface broadcast application of ammonium sulfate at rates of 75 and 150 lb/acre N, respectively.

Subsurface placement of fertilizers requires substantially more fuel energy than surface broadcast application, especially for no-tillage. As pointed out previously, additional energy input that produces a substantial yield increase is likely to be an energy-efficient practice because of a favorable Energy O/I relationship. If conducted as a separate operation, a reasonable estimate of the fuel energy required to apply dry or liquid fertilizers in a subsurface band might be the same as for anhydrous ammonia injection. This value is estimated to be 1.18 gal DFE/acre in no-tillage soil and 0.64 gal DFE/acre into conventionally tilled soil (Frye, 1984). Since both these values represent less energy than is contained in a bushel of corn (2.6 gal DFE/bu), only a small increase in yield due to the subsurface-band placement would be necessary to make it energy efficient.

The approxiinately 10-bu/acre increase obtained by Earles (1985) represents about 26 gal/acre additional biological energy production. To determine the economic feasibility, however, one must take into account labor and time, both of which are greater for subsurface banding than for surface broadcast application.

NITROGEN FROM LEGUME COVER CROPS

Current research in several states shows that a substantial amount of nitrogen can be provided by legume cover crops in nonlegume row-crop production. The method most often used to determine the amount of nitrogen supplied to the nonlegume crop is to equate the yield response to the legume cover crop without nitrogen fertilizer to the yield response to nitrogen fertilizer without the legume cover crop. However, that method is not completely satisfactory. In many cases, the legume cover crop has an effect on yield of the nonlegume crop that appears to be in addition to the effect of nitrogen supplied. That is, the yield response of the nonlegume crop to a combination of nitrogen fertilizer and the legume cover crop tends to parallel, at a higher level, the crop's response to nitrogen fertilizer with a nonlegume cover crop or no cover crop. The results in Table 3 show this. Because of this, it would be a mistake to assume that the nitrogen fertilizer recommendation could be decreased by the amount estimated to be provided by the legume cover crop.

Table 3. Effect of hairy vetch cover crop on yield of no-tillage corn at Lexington, Kentucky, 1977-81 (adapted from Frye, 1984).

	N applied (lb/acre)		
Winter cover	0	44	88
	--Yield of grain (bu/acre)---		
Corn stalk residue	60	83	109
Rye	64	91	121
Hairy vetch	103	119	144

Since the legume cover crop tends to result in additional yield instead of simply replacing nitrogen fertilizer in the cropping system, it is difficult to evaluate the energy conservation value of the cover crop. Several methods may be used, all of which give different views that can be interpreted in different ways. One is the method discussed above in which the yield with a legume cover crop and without nitrogen fertilizer is plotted on the response curve of yield without a legume cover crop but with nitrogen fertilizer. Applying this method to the yield data in Table 3, it has been estimated that hairy vetch provided about 80 lb/acre/yr nitrogen to the corn (Frye, 1984). In terms of fossil fuel this would represent almost 14 gal DFE/acre.

Another method is to place a biological energy value on the additional yield attributed to the legume cover crop, i.e., yield with legume cover crop minus yield with nonlegume cover crop or no cover crop. Evaluating hairy vetch in comparison with rye (Table 3) in this way gives 99, 73, and 60 gal/acre DFE with 0, 44, and 88 lb/acre fertilizer nitrogen, respectively. This is energy produced essentially free of fossil energy expenditure, since it represents energy in add-on yield due to the presence of the legume.

SUMMARY

Energy conservation has played an important role in relieving the energy crisis of the 1970's. The motivation for energy conservation is mainly to save money rather than to save energy per se as a resource. This is especially true in production agriculture because only about 3% of the total U.S. energy demand is used in production agriculture. Energy conservation through improved efficiency of energy use in crop production saves money and increases the farmers' profits.

Since tractor fuel for tillage and nitrogen fertilizer represent the two largest inputs of energy into crop production, conservation efforts should be directed toward these inputs because that is where conservation will have the greatest effect. No-tillage has advantages over conventional tillage in both of these areas. Because most tillage is eliminated, less fuel is required in the no-tillage system. Some of the fuel energy saving is offset by increased herbicide requirement, but the increase due to herbicides is much less than the fuel saved. Nitrogen fertilizer use-efficiency has been shown to be greater for no-tillage than conventional tillage corn. The result is a higher energy output:input ratio with no-tillage. This is usually explained as an effect of improved soil water relations associated with the mulch.

Other practices to increase nitrogen efficiency and conserve fossil energy or produce additional biological energy include delayed application of all or most nitrogen fertilizer for 4 to 6 weeks instead of applying it all at planting, subsurface banding compared to surface broadcast of nitrogen fertilizer, use of starter fertilizers in some areas, in-row subsoiling in some soils, and using legumes to provide a portion of the nitrogen needs of nonlegume crops or to increase their yield above that with nitrogen fertilizer alone. Energy conservation occurs through management when the same yields are produced with less energy, higher yields are produced with the same amount of energy, or higher yields are produced more efficiently (higher energy 0utput:input ratio) with more energy.

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Crop Management
and
Cropping Systems

Crop Management and Cropping Systems

Joe Touchton and Ken Wells

Auburn University and the University of Kentucky

No-till research has been conducted sporadically in the Southeast for many years. Intensive or large scale research programs were not, however, initiated until the mid 1960's in the upper South (primarily Virginia and Kentucky) and in the early to mid 1970's in the lower South.

The advantages of no-till such as soil and water conservation are understood by almost everyone associated with crop production. Extensive research conducted in Georgia, Tennessee, and Mississippi illustrates the advantages of mulches in soil and water conservation. Recent research conducted in Alabama and Kentucky documents the value of topsoil for maximizing corn, soybean, and cotton yields. Initial studies with no-till primarily involved comparing no-till yields with conventional tillage yields. From these studies came a wide range of conclusions; some favored no-till and some did not.

Although some studies suggested that no-till reduced yields or was not as economical as conventional tillage, most researchers realized that the advantages and long term benefits of no-till were great enough that elimination of these effects was necessary. Studies designed to improve the profitability of no-till systems are still in their infancy, but sufficient data have been collected to indicate that management is the key to success. Management is definitely more intense with no-till than conventional tillage. Studies currently being conducted through the Southeast include mulch selection and management, fertilizer application and placement, planter selection, row width, effects pest control and pesticide use, and cropping and tillage systems.

Pesults from studies conducted to date suggest that specific management practices for successful no-tillage may vary widely from region to region within the Southeast. Basic principles are, however, fairly uniform. Since specific management practices vary, only basic principles will be discussed in this paper.

Mulch Selection and Management

Mulch selection (winter cover crop) and management encompass a wide and diverse territory. Commonly listed disadvantages of winter cover crops are: soil water depletion, lower soil temperatures, and increased cost. Research studies are currently in progress to identify methods of managing these disadvantages.

One important aspect of mulch management is deciding when **it** is best to kill the winter cover crop. Research is currently being conducted in several states to determine this. In Alabama, cotton no tilled into green rye and vetch reduced seed cotton yields 380 and 1,670 pounds per acre, respectively, when compared to killing the cover crops 10 to 14 days prior to planting. In South Carolina, corn yielded better when planted into rye killed 20 days prior to planting than when planted into rye killed at planting. For soybeans, however, killing mulches in advance of planting has not shown any influence on yields. The better cotton and corn yields resulting from early kill dates are most likely due to less soil water depletion and better crop stands. In most Southeastern soils, water holding capacities are low, and it is a definite disadvantage to plant summer crops into soils with low water levels.

In some situations, killing winter cover crops prior to planting may result in warmer soils at planting. The adverse effect of cool soil temperatures is primarily associated with poor seed germination. There is also a relationship between immobile nutrient uptake and cool soil temperatures. A cool soil high in residual nutrients may not he able to provide a sufficient quantity of available plant nutrients. In some situations particularly in compacted soils, reduced nutrient uptake may well be one of the primary reasons why early-planted no-till crops sometimes grow slower and yield less than crops grown with conventional tillage.

It has long been known that the use of relatively low rates of starter fertilizers will help eliminate the adverse effect of cool soil temperatures on early season nutrient uptake. Several studies reported from heavy, compact soils in the upper corn belt have shown a beneficial effect from use of starter fertilizer, even on medium to high testing soils. A study conducted on a Zanesville soil in Kentucky showed no effect from use of a starter, while studies in Alabama have shown some positive responses, particularly on Coastal Plains soils with compacted layers in the root zone. Table 1 shows results obtained from starter fertilizer tests conducted in Alabama. Similar results have been obtained in Alabama with grain sorghum, cotton and in some situations, with soybeans and peanuts.

Table 1. Yield of corn grown in conservation tillage systems in South (Dothan soil) and North (Decatur soil) Alabama as affected by starter fertilizer, in-row subsoiling, and fertilizer placement.

Starter fertilizer[1/]	In-row subsoil	Fertilizer placement	Soil	
			Dothan	Decatur
			-yield,	bu/acre-
None	Yes	--	109	158
	No	--	40	125
N	Yes	deep	114	169
	Yes	2 x 2	128	165
	No	2 x 2	51	136
N-P	Yes	deep	124	167
	Yes	2 x 2	141	168
	No	2 x 2	57	140
FLSD (0.10)			10	14

[1/] Application rate was 22 lb/acre N and 22 lb/acre P_2O_5.

Another aspect of planting winter cover crops is the cost involved. This can be a disadvantage in no-till systems. Although the soil conserving benefits of cover crops will likely exceed production cost, it may take years to realize these benefits, while the costs incurred for cover crop production costs are yearly expenses. Studies in several states have been established with the objective of finding methods of allowing the mulch crops to offset their cost on a year-to-year basis. Most of these studies have used winter legumes instead of cereal crops in hope that the value of N fixed by them would cover establishment costs. Results and conclusions from these studies have been somewhat erratic, but it appears that in most regions of the Southeast, N fixed by adapted legumes will be approximately equal to the cost of growing the legume which essentially results in a free mulch for no-till.

Studies have also tested reseeding systems as a method that can be used to reduce the cost of growing legumes and to increase N production. In these systems, a legume crop is allowed to mature before no-tilling a late summer crop such as grain sorghum or cotton into the mature legume. This has worked best in the deep South where legume seeds lying in the surface mulch germinate in late summer. This late summer germination prior to harvest of the summer crops often allows time for considerable growth and N production before winter dormancy. These reseeding systems eliminate seeding cost in subsequent years, and in addition, reseeded legumes can better tolerate severe winters as a result of the extra fall growth. Nitrogen production by early spring is also generally high as a result of the increased growth.

Growers using reseeding systems often wait longer than necessary to plant the summer crop which can reduce yields. In an attempt to overcome this, research was recently conducted in Alabama to determine the necessity of allowing crimson clover to mature before killing it for a mulch. This research (Table 2) indicates that crimson clover in full bloom contains an adequate number of hard seed for a viable reseeding system and allows planting the summer crop 3 to 4 weeks earlier.

Table 2. Seed production for crimson clover of the early and late bloom growth stages.

	Seed			
Growth stage	Soft	Hard	Dead	Production
	--------%	--------		lb/acre
Early bloom	48	31	21	30
Late bloom	7	91	2	500

Unfortunately, the optimum planting date for corn commonly occurs prior to maximum N accumulation by the winter legume cover crop and prior to seed set. This early planting-date requirements for corn in many areas of the Southeast reduces the economical advantage of using winter legumes as a N source and no-till mulch for corn. Some growers have attempted to improve the economics of legume-corn systems by planting corn into winter legumes before killing them. In these systems, herbicides are applied in a 9 to 12-inch band directly over the corn row at planting. Legumes between the corn rows continue to grow, produce N, and set seed for a reseeding system. When the winter annual legume matures, a shielded sprayer is used to apply herbicides to the corn middles. An upright legume such as crimson clover is more suitable for these systems than a spreading type legume such as hairy vetch. In some years, these systems produce excellent results but in others, especially dry years, they are detrimental (Table 3).

Table 3. Yield of no-till corn as affected by sidedress N and width of killed crimson clover strips in the corn row at planting. (Auburn data)

Sidedress N	Strip killed width for clover (inches)[1/]			
	0	9	18	36
	----------corn yield, bu/acre----------			
0	18	34	32	50
60	65	75	76	91

[1/] Row width was 36 inches, and the 36-inch kill width was a complete kill.

With carefully planned cropping systems, rotations can be established that will allow early planted crops to take advantage of N produced by legumes. Two cropping systems have been used with success in the mid to deep south. The first system is based on the fact that a legume crop will produce a sufficient number of hard seed to allow for stand establishments for 2 or 3 consecutive years with a single seed crop. In this system, grain sorghum or soybeans are planted into the first mature legume crop. If soybeans are used as the summer crop, seeding rates for the legumes can be cut by at least 50%. The first reseeded crop is killed during the early bloom stage in March just prior to planting corn and the second reseeded crop is allowed to mature and produce another seed crop. No-till corn yields from seeded vetch - no till soybeans - early corn - reseeded vetch - early corn system are presented in Table 4.

Table 4. Effect of N rates on yield of corn grown in a cropping system which included: 1st fall-seeded vetch, 1st summer - no till soybeans, 2nd fall-reseeded vetch, 2nd summer-no-till corn, 3rd fall-reseeded vetch, and 3rd summer-no-till corn. (Auburn data)

Applied N	First Yr corn	Second Yr corn
lb/acre	-----------bu/acre--------	
0	101	80
45	102	86
90	102	99
135	102	99

A second system consisted of planting low rates of crimson clover with wheat. Soybeans are no-till planted after wheat grain harvest, and corn can be planted into the reseeded clover the second summer. Since wheat and crimson clover are rapidly growing during the same time period, the wheat will not be able to utilize N produced by the clover. The purpose of planting crimson clover with wheat is to establish a clover reseeding system. High clover seeding rates will reduce wheat yields (Table 5); therefore, clover seeding rates should be 3 to 5 lb/acre.

Table 5. Wheat grain yields as affected by rates of interseeded crimson clover and N applied to wheat. (Auburn data)

Applied N	Clover seeding rate, lb/acre			
	0	5	10	15
lb/acre	---------grain yield, bu/acre--------			
0	49	46	44	36
30	65	62	60	40
60	64	59	56	45
90	62	60	55	45

Although corn is often successfully no-tilled into killed legume sods, some Alabama data has shown that planting summer crops directly into live or recently killed legumes can be detrimental to stand establishment. Shortly after killing legumes, a quick release of ammonia nitrogen can occur and some crop seeds, especially cotton, are extremely sensitive to ammonia. In research conducted in Alabama, cotton seedling mortality has been as high as 100% when legumes were killed the same day cotton was planted. This problem has been avoided by killing the legumes 10 to 14 days prior to planting. Some damage to grain sorghum planted into live legumes has also been reported.

Wheat straw and residue remaining in the field after wheat grain harvest is a good example of a free mulch. The value of the wheat grain should more than cover production cost. In some areas of the Southeast there are some questions concerning straw management in these systems. Whether the straw should be burned or used as a mulch is probably the most common question and research reports on the benefits of straw mulches are conflicting. A Georgia study by R.N. Gallaher indicated that physically removing rye straw would result in lower summer crop yields as compared to planting into green rye. Improved yields due to the rye mulch were attributed to the mulch-related soil moisture conservation. Research conducted by N.C. Edwards in Mississippi suggests that higher soybean yields can be obtained by burning the straw before planting. In a 3-year test conducted in Louisiana, grain sorghum yields were higher where straw had been burned in one year, lower in another, and equal in the other year. The 3-year average yield for burned and unburned straw was approximately equal. No general problems have been reported from the upper south where over a million acres of soybeans are no-tilled each year into straw and stubble directly following wheat and barley harvest.

No one is absolutely sure why burned straw sometimes results in higher yields than unburned straw. Some researchers suggest that straw can release toxic substances, but others believe the problem may be related to ineffective planting in unburned straw. In some situations, some planters cannot adequately cut through a straw mulch and place seed in good contact with the soil. In these situations, the straw should be burned. Burning straw can result in more weed problems than when straw is not burned. Increased weed pressure can be attributed to several factors including herbicide deactivation by charcoal and sunlight penetration to the soil surface.

Soil Fertility

Some of the first management research in no-till systems was directed toward soil fertility. This research was initiated in Virginia and Kentucky in the mid 1960's and spread into the Deep South in the 1970's. Although some concern has been expressed about possible phosphorus fertilization problems, most research has shown that the primary difference in fertility practices among tillage systems centers around soil pH and N fertilizers.

In continuous no-tillage systems, soil pH in the surface inch or two of soil may drop rapidly. The drop in pH is most likely due to surface applied N fertilizers and to organic acids released from decomposing mulches. The low pH problem can be easily corrected with lime, but if soils are not sampled correctly, the low surface pH might not be detected. A low surface pH may not affect plant growth, but **it** can result in severely reduced herbicide activity. To prevent this problem, some states are recommending that 0 to 2- or 0 to 3-inch depth soil samples be taken for determining lime requirements.

Nitrogen fertilizer selections and application methods probably are more critical in no-till than conventional-tillage systems. Surface residues contain high concentrations of urease enzymes, and when urea is surface applied, the potential for nitrogen losses through ammonia volatilization is high. In some areas of the Southeast, nitrogen solutions are widely used. A key point to remember is that most nitrogen solutions contain 50% ammonium nitrate and 50% urea. The urea in these solutions is as susceptible to nitrogen loss through ammonia volatilization as prilled urea. Dribbling nitrogen solutions onto the surface has been shown to be more effective than spraying them on the surface of no-till corn fields. In a study recently completed in Georgia, a surface spray application of 240 lb/acre N (32% solution) resulted in approximately 60 bu/acre less corn yield than from 160 lb/acre of ammonium nitrate-nitrogen.

Planter Selection

No-till planter comparison studies conducted during the past few years have shown few differences among brands. Most differences found were due to different types of planter units. These differences occur between units with in-row subsoilers and those without in-row subsoilers. Whether a subsoiler is needed is difficult to determine, and the need varies from region to region. Currently, **it** appears that in-row subsoilers are needed on many sandy Coastal Plain soils, but due to interactions between climatic conditions and subsoiling effects, yield responses to in-row subsoiling are not always obtained. Yield increases with in-row subsoiling have been reported on some Piedmont soils even though they do not generally contain severe root restricting hardpans. Higher yields from in-row subsoiling on these soils are probably due to improved water infiltration. Unfortunately, the use of in-row subsoilers on soils that do not need subsoiling will sometimes result in yield decreases. To determine if subsoiling is needed, fibrous rooted crops such as corn or sorghum probably should be grown as the test crop instead of tap rooted crops such as cotton and soybeans.

There are two major disadvantages associated with in-row subsoilers: operational cost and row-width restrictions. Subsoilers are expensive to pull, but the expense is justifiable on soils with severe root restricting hardpans. Subsoil units currently on the market are not designed for row widths narrower than 30 inches. This row width restriction may be a yield limiting factor as discussed in the followina section.

Row Widths

Row widths are important considerations in any cropping system. Data from research conducted in the Southeast for many years generally indicate that the later the planting date, the more important narrow rows become. Except for cotton, row widths probably should be narrow enough to permit a closed canopy by the early bloom stages. The primary purpose of green plants is to convert sunlight into usable energy. When sunlight penetrates to the soil surface, three adverse effects are occurring: 1) sunlight is being lost, 2) soil moisture is being evaporated, and 3) weed seeds are germinating Most of the residual herbicides used in the Southeast are effective for approximately 4 to 8 weeks. If the crop canopy is not closed when herbicide activity is lost, weeds can become a problem. Soil moisture is a valuable resource and every possibly inch should be preserved. Mulches help decrease evaporation losses, but like herbicides, mulches do not last all summer, especially in the Deep South. Narrow rows help ensure a fast-closing canopy which can protect soil moisture after the effectiveness of the mulch is lost. Optimum row width is difficult to define, but a reasonable rule to follow is that if the canopy is not closed by the early bloom stage, row widths are too wide.

Too often, no-till gets blamed for low yields of crops planted after wheat harvested for grain. The low yields are, however, often due to wide rows and not to double cropping or no-tilling. Research conducted in several states indicates that soybeans planted after wheat may yield nearly as high as early planted soybeans, if optimum row widths are used. One should not, however, expect late-planted soybeans in 36- or 40-inch rows to yield as high as full-season early planted soybeans. In addition, we normally do not expected soybeans planted 1 to 3 weeks after wheat harvest to yield as high as soybeans planted immediately after wheat harvest.

Pests

Weed control efficiency and cost are a big concern in no-till systems. Herbicide research is being conducted in every state in the South. Some researchers have begun looking at cropping systems as a valuable aid in weed control. Because of different weed problems from area to area within the South and from field to field within a specific area, it is difficult to generalize on results of weed control studies.

There are, however, some generalizations that can be made on weed control in no-till systems. The primary generalization is that the economic advantage of no-tillage depends tremendously on weed control systems cost. The economics of any system requiring a complex mixture of herbicides costing $40 to $100 per acre are definitely questionable. When exceptionally high herbicide costs occur, they are often due to poor management or improper herbicide selections. Excess herbicide costs are generally associated with postemergence applied herbicides.

Letting weeds get too big prior to herbicide application requires higher herbicide rates for adequate control than applying herbicides to small weeds and often do not completely kill them. A post-emerge over-the-top herbicide application is an effective method of controlling some weeds in some crops, but some of these herbicides are expensive. Unless big weeds are directly in the row, directed spray applications with shielded sprayers and/or drop nozzles may be the most economical approach to postemergence herbicide applications. Herbicides used with directed spray applications sometimes cost 60 to 70% less than herbicides used in over-the-top applications.

Several researchers in the South are working with insecticide, nematicide, and fungicide applications in various tillage systems. Research reports suggest that complexes of various pests can change with tillage and cropping systems, but there are no strong indications that the overall pest complex is better or worse with no-till than conventional tillage. Published data indicate that **if** populations of pests are high enough, yield increases can be obtained with pesticide applications regardless of tillage systems.

Summary

An aggressive no-till research program is currently being conducted in most of the southern states. The amount of data reported from these programs was too large for all projects to be adequately documented in this paper. The general concepts presented were developed from many published reports and personal communications with researchers in almost every state in the South, and they are probably valid throughout most of the South. However, specific production practices do vary widely, primarily because of different climatic conditions, soils, and cropping systems. The Cooperative Extension Service in each state can provide information on specific practices.

Influence of Tillage on Performance of Soybean Cultivars

W. L. Hargrove, D. G. Cummins, M. J. Cordonnier, and J. L. Day

Agronomy Department, University of Georgia College of Agriculture. Georgia Experiment Station. Experiment, GA 30212

Introduction

No-tillage production results in a unique environment that is characterized by an undisturbed soil profile and abundant plant residues on the soil surface. Production practices involving crop cultivars generally have been developed for conventional tillage agriculture. Because of the unique environment associated with no-tillage production, many of these practices may not be directly transferrable. They must be reevaluated, adapted, and integrated into new systems specifically designed for crop production under no-tillage management.

The influence of tillage on cultivar performance is one such factor which has been heretofore unaddressed. The objective of this study was to evaluate soybean cultivar performance in a double-cropping system under three tillage methods.

Materials and Methods

This study was conducted near Griffin, Georgia over a four-year period, 1979-80 and 1982-83. The soil series was Cecil sandy loam, a member of the clayey, kaolinitic, thermic family of Typic Hapludults.

1979-80

During 1979-1980, six soybean cultivars were evaluated with conventional disk tillage and no-tillage. The six soybean cultivars were: 'Davis', 'Bragg', 'Ransom', 'Hutton', 'GaSoy 17', and 'Duocrop'. The tillage treatments were whole plots and the cultivars were split plots. Individual plot size was 4 rows x 21 ft. Planting dates were in mid-June following wheat (*Triticum aestivum* L.) grain harvest. Plots were fertilized with 30 lbs P/A and 100 lbs K/A each year before planting. Seed yields were obtained by combine-harvesting a length of 16 ft from two rows for each cultivar and were calculated at 13% moisture content.

1982-83

Three tillage practices were studied in a randomized complete block design with four replications. The tillage treatments for each fall/spring were: no-tillage/no-tillage, conventional tillage/no-tillage, and conventional tillage/conventional tillage. The conventional tillage treatment was plowed with a moldboard plow (approximately 10 in deep), disked twice, and planted. The no-tillage treatment was planted into standing wheat stubble with a fluted coulter planter. The tillage treatments had been conducted on these plots for six years before these evaluations were conducted. Wheat and soybean were double-cropped during the first five years; wheat and grain sorghum (Sorghum bicolor L. Moench) were grown in the sixth year. The size of each whole plot was 9 x 60 ft. Ten soybean cultivars in maturity groups VII and VIII were planted on each whole plot in a split-plot design. The ten cultivars were 'Agripro-70' 'Bragg', 'Braxton', 'Coker 237', 'Coker 333', 'Duocrop', 'GaSoy 17', 'Hutton', 'Ransom', and 'Wright'. Subplots were two rows wide (5 ft) and 30 ft long. Two border rows were planted on each side of each whole plot. Planting dates were 21 June and 1 July in 1982 and 1983, respectively. Plots were fertilized and limed uniformly over the tillage treatments.

Seed yields were obtained by combine-harvesting a length of 20 ft from two rows for each cultivar and were calculated at 13% moisture content. Analyses of variance were conducted using SAS. Mean comparisons were conducted using Duncan's Multiple Range Test.

Results and Discussion

Analyses of variance for treatment effects showed the following: 1) Results were significantly different between years. 2) Tillage significantly affected soybean yields in 1979 and 1983, but not in 1980 and 1982. 3) Significant differences in yield between cultivars occurred each year, but the interaction of tillage with cultivar was not significant in any year. The soybean yields as influenced by tillage are shown in Tables 1, 2, 3, and 4 for 1979, 1980, 1982 and 1983, respectively. In general, the ranking of cultivars was not affected by tillage; the better cultivars under conventional tillage tended to be the better cultivars under no-tillage also.

Table 5 shows the influence of tillage on several crop parameters in 1982 and 1983. The values in Table 5 are averaged over the ten cultivars. The seed yield and seed weight were not affected by tillage in 1982 but were affected in 1983. The lack of significant differences in yield in 1982 is probably a result of moderately good rainfall amounts and distribution. In 1983, continuous no-tillage resulted in the greatest yield and seed weight and conventional tillage in the least yield and seed weight. This is probably a reflection of moisture conservation with no-tillage in a year with less than adequate rainfall. The mean plant height was also affected by tillage and was greater for no-tillage than for conventional tillage.

In summary, significant differences in yield between cultivars occurred each year, but the interaction of tillage with cultivar performance was not significant in any year. In other words, the ranking of cultivars was not affected by tillage; the better cultivars under conventional tillage tended to be the better cultivars under no-tillage also. However, the ranking of cultivars was different between years.

Table 1

Yield of Six Soybean Cultivars as Influenced by Tillage in 1979.

	Tillage		
Cultivar	**Conventional**	**No-Tillage**	**Mean**[†]
	bu/A		
Davis	19.9	12.4	16.2bc
Bragg	19.9	14.6	17.3b
Ransom	16.8	10.3	13.5c
Hutton	28.1	15.5	21.7a
GaSoy 17	24.9	18.5	21.7a
Duocrop	23.8	24.0	23.9a
Mean[+]	22.2a	16.5b	

[+] Means in a row or column followed by the same letter are not significantly different at the .05 level of probability.

Table 2

Yield-of Six Soybean Cultivars as Influenced by Tillage in 1980.

	Tillage		
Cultivar	Conventional	No-Tillage	Mean[†]
	bu/A		
Davis	12.9	19.9	16.5b
Bragg	14.6	17.9	16.4b
Ransom	18.8	19.3	19.0ab
Hutton	25.4	22.3	24.0a
GaSoy 17	24.1	24.9	24.6a
Duocrop	13.4	20.4	17.0b
Mean'	17.9b	20.4a	

[†] Means in a row or column followed by the same letter are not significantly different at the .05 level of probability.

Table 3

Yield of Ten Soybean Cultivars as Influenced by Tillage in 1982.

Cultivar	Tillage (fall/spring) CT/CT	CT/NT	NT/NT	Mean t
		bu/A		
Agri-Pro 70	35.3	33.5	33.5	34.1 ab
Bragg	32.4	28.6	25.6	28.9c
Braxton	35.3	42.3	33.5	37.1ab
Coker 237	36.3	40.3	38.4	38.4a
Coker 338	32.4	31.4	31.4	31.7bc
Duocrop	40.3	35.3	33.5	36.3ab
Ga Soy 17	33.3	38.4	31.4	34.4ab
Hutton	36.3	39.3	39.3	38.2a
Ransom	35.3	34.5	34.5	34.8ab
Wright	37.4	35.3	35.3	36.0ab

Table 4

Yield of Ten Soybean Cultivars as Influenced by Tillage in 1983.

Cultivar	Tillage (fall/spring) CT/CT	CT/NT	NT/NT	Mean $^{+}$
		bu/A		
Agri-Pro 70	9.8	26.6	29.9	22.2abc
Bragg	10.0	24.1	24.1	19.3cd
Braxton	8.8	21.4	23.8	18.0d
Coker 237	10.4	23.5	33.9	22.6abc
Coker 338	10.3	28.6	35.9	24.8a
Duocrop	9.4	23.5	31.5	21.4abcd
Ga Soy 17	11.3	26.3	31.2	22.9abc
Hutton	10.4	23.4	29.8	21.1abcd
Ransom	10.3	25.3	33.8	23.1ab
Wright	9.8	25.6	27.5	21.0bcd

$^{+}$Means followed by the same letter are not significantly different at the 0.05 level of probability.

CT = conventional tillage

NT = no-tillage

Table 5

Influence of Tillage on Several Soybean Crop Parameters in 1982 and 1983 . (These values are averaged over the ten cultivars.)

Tillage Treatment (fall/spring)	Plant Height in	Maturity Date Day of Year	Seed Yield bu/A	Seed Wt g/100 seed
		1982		
CT/CT	37b	294b	36.2a	14.5a
CT/NT	40a	295ab	36.3a	14.5a
NT/NT	36b	296a	34.2a	14.4a
		1983		
CT/CT	14c	306a	10.3c	14.5c
CT/NT	22b	304b	25.1b	15.1b
NT/NT	25a	305ab	30.7a	15.9a

CT = Conventional tillage; NT = No-tillage.
For each year, values within a column followed by the same letter are not significantly different at the .05 level of probability using Duncan's Multiple Range Test.

Soybean Relative Yield as Affected by Cropping Sequences and Conservation Tillage

J. H. Edwards, D. L. Thurlow, and J. T. Eason

U. S. Department of Agriculture, Agricultural Research Service,
Alabama Agricultural Experiment Station, and Sand Mountain Substation, Auburn University, AL 36849

ABSTRACT

Tillage and cropping sequence studies were conducted on a Hartsells fine sandy loam from 1981 to 1984 to determine the influence of tillage systems and crop rotation on soybean relative yields. The tillage systems were conventional, strip-tillage, and no-tillage. Crop rotation was continuous soybeans, corn-soybeans (full season), corn-wheat-soybeans (double-cropped soybeans). In 1982 through 1984, conventional tillage with continuous soybeans resulted in lower soybean yields than strip-tillage or no-tillage. Corn-soybean rotation consistently resulted in higher soybean yields than continuous soybeans. Double-cropped soybean yields were reduced by 10% when compared to full season soybeans, but wheat yields associated with double-cropped soybeans ranged from 3000 to 3900 kg/ha. The buildup of soybean cyst nematodes (continuous soybean with conventional tillage) appears to have a greater effect on soybean yields than soil compaction, soil nutrient levels, or rainfall distribution.

Introduction

Conservation tillage is a system of managing crop residue on the soil surface with minimum or no tillage. Goals of conservation tillage are to leave enough plant residue on the soil surface for control of water and wind erosion, to reduce energy requirements; and to conserve soil water (5). Although the use of crop residues on the soil surface has been widely practiced for many years, additional information is needed on the influence of tillage systems on physical, chemical, and biological soil environment, and on crop production. With the development of effective chemical weed control and suitable planting equipment, the potential for conservation tillage systems has increased. During the past several years, research in tillage systems has been expanded to include crop rotation and cropping systems. The purpose of this study, which was established in 1980, was to determine the influence of crop rotation and cropping systems on soybean yields.

Materials and Methods

Conventional tillage was compared to strip-tillage and no-tillage systems with soybeans, corn, and wheat on a Hartsells fine sandy loam (fine-loamy, siliceous, thermic, Typic Hapludults) soil. The strip-tillage consisted of planting corn and soybeans over 20 to 23 cm deep chisel slots (in-row chiseling); with no-tillage corn and soybeans were planted with a double-disk opener planter directly in the untilled soil surface. Row spacing was 90 cm for corn and 68 cm for soybeans. The soybean plots were 15 m long, with the center two rows harvested for yields.

Cropping sequences were continuous soybeans; continuous corn, corn-soybeans, and corn-wheat for grain-soybeans. Wheat was planted as winter cover on all plots including those not used for grain crop. The wheat was killed with an over-the-top application of paraquat 10 days before planting corn or soybeans. Planting dates ranged from 14 March to 1 April for corn, from 1 May to 10 May for full season soybeans, and 15 June to 1 July for double-cropped soybeans. Planting date for the double-cropped soybeans depended on soil moisture conditions when wheat was harvested.

Results and Discussion

The highest soybean yields in the first cycle occurred with continuous, full season soybeans in the strip- and no-tillage systems (Table 1). However, in the second, third, and fourth years, the no-tillage system rotated with corn resulted in the highest yields. The yields for this treatment were 45.2 bu/acre in 1981, 46.7 in 1982, 35.4 in 1983, and 44.2 in 1984. Yield averages for full season soybeans rotated with corn were 32.7, 41.8 and 42.9 bu/acre for conventional, strip, and no-tillage.

After 1981, yields of continuous soybeans grown with conventional tillage ranged from 29 to 88% as high as the no-tillage soybeans rotated with corn. With continuous full season soybeans, yield averages were 26.9, 36.4, and 41.7 bu/acre for conventional, strip-, and no-tillage. Yields of the double-cropped soybeans were lower each year than full-season soybeans rotated with corn. Yield averages for double-cropped soybeans were 35.9, 38.6, and 34.3 bu/acre for conventional, strip-, and no-tillage.

To determine the best rotation and tillage systems for consistent soybean production, these factors should be considered: soil nutrient levels, soil physical condition (compaction, tillage pans), climate (rainfall distribution) and change in soil microflora by tillage and rotation systems.

Soil nutrient levels are easily monitored by soil test to eliminate them as limiting factors in soybean yields. Each fall nutrients were applied to all plots to maintain high levels of P and K; however, fertilizer was applied on an individual plot basis since differing amounts of P and K were removed, depending on tillage and crop rotation. Nitrogen (90 lb/acre) was applied to wheat for cover and wheat for grain.

High soil strength and low soil oxygen are two important factors restricting root growth in soil with compactible layers. Conservation tillage systems eliminated these limiting factors. With conventional tillage, soybean rooting was restricted to a soil volume of 15 cm or the Ap layer. The restricted rooting depth was also verified by taking soil penetrometer measurements under the row in June 1983 (Table 2). Soil strength was less than 1 Pascal at the 40-cm depth for the strip-tillage system. The energy for penetration of the no-tillage system was reduced only at the 0- to 15-cm depth, and increased from the 15- to 60-cm soil depths. Thus, under conditions of low rainfall during critical moisture periods, increased soil strength could have an adverse effect on soybean yields by restricting root growth and water removal to the soil volume above the hardpan.

Tillage systems that enhance water infiltration and/or reduce evaporation have a better chance of maintaining adequate soil water during periods of drought stress. In 1982-1984, poor rainfall distribution (Fig. 1) resulted in periods of drought stress of 14 days or more. However, soybean yields did not appear to be affected in the tillage systems that maintained some residue on the soil surface (strip-tillage and no-tillage). The moisture conserving advantage of the mulch may have been one of the primary factors responsible for higher yields with conservation tillage than with conventional tillage in 1982-1984.

After 4 years of continuous soybeans, yield in 1983 with conventional tillage was only 10 bu/acre. The soybean plants were stunted in late August and began to defoliate prematurely (1,2,3,4). Observation of the soybean roots and soil samples collected in late August suggested a nematode infestation. In 1984 high populatons of soybean cyst nematodes were found in soil samples from continuous soybean-conventional tillage.

In summary, soybean yields in this conservation tillage study were influenced by rainfall distribution, soil physical conditions, and change in the soil microflora. Effects of rainfall distribution can only be controlled by supplemental irrigation, while the adverse effects of soil compaction can be controlled to some extent by maintaining some plant residue on the soil surface to enhance water infiltration and reduce evaporation losses. Nematode populations can be kept in check by growing corn or some other grass in rotation with soybeans; however, the greatest increase in soybean yields due to rotation was more evident when grown with some form of conservation tillage system.

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Table 1. Effects of tillage and crop rotation on soybean relative yields for 1981 through 1984 at Crossville, Alabama

Tillage systems	Relative yield of soybeans (% of standard)"			
	1981	1982	1983	1984
		Continuous soybean		
Conventional	88	65	29	63
Strip-tillage	114	88	66	67
No-tillage	127	89	93	79
		Soybeans-corn rotation		
Conventional	81	89	70	63
Strip-tillage	94	98	94	100
No-tillage	100*	100*	100*	100"
		Wheat-soybeans-corn		
Conventional	96	91	81	66
Strip-tillage	94	92	79	92
No-tillage	71	88	77	82

* Yields for'standard were 45.2 bu/acre in 1981; 46.7 in 1982; 35.4 in 1983; and 44.2 in 1984.

Table 2. Effects of conservation tillage systems on soil strength at Crossville, Alabama in 1983.

Tillage systems	Soil depth (cm)			
	15	30	45	60
	Pascal 10 x10^6			
Conventional	0.75	1.18	1.73	1.93
Strip-tillage	0.29	0.59	0.89	1.41
No-tillage	0.51	1.00	1.62	1.15

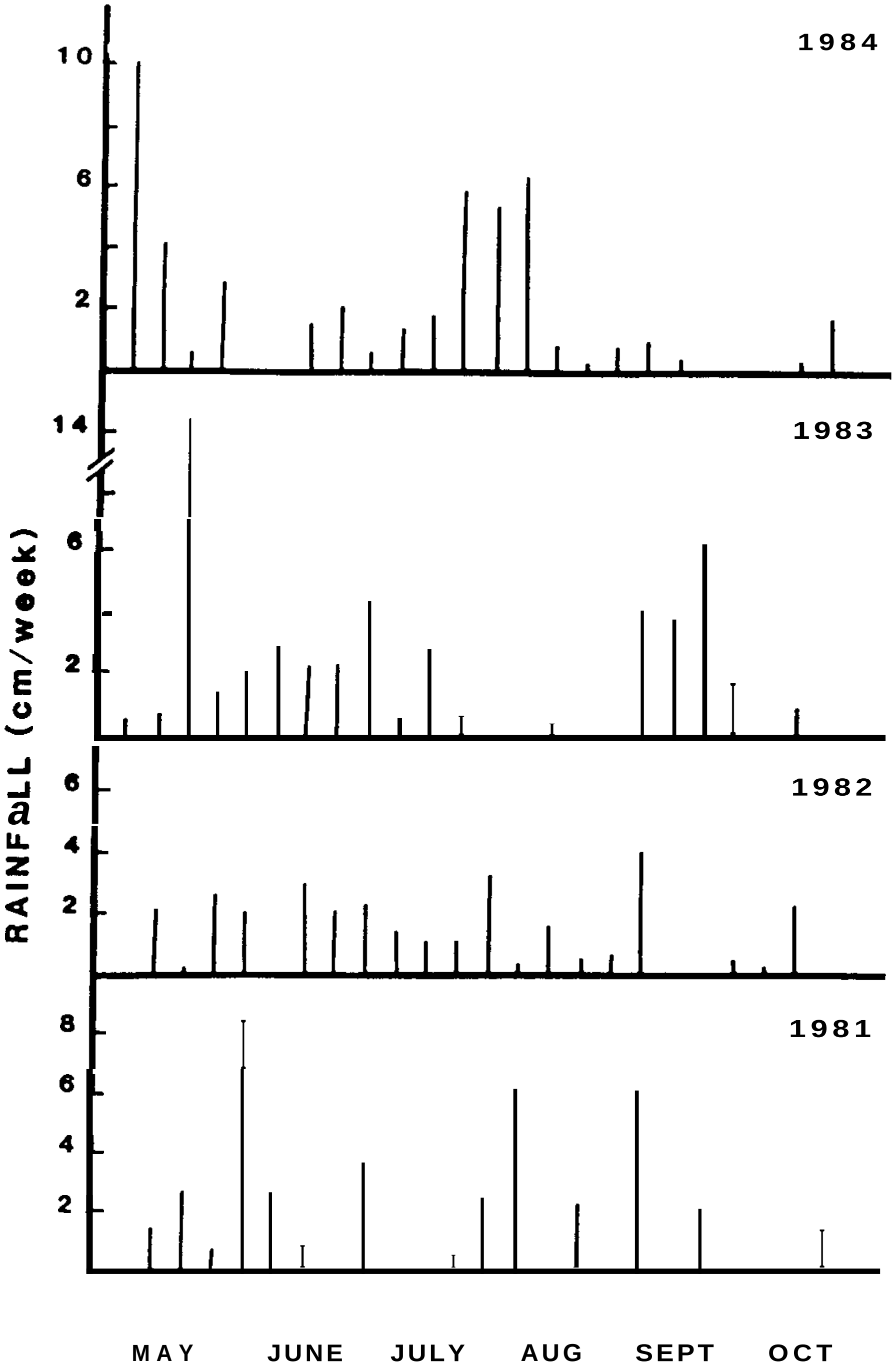

Figure 1. Rainfall in cm/week at Sand Mountain Substation for 1981 through 1984 for the soybean growing season.

Influence of Tillage and Crop Rotation on Soybean Yields and Cyst Nematode Population

D. L. Thurlow, J. H. Edwards, W. Gazaway, and J. T. Eason

Alabama Agricultural Experiment Station, U S Department of Agriculture, Agricultural Research Service,
Alabama Cooperative Extension Service, and Sand Mountain Substation. Auburn University, AL 36849

ABSTRACT

Strip-tillage (in-row chiseling), no-tillage, and conventional tillage (turnplow) systems were evaluated for 4 years together with cropping sequences of continuous corn (Zea mays L.), continuous soybeans (*Glycine* max [L.] Merr.), and corn-wheat (*Triticum aestivum* sp.)-soybeans. The field experiment was conducted on a Hartsells fine sandy loam (fine-loamy, siliceous, thermic, Typic Hapludults). Soybean cyst (*Heterodera* glycine Ichinohe) nematode (SCN) population was determined before and 58 days after planting soybeans. Corn yields in 1984 were not affected by cropping sequences or tillage systems. Soybean yields in 1984 were highly correlated with SCN population, were 39% higher with strip- and no-tillage than with conventional tillage, and were 28% higher when rotated with corn. SCN population 58 days after planting soybeans was highest with continuous soybeans and lowest with a combination of crop rotation and no-tillage.

Introduction

In a conservation tillage study conducted for 4 years on a Hartsells fine sandy loam (fine-loamy, siliceous, thermic, Typic Hapludults) conservation tillage resulted in 16 to 39% higher yields than conventional tillage in 3 of 4 years (1,2,3,4). In 1983, soybean yields with conventional tillage yielded only 690 kg/ha compared to 1660 and 1930 kg/ha with strip-till or no-till. With conventional tillage, the soybean plants were severely stunted in late August and began to defoliate 4 weeks before plants on other tillage treatments matured. Observation of the soybean roots suggested a nematode infestation.

The appearance of the soybean plants in mid-August 1983, and results of soil samples collected for nematode determination in late August suggested that the reduction of soybean yield under continuous soybeans may be caused by a buildup of a high soybean cyst nematode (SCN) population after 3 years of conventional tillage and continuous cropping. Thus, the objective of this study was to determine the rate of increase of SCN in 1984 in cropping and tillage systems started in 1980.

Materials and Methods

Minimum-tillage treatment consisted of planting soybeans over 20- to 22-cm deep chisel slots. No-tillage treatments were planted with a double-disk opener planter directly into the untilled soil surface. Conventional tillage consisted of turning the wheat cover in spring, disking in herbicides, and planting. Cropping sequences were continuous soybeans; continuous corn; corn-soybean; and corn-wheat for grain-soybean. Wheat was planted in the fall on all plots as a winter cover, including those plots not used for grain crop. The wheat was killed on the winter cover plots 10 days before planting corn or soybeans. The experiment was located on a Hartsells fine sandy loam soil on the Sand Mountain Substation at Crossville, Alabama, which is in the Appalachian Plateau area of Alabama. The experiment was a split plot design in a randomized complete block with four replications. The corn treatment was planted in six 90-cm rows 16 m long, and the soybean treatment was planted in eight 68-cm rows 16 m long. 'Essex' soybeans have been used since the experiment was started in 1980.

Soil samples were taken in the last week of August 1983, and cyst nematode counts were determined by the flotation method on 50 cc of soil. These samples were taken 12 to 14 cm deep under the rows of each plot. Soil sample were collected in March, July, and August for nematode analysis. The July and August samples were taken 58 and 59 days after planting full-season and double-cropped soybeans. The full-season soybeans were planted on 24 May and double-cropped soybeans were planted on 20 June after wheat was harvested for grain. All plots were uniformly fertilized according to soil test recommendations.

Results and Discussion

Soybean yields in 1983 followed trends established in previous years: lower yields with continuous soybean than soybean in rotation with corn, and lower yields with conventional tillage than conservation tillage (Table 1). The lowest yields were from continuous soybeans grown in the conventional tillage system. Low yields with this system were probably due to high nematode population in spring, which caused stunting and low vigor of soybean plants (Table 2).

In 1984 soil samples for nematode determination were taken in March, in July, (58 days after planting full season soybeans), and in August, (59 days after planting double-cropped soybeans). The number of cyst nematodes where soybeans had been continuously cropped for the past 4 years was very high in July and August, but SCN count in double-cropped soybeans, no-till, dropped in August. This reduced SCN count in the conventional tillage was similar to that in 1983, and was probably due to plants and roots dying in these plots (Table 2).

The SCN count increased throughout the growing season with full season soybeans in the strip-tillage and no-tillage treatments when rotated with corn. However, the rate of SCN increase in the no-tillage system appears to be 1 to 2 years behind strip-tillage with full season planting. However, when planting was delayed each year due to double-cropping soybeans behind wheat, SCN number was lower than when compared to full season soybeans. The no-tillage system with double-cropped soybeans had the lowest SCN numbers, and SCN did not affect soybean yields.

Soybeans yields in 1984 were lowest with the conventional tillage treatment across all cropping sequences (Table 1). The highest soybean yields occurred with full season soybeans grown in rotation with corn and with strip-tillage. The double-cropped soybean yields were approximately 300 kg/ha lower than the full season soybeans, however, wheat yield ahead of the double-cropped soybeans was 3670 kg/ha. Soybean seed size was also affected by SCN. The largest soybean seeds were from the tillage and crop rotation systems that gave the the highest yields. The double-cropped soybean seed size was affected by reduced rainfall in late August and September (Table 3). Late season rainfall was only 0.4 cm for September, and 2 cm or less the last 10 days of August and the first 10 days of October.

In summary, SCN populations built more slowly with conservation tillage than with conventional turning and disking; yields were higher when soybeans were in a 2-year rotation with corn than under continuous soybeans; and increased yield of soybeans in rotation with corn was even more evident when grown with conservation tillage than with conventional tillage systems.

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Table 1. Soybean yields as affected by tillage and crop rotation systems at Crossville, Alabama, for 1983 and 1984.

Tillage treatments	Yield					
	1983	Rotation mean	1984	Rotation mean	Tillage mean	
					1984	1985
	kg/ha					
	Continuous soybean					
Conventional	690		1818			
Strip-tillage	1569		1980			
No-till	2210		2360			
		1490		2070	1430	1900
	Soybean-corn rotation					
Conventional	1660		1870			
Strip-tillage	2230		3070			
No-tillage	2380		2970			
		2090		2640	1890	2590
	Wheat-soybean-corn					
Conventional	1930		1960			
Strip-tillage	1880		2720			
No-Tillage	1840		2450			
		1880		2380	2140	2590

Table 2. Soybean cyst nematode counts found in soybeans grown in 1983 and 1984 at Crossville, Alabama, under different tillage and crop rotation systems.

Tillage treatments	SCN counts[2] by sampling dates August 1983	 March 1984	 July[x] 1984	 August[x] 1984
		Continuous soybeans		
Conventional	460	13	590	122
Strip-tillage	806	72	741	693
No-tillage	498	97	785	599
Rotation mean	588	57	705	471
		Soybean-corn rotation		
Conventional	100	57	741	297
Strip-tillage	23	16	497	742
No-tillage	4	1	59	130
Rotation mean	42	25	432	356
		Wheat-soybean-corn		
Conventional	54	21	150	521
Strip-tillage	29	8	130	187
No-tillage	3	0	32	39
Rotation	29	9	107	249

[2] SCN counts in 50 cc sample of soil

[x] July and August samples were taken 58 and 59 days after planting full season and double-cropped soybeans.

Table 3. Soybean seed size at harvest as affected by tillage and cropping systems at Crossville, Alabama, for 1984.

Tillage treatments	Continuous soybeans	Soybeans-corn	Wheat-soybeans	Avg.
		g/100 seeds		
Conventional	9.8	11.8	10.5	10.7
Strip-tillage	11.0	14.8	11.8	12.5
No-tillage	12.8	14.8	11.3	12.9

Late Season Alfalfa Planting: Conventional Versus No-Till

D. D. Wolf and B. W. Kirby

Virginia Tech Department of Agronomy and the Chevron Chemical Company

INTRODUCTION

The last date recommended for conventional alfalfa (*Medicago sativa* L.) seeding in southwest Virginia is 1 September. Conventional plantings after this date often do not survive. The last date for no-till alfalfa plantings have not been established but may be later than for conventional plantings because of favorable moisture, quicker germination, and firm soil that resists heaving of seedlings. If no-till alfalfa could be planted several weeks later than conventional alfalfa, seedings could be made following removal of corn silage allowing for greater planting flexibility. The objective of this study was to compare conventional and no-till alfalfa plantings made at several different dates in late summer and early fall.

MATERIALS AND METHODS

German millet was removed as hay in early August. No-till alfalfa at 15 lb. seed per acre, and conventional alfalfa at 20 lb. per acre were planted on 1, 10, 20, 30 September, and 10 October of 1983 and 1984. A conventional seedbed was prepared prior to each planting date. Conventional treatments were planted with a cultipacker seeder. A no-till drill was used to establish no-till treatments after application of 1 pint paraquat per acre. Plant population counts were made On 16 November and in early April the next year. Top growth weight, root weight, and plant height were measured in mid-November following seeding. Gravimetric measurment of soil moisture was made on 18 Oct. 1984. Yields were obtained from all late season planting dates from a small subplot in the spring at the date when 1 September plantings were ready for first hay harvest. First hay harvest was made from each late season planting date when each treatment was ready for hay harvest. All subsequent hay harvests were made at 1/10 bloom stage of development. Yield data are from 1984 season of plantings made in 1983. Growth characteristics of alfalfa in November following establishment are from 1984 plantings.

RESULTS AND DISCUSSION

Seeds of conventional plantings made on 1, 10, and 20 September 1984 did not germinate because of dry soil until rainfall on 31 September (Table l), whereas seeds of no-till plantings germinated and began growth soon after planting. Thus, seedling development by 16 November was similar for 1, 10, 20, and 30 September conventional plantings. Rapid plant development from no-till plantings occurred because seeds were placed at approximately one inch depth where firm soil provided adequate moisture for germination (Table 2). No-till seedbeds are more ideal than conventional seedbeds that are often loose and dry because of machine operations required for soil preparation.

Table 1. Rainfall during late season establishment of alfalfa (1984 data).

Month	Dav	Rainfall Inches
Aug.	1 to 10	0.4
	11 to 20	2.9
	21 to 31	1.1
Sept.	1 to 10	0.8
	11 to 20	0.0
	21 to 30	0.2
Oct.	1 to 10	1.3
	11 to 20	0.1
	21 to 31	2.2

Table 2. Soil moisture on 18 Oct. 1984 in the top one inch of soil.

Planting method	Soil moisture
	%
Conv.	8.3 +
No-till	11.7

+ This value is less than wilting point and no seed would germinate.

Seeding weight and height in mid-November from no-till plantings were greater than conventional plantings made on 1, 10, and 20 September plantings. Shoot-root ratio of no-till seedlings was considerably less than conventionally established seedlings for all seeding dates except 30 September and 10 October plantings when all seedlings were very small. The low ratio indicates that no-till seedlings diverted much more photosynthetic energy to the development of roots in comparison to the conventionally established plants. These data along with root and top weights indicate that root systems of conventionally planted alfalfa were considerably smaller when compared with no-till plantings (Table 3).

Seedling population in November of 1983 was similar for conventional and no-till plantings even though considerably less seed was used for no-till plantings. Some differences in plant population occurred between planting dates because of environmental conditions following planting. All plant populations on 16 November were sufficient for maximum stands if plants survived through the winter (Table 4). Plant population decline between

Table 3. Growth characteristics of alfalfa planted at 5 dates in late season of 1984 using conventional and no-till planting methods. Data taken on 16 Nov. 1984

Planting	September				Oct.	LSD
method	1	10	20	30	10	0.05
			Height (mm)			
Conv.	88	45	39	32	16	
No-till	182	124	87	42	19	14
			Top weight (mg per plant)			
Conv.	198	64	56	49	11	
No-till	299	200	80	43	18	45
			Root weight (mg per plant)			
Conv.	37	11	10	13	3	
No-till	90	53	17	9	5	9
			Shoot-root ratio			
Conv.	5.4	5.8	5.6	3.8	3.7	
No-till	3.3	3.8	4.7	4.8	3.6	1.3

November 1983 and April 1984 was greater for conventional plantings at all planting dates as compared with no-till plantings. Only the 1 and 10 September conventional plantings had sufficient plant population the following spring whereas all no-till plantings other than the 10 October planting had sufficient plant population in April after late season seeding.

Dry matter accumulation by 19 May decreased with each delay in planting. Both no-till and conventional plantings made on 1 September were ready for first hay harvest on 19 May the following spring (Table 4). First hay harvest in the spring was delayed approximately eight days for each ten days of delay in planting beyond 1 September the previous season. Yields at first hay from no-till plantings were similar to conventional plantings made on 1 September. Yields from no-till plantings at all other dates were much higher than conventional plantings with inadequate stands resulting from conventional plantings made on 20 September or later.

SUMMARY

No-till alfalfa can be successfully planted three to four weeks later in the growing season than conventionally planted alfalfa. Firm soil and deep placement of alfalfa seed provides moisture for germination soon after planting, whereas conventional plantings must be made early so that adequate rainfall will occur for plants to become established. Conventional preparation of a seedbed causes loose soil and loss of surface moisture. Small plants resulting from late conventional plantings are subject to heaving, while the soil in no-till plantings is firm and plants are anchored against heaving. Seeding rates can be greatly reduced in no-till as compared with conventional plantings. Hay harvest in the spring after late season establishment must be delayed approximately eight days beyond typical first hay harvest for each ten days of delay in planting after 1 September the previous season.

Table 4. Yield and plant population of alfalfa (1984) no-till and conventionally planted at 5 dates in 1983.

Planting method	Sevt. 1	10	20	30	Oct. 10	LSD 0.05
	19 May yield (Tons per acre)					
Conv.	1.38	0.41	0.07	0.00	0.00	
No-till	1.74	0.76	0.56	0.31	0.00	0.22
	1st hay (Tons per acre)					
Conv.	1.38	1.19	0.84	0.12	0.00	
No-till	1.74	1.48	1.85	1.41	0.72	0.30
	Total season (Tons per acre)					
Conv.	4.04	3.39	2.20	1.28	0.79	
No-till	4.12	3.82	4.13	3.64	2.37	0.46
	Plant pop. 16 Nov. 1983 (No. per sq. ft.)					
Conv.	36	50	37	34	50	
No-till	44	52	39	39	54	10
	Plant pop. Apr. 1984 (No. per sq. ft.)					
Conv.	20	17	5	1	0	
No-till	38	54	39	28	8	11
	Plant pop. (% decline)					
Conv.	44	70	87	97	100	
No-till	14	0	0	28	85	14
	Date of first harvest					
Both	19 May	29 May	7 Jun	14 Jun	23 Jun	-
	Days delay for 1st cut+					
Both	0	10	18	25	34	-
	Days delay in planting++					
Both	0	10	20	30	40	-

\+ Delay beyond first harvest of 1 Sept. planting.
++ Days delay in planting after 1 Sept.

Retardation of Germination and Early Growth of Corn Planted No-Till in Sub Clover Cover Crop

D. A. Berger and S. M. Dabney

Agronomy Department, Louisiana Agricultural Experiment Station, Louisiana State University Agricultural Center

During the past several years interest in using legume cover crops to fix nitrogen and to control winter erosion has grown considerably as has interest in reduced tillage. However, combining the two methods does not always give good results.

Research done in Baton Rouge, Louisiana using sub clover (Trifolium subterraneum) as a cover crop for corn (Zea mays), has resulted in unacceptably poor stands in the past three years, 1982-1985. The corn was planted on the same experimental area, a silty clay loam soil (Commerce/Mhoon series).

In 1983, cover crops of Tibbie Crimson Clover (T. incarnatum), Mt. Barker Sub clover, Nova II Vetch (Vicia sativa), Coker 762 Wheat (Triticum cestivum) and fallow were used. On March 14, Funk's hybrid G-4611 corn was planted on 0.72 in rows using a Moore no-till grain drill. Herbicide (0.56 kg ai/ha Paraquat and 3.36 kg ai/ha atrazine were sprayed at planting. The mean stand count reported as plants/ha for the various covers were 29,340 fallow, 12.325 wheat, 4,910 crimson, 2,100 sub, and 1,785 vetch. The cause of the poor and varying stand was not determined. Birds, insects and allelopathy were suspected. The corn was replanted (April 21) 38 days after the initial application of herbicide, and except in the previously unsprayed plots an adequate stand was achieved.

The experiment was modified for 1984. The corn was planted with a four row planter at a 0.76 m row spacing. The planter consisted of ripple colters mounted on a toolbar ahead of John Deere 77 planting units. The only cover crop was sub clover. One strip in each replication was subsoiled and disked, and one was left fallow and not tilled. One set of clover plots received the broadcast and strip spray 3 weeks prior to planting. The intention of the early spray treatment was to reduce or eliminate any allelopathic effect that may result from planting directly into clover sprayed at planting time. Early spraying was also intended to reduce the danger of plant feeding insects moving from the dying clover plants to the newly emerging corn.

The emergence of the corn in the sub clover plots was somewhat slower and less uniform then in the tilled and the fallow plots, and the early growth appeared to be retarded. It was suspected that shading of the soil by the clovers was reducing the soil temperature and was thereby retarding the growth. Soil temperatures were taken at the depth at which the seeds were located. There was a significant difference in soil temperature between the different treatments (See Table 1). However, this temperature difference may not have been the cause of tlie reduced stands. In the areas of the heaviest vegetation, the press wheels did not close the slit produced by the disk openers and the seed could be seen laying in the bottom of or wedged between the walls of the open slit. In other cases, seeds that failed to germinate were found between layers of vegetation and were not in contact with the soil. Little rainfall after planting and the corn seedings in the clover areas appeared severely stressed.

In 1985, Funk's G4765 corn was planted April 4, on the same area used in 1983 and 1984. Plot size was 7.62 m x 3.05 m. One week before planting the entire area had been sprayed with Roundup at a rate of 4 l/ha. The planter consisted of 4 John Deere 77 units with dual disk openers mounted at a 0.76 m row spacing on a set of toolbars designed by the Agricultural Engineering Department at Louisiana State University. This arrangement allowed various tools such as colters, cultivator sweeps and disks to be mounted ahead of the planter units. Using this one pass planter, the seeds were planted into 3 types of seed beds: conventionally tilled, consisting of subsoiling, disking and disking again just before planting; no till, consisting of scattered vegetation of weeds and bare ground; and sub clover. Most of the weeds and clovers were dying but not yet dead as a result of the herbicide application. Vegetation samples taken March 28 gave mean dry matter yields of 1379 kg/ha on the fallow plots and 3112 on the sub clover plots.

Four combinations of tools were used on the toolbar ahead of the planters in an effort to improve the stand. These consisted of (1) ripple colters ahead of John Deere 77 planter units; (2) same as 1 but with a 15 cm sweep between the colter and planter unit with the sweep set to run about 2.5 cm deep; (3) the same as 2 but with disks on either side of the area worked by the sweep to push the soil back; (4) the same as 3 but without the sweep closing somewhat the slit opened by the colter to provide better contact of the seed with the soil.

In an attempt to see if different soil temperatures were an important cause of retarded germination soil temperature probes were placed in selected plots in two of the reps to detect if there was a difference in soil temperature under the different treatments. They were connected to Dataloggers and were automatically read and recorded at hourly intervals. Maximum and minimum soil temperatures in tilled and no-till clover plots are reported in Table 2. During the first week after planting, the clover areas had maximum temperatures 5–6°C cooler than tilled plots and minimum temperatures one or two degrees warmer. No–till fallow plots had similar soil temperature to tilled plots. All temperatures became similar following 7 cm of rain which fell on days 12 and 13 often planting.

Soil cores were taken at planting time to determine water content on the different plots. The data are presented in Table 3. It does not appear that soil moisture or bulk density would limit germination or emergence although the lower moisture at the over 7.6 cm depth may have slowed growth in the clover plots.

Table 1. 1984 Corn plant population and soil temperature.

Treatment	1000 plants/ha Stand	C° Temperature
Rand early	36	25.8
Band late	49	22.4
Disc	50	29.8
No till	49	29.0
Broadcast early	35	23.8
Broadcast late	33	21.8

Note: A general linear models procedure did not show significant differences in the stand. However, temperatures varied significantly, with an F value of .0003.

Table 2. 1985 Daily maximum and minimum temperatures in tilled plots and no till and clover plots recorded by datalogger at 2 cm below soil surface.

Temper-atures		Days After Planting														
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Maximum	tilled		30	27	30	34	28	29	30	30	22	29	30	27	32	32
	no-till		31	26	29	31	28	28	28	30	21	28	28	28	32	31
	clover		25	22	24	28	22	24	26	28	20	27	28	27	31	31
Minimum	tilled		18	11	15	14	12	12	15	18	15	16	14	16	16	17
	no-till	12	18	12	16	14	12	12	16	19	16	18	15	16	16	17
	clover		18	14	16	14	12	13	15	19	16	17	15	16	16	17

Note: Temperature data from soil probes 2 cm below soil surface recorded by datalogger.

Table 3. Bulk density and soil moisture taken at time of planting corn, 1985.

	Bulk Density (g cm^{-3})		Volumetric Soil Moisture	
	0 - 7.6 cm	7.6 - 15.2 cm	0 - 7.6 cm	7.6 - 15.2 cm
Tilled	1.09	1.48	.27	.39
No-till	1.31	1.52	.31	.35
Clover	1.22	1.48	.31	.29

Twelve days after planting, germination was measured by searching for corn seeds in a 0.5 m long area in the center of the second row of each plot. The number of seeds found was recorded, as was the depth of the bottom of each seed below the soil surface and the height of the plant from the seed to the highest point of the plant. (The leaves were not lifted to an upright position for this measurement.) In addition to this, the number of plants in each of the two center rows of the four row plots was counted. In Table 4 mean data are presented regarding mean depth of seed placement, plant height and stand counts made 12 days after planting. None of the planter arrangements was successful in producing a stand of corn.

Table 4. 1985 Mean planting depth, plant height, and stand of corn 12 days after planting.

Mean of 16 Plots/Treatment	cm Seed depth	Plant Height	Plants per ha	Plants per acre
Conventional till	2.9	18	58210	23567
No-till fallow	2.1	15	54604	22107
No-till sub clover	1.0	3	11942	4835

Note: Stand data is derived from the mean of all plants in 2 center rows of 7.5 m long plots; 16 plots per treatment. Seed depth and plant height are from .5 m long area in the same plots.

Data on plant height was grouped into classes of 0, <15m and >15cms. Data on depth of seed placement was grouped into two classes, < 1 cm or > 1 cm. Table 4 presents the distribution of these classes as influenced by cover treatments. In the conventionally tilled plots, only one of the 43 seeds in the measured area was at less than one cm; two seeds failed to grow; and 35 of the plants were over 15 cm tall. In the no-till fallow plots, 7 seeds were at less than one cm. Of the 43 seeds in the measured areas, 4 failed to grow and 25 grew to more than 15 cm. In the no-till sub clover, 22 seeds located were at less than 1 cm, and only half of the 22 grew. Of the 13 seeds that were deeper than 1 cm, only 1 grew. Only 1 of the plants grew more than 15 cm. It appears that if the planter had been adjusted to more effectively plant through the 3 ton per ha dry matter of clover tops, the stand would have been even worse than 11,900 plants per ha.

Table 5. 1985 Frequency distribution of plant height and seeding depth classifications.

	Height of Plant			Depth of Seed	Total
	0	<15 cm	>15 cm	cm in soil	Seeds
Conventional till	0	0	1	<1	
	2	6	34	>1	43
No till fallow	3	3	1	<1	
	1	10	25	>1	43
No till clover	11	10	1	<1	
	12	1	0	>1	35

Observations were made in 1982 and 1983 that johnsongrass was inhibited early in the season where sub clover residues remained. These observations and difficulties in obtaining a stand of corn prompted a laboratory trial in which germination tests were conducted in the lab placing seeds in petri dishes on filter paper saturated with water in which sub clover had been soaked. In one study, the sub clover leachate did not appear to prevent germination or root growth rate. In a second trial root elongation rates were severely reduced by watering with extracts (Table 6). The depression could be due to substances present in the clover, or to microbial degredation products.

Table 6. Root elongation of corn seedlings as influenced by sub clover leachates.

Source of sub clover leachates	Mean Length (mm) of shoot at 4 days	Mean Length (mi) of shoot at 7 days	Mean growth mm per day; Day 4-7
Fresh tops	12.9	19.7	2.3
Dried tops	10.7	25.8	5.0
Distilled water	21.8	69.4	15.9
Fresh roots	17.6	46.0	9.5

In the field, lack of stand establishment may be due to a combination of many factors. The slowing of growth by clover leachates may combine with any retardation in germination due to the lower soil temperatures and with problems in seed placement due to vegetation to reduce stand and growth rate. This slowed growth would make the seedlings more susceptible to bird, insect, and pathogen damage. Deep placement, by delaying establishment and increasing coleoptile length increases exposure of seedings to a hostile environment under heavy residue.

Summary

Minimum tillage appears to be very promising. Adequate seed placement in the soil can be achieved in most cases. However, there is definitely a problem in getting adequate germination and good early growth when corn is planted into untilled sub clover sod. Germination and early growth of the Johnsongrass weeds was also very much retarded indicating that planting no-till in sub clover may be beneficial in weed control in the absence of herbicide application. There appears to be a need for more basic research into possible alleopathic interactions between various cover crops and crops and weeds when used in no till planting.

No-Till Production of Corn and Sorghum Silage in Southeast Louisiana

R. E. Joost, D. L. Friesner, L. F. Mason, F. Jodari, and M. Allen

Southeast Research Station,
Louisiana Agricultural Experiment Station, Louisiana State University Agricultural Center, Franklinton, LA 70438

Much of the farmland in the southeastern United States is on hilly, highly erodable land. Erodable soils can be managed to produce row crops while protecting them from soil loss through use of minimum tillage.

No-till production of summer annual crops has been limited almost exclusively to plantings in crop residues and cool-season sods. The warm-season perennial grasses which dominate swards in the hill regions of the lower South offer a challenge to no-till production of summer annuals. Since sod and summer annual growth cycles peak at identical times, it is necessary to drastically suppress sod growth in order to obtain adequate production from annuals. However, it is also desireable to maintain the sod for cover and late season production, in addition to avoiding reestablishment costs.

This study was initiated to evaluate methods of no-till production of corn and forage sorghum for silage in the hilly Coastal Plain region of southeast Louisiana. The effects of planting date, sod type, sod suppressant herbicide and planting method have been evaluated.

METHODS

In 1982 and 1983 Dekalb-Pfizer XL-80 corn was established no-till, using a four-row Cole subsoiler planter, into Alicia bermudagrass and Pensacola bahiagrass sods. An adjacent area was prepared conventionally, as a check, by chisel plowing, discing twice, and planting with a conventional four-row John Deere planter.

Paraquat at 0.56 kg ha^{-1} glyphosate at 0.22 kg ha^{-1}, or atrazine at 1.68 kg ha^{-1} were evaluated in relation to an unsprayed control for suppression of sod and weeds in no-till plantings of corn in 1982. In both 1982 and 1983 these same chemicals were evaluated for use in no-till production of forage sorghum silage using Northrup King NK 300 seeded with the Cole planter. Corn was harvested by hand for silage yield and quality determinations at the early-dent stage each year, while forage sorghum was harvested at the hard-dough stage.

RESULTS

No-till yield of corn in neither bermudagrass nor bahiagrass was significantly ($p=0.05$) different from that of conventional tillage in either year of the study (Table 1). Grain content of the silage was unaffected by tillage method. Bermudagrass sod tended to offer more competition with corn plants for moisture and nutrients than did bahiagrass sod. This effect would be more severe in years of extreme drought stress.

Sod competition with corn was affected by planting date (Table 2). Early planting allowed corn seedlings to develop with a minimum of sod competition, producing a canopy which supressed the grass sod by shading. The improved performance of corn in bahiagrass plots treated with paraquat and glyphosate, as compared to the control or bermudagrass sod, suggests an earlier spring growth of bahiagrass in relation to bermudgrass. Residual weed control obviously is most important in early sod seedings as evidenced by silage yields of atrazine-treated plots.

There was also a much better distribution of rainfall in July during the grain filling stage of the late-planted corn which probably explains the higher grain percentage for this planting. Grain percentage was affected by herbicide treatment in the same manner as yield.

Late season plantings failed in bermudagrass sod unless glyphosate was utilized to supress the sod. Paraquat was ineffective in both sods, however, atrazine worked well in bahiagrass.

Forage sorghum was planted in early May each year of the study. Yield results indicate the same herbicide responses as for late-season corn (Table 3). These results emphasize the need for a strong sod suppressant chemical when silage crops are to be planted in actively growing sods.

A major problem with this system is loss of sod cover from heavy suppression when repeatedly planted to no-till silage crops. Since the goal is to develop multiple cropping, no-tillage systems in which a silage crop can be followed by grazing or hay harvest, it is necessary to identify a herbicide program which will suppress sod growth during the first month of corn growth to allow canopy development. If sod is then allowed to begin regrowth, shading will be sufficiently suppressive to allow corn maturation, while maintaining the sod stand.

Currently, a number of planter-herbicide combinations are being evaluated to address this problem. The erodable nature of many soils in the Southeast where warm-season grasses comprise the dominant sod type enhances the value of no-till research in this area. The findings of this study, indicating sod plantings to be comparable to conventional tillage, show that no-tillage silage production has potential in this area.

Table 1. Mean effects of tillage system, averaged over planting dates and herbicide treatments,in bermudagrass and bahiagrass sods, 1982–83.

	Dry matter yield			Grain content		
Tilage method	1982	1983	mean	1982	1983	mean
	--- Mg ha^{-1} ---			------ % ------		
Conventional	8.7	12.1	10.4	45.9	29.8	37.9
No-till bermudagrass	8.1	8.3	8.2	36.7	25.5	31.1
No-till bahiagrass	9.2	11.2	10.2	42.8	32.0	37.4
LSD (0.05)	NS	NS	NS	NS	NS	NS

Table 2. Effects of herbicide and planting date on no-till corn silage production, 1982.

	Dry matter yield, Mg ha^{-1}			Grain content, %		
Herbicide	Mar. 9	May 10	mean	Mar. 9	May 10	mean
--------------- Bermudagrass sod ---------------						
Paraquat	6.2	3.2	4.7	10.8	36.5	23.6
Glyphosate	6.4	6.2	6.3	10.8	35.3	23.1
Atrazine	10.9	3.5	7.2	14.6	33.8	24.2
Control	7.9	0.5	4.2	12.4	18.5	15.5
LSD (0.05)	0.6	0.6	0.4	NS	7.7	5.5
--------------- Bahiagrass sod ---------------						
Paraquat	8.5	3.5	6.0	9.4	35.6	22.5
Glyphosate	9.4	9.0	9.2	6.4	44.5	25.5
Atrazine	9.3	8.6	8.9	10.1	47.6	28.8
Control	6.4	1.9	4.1	6.0	25.1	15.6
LSD (0.05)	0.6	0.6	0.4	NS	9.2	6.5

Table 3. Effects of herbicide treatment on no-till sorghum silage production, 1982–1983.

	Dry matter yield, Mg ha^{-1}			Grain content, %		
Herbicide	1982	1983	mean	1982	1983	mean
--------------- Bermudagrass sod ---------------						
Paraquat	5.2	6.9	6.0	13.1	19.1	16.1
Glyphosate	7.9	10.0	9.0	17.8	22.5	20.2
Atrazine	5.2	7.4	6.3	9.3	21.1	15.2
Control	3.3	4.7	4.0	11.6	21.0	16.3
LSD (0.05)	1.0	2.5	0.8	NS	NS	NS
--------------- Bahiagrass sod ---------------						
Paraquat	7.3	10.5	8.9	9.5	25.4	14.2
Glyphosate	11.5	10.1	10.8	9.1	19.4	17.3
Atrazine	10.7	9.0	9.8	15.1	19.8	17.4
Control	8.7	5.6	7.2	5.6	29.0	17.4
LSD (0.05)	0.9	4.3	NS	NS	NS	NS

Preliminary Evaluation of Legumes as Cover Crops for Alkaline Clay Soils

T. J. Gerik, F. W. Chichester, C. L. Neely, and J. E. Morrison, Jr

Texas Agricultural Experiment Station and USDA-AAS, Temple, TX

Six legume species were evaluated as potential winter cover crops for no-tillage cropping systems at Temple, Texas. Legumes were planted on an Austin silty-clay (Entic Hapustolls, fine-silty, carbonatic, thermic, pH 8.3) on 28 October 1984 and included crimson clover, T. incarnatum (var. Dixie); sub-clover, T. subterraneum (var. Mt. Barker and Clare); arrowleaf clover, T. vesiculosum (var. Yuchi); barrel medic, Medicago truncatula (var. Jemalong); hairy vetch, Vicia villosa; and rose clover, T. hirtum (var. Kondinin, Wilton, Hykon, and seven experimental lines).

Periodic evaluations were made to determine percent ground cover, plant height, percent winter kill, forage potential, and flowering dates. Hairy vetch, 'Wilton' rose clover, and the experimental rose clover lines RM16 and RH7 had the highest plant growth ratings. Severe winter kill from frost heaving of soil prevented accurate estimations of plant growth for barrel medic and both sub-clovers. Leaf chlorosis was not evident in the surviving plants of barrel medic, but it severely affected crimson, arrowleaf, and the subterranean clovers. Flowering dates ranged from 29 March 1985 for barrel medic to 23 April 1985 for hairy vetch. These dates are considered too late to permit natural reseeding of winter cover crops for no-tillage cropping systems with grain sorghum and corn in central Texas, but they may be suitable for cotton.

Given the favorable plant growth rating of hairy vetch, further studies will be conducted this summer to determine the total amount of nitrogen fixed, rate of plant residue decomposition, and the rate of nitrogen release from the residue for vetch under conventional tillage and no-tillage with two irrigation levels.

Functions of Legume Cover Crops in No-Till and Conventional Till Corn Production

M. Utomo, W. W. Frye, and R. L. Blevins

Department of Agronomy, University of Kentucky, Lexington, KY 40546-0091

Legumes are important in crop production due to their capability of fixing atmospheric nitrogen. In addition to supplying biologically fixed N to the corn, they add organic matter, affect the supply of available water and plant nutrients, improve the physical properties of the soil, and provide erosion control (3).

In Kentucky, research conducted from 1977 through 1983 (1, 3) showed that winter annual legumes could be grown as cover crops in a continuous no-till corn system. Hairy vetch resulted in the greatest yields of corn grain, because it produced more dry matter, thus more mulch, and higher nitrogen content than the other cover crops. The plots used for the above experiment were split in 1984, and one-half of each plot was conventionally tilled. The objectives of this were to (a) determine the effects of legume cover crops in both conventional till and no-till systems, (b) compare the effects of continuous no-till with that of periodic conventional tillage following several years of no-till, and (c) evaluate the system under higher rates of fertilizer N than was used previously.

MATERIAL AND METHODS

The experiment was conducted at Lexington, Kentucky on a Maury soil (fine-silty, mixed, mesic, Typic Paleudalf). The plots were established in 1976 and maintained through 1983 under a system of continuous no-till corn with annual legumes as cover crops (1). In 1984 the plots were split into conventional till and no-till treatments. The winter cover crops were overseeded in mid-September 1983 into the standing no-till corn. Cover treatments were hairy vetch alone, hairy vetch mixed with annual ryegrass, big flower vetch, rye, and corn residue alone. The annual ryegrass winter-killed leaving a pure stand of hairy vetch, therefore, results from that treatment were omitted from this paper. Each of the cover treatments were combined with 0, 85 and 170 kg/ha N from NH NO fertilizer, broadcasted at corn planting time. Cover crop samples were taken on four 0.25-m^2 areas from each plot before planting and N fertilization. Dry matter yield and N content were determined from those samples. On 18 May 1984, corn was planted at a rate of 50,000 plants per ha using a no-till corn planter. Following planting, the plots were sprayed with 1.17 L/ha paraquat mixed with 3.36 kg/ha cyanazine. Soil samples were taken at monthly intervals from depths of 0 to 7.5 cm and 7.5 to 15 cm and analyzed for NH_4 and NO_3 and total soil N. Soil samples for moisture determination were taken weekly at the 0- to 15-cm depth in each plot. Daily maximum and minimum soil temperatures were measured at 5-cm depth in the rows and between the rows for the first 30 days after corn planting. Corn grain was harvested in early October 1984.

RESULTS AND DISCUSSION

Legumes as Nitrogen Source

Hairy vetch produced more dry matter and had greater N content than big flower vetch or rye at any N fertilizer level (Table 1). With no N fertilizer, hairy vetch contained 117 kg/ha N compared to 47 and 27 for big flower vetch and rye, respectively. With 170 kg/ha N, hairy vetch produced 131 kg/ha N compared to 46 and 56, respectively, for big flower vetch and rye. Big flower vetch contained significantly higher N percentage than rye, but produced the lowest amount of dry matter, and that low dry matter production was reflected in the unusually low level of N content of the big flower vetch at the 170-kg/ha N treatment.

Table 1. Dry matter production and N content of cover crops (top growth), 1904.

	Fertilizer N rates 1977-83 (kg/ha)					
	0 to)+		50 (85)		100 (170)	
Cover	DM‡	N	DM	N	DM	N
Rye	1.7	27	3.0	45	3.5	56
Big flower vetch	1.5	47	2.2	75	1.6	46
Hairy vetch	3.0	117	3.1	119	3.3	131

\+ Numbers in parentheses are 1984 fertilizer N rates.

‡ DM = dry matter, Mg/ha; N = N content, kg/ha.

At planting and before N fertilizer was applied, total N of the 0- to 7.5-cm depth of soil was consistently higher under no-till than conventional till for all cover treatments (Table 2). The ratios of total N of no-till to that of conventional till ranged from 1.15 to 1.30. In the 7.5- to 15-cm depth, however, total N tended to be higher under conventional till, and the ratios were from 0.88 to 1.07. This resulted from inverting the surface 15 cm of soil by moldboard plowing, so that the higher organic matter content was in the 7.5- to 15-cm depth.

Table 2. Effects of tillage, cover treatment, and N fertilizer rate on total soil N before N fertilization, 1984.

	Fertilizer N rates 1977-83 (kg/ha)			
	0 (0)[+]		100 (170)	
Cover	CT[‡]	NT	CT	NT
	Total soil N, %			
	0- to 7.5-cm depth			
Corn residue	0.165	0.190	0.189	0.202
Rye	0.164	0.196	0.161	0.210
Hairy vetch	0.174	0.212	0.169	0.217
	[illegible] m depth			
Corn residue	0.166	0.160	0.153	0.164
Rye	0.157	0.156	0.168	0.158
Hairy vetch	0.182	0.160	0.179	0.161

[+] Numbers in parenthases are 1984 fertilizer N rates.

[‡] CT = conventional tillage (plowed one week before sampling); NT = no-tillage.

At planting, prefertilization values of available N (KCl extractable NH_4^+ plus NO_3^-) under no-till tended to be higher in the 0- to 7.5-cm depth and lower in the 7.5- to 15-cm depth than under conventional till, although differences were small (Fig. 1). Regardless of fertilizer treatments, hairy vetch resulted in more available N in the at 0- to 7.5-cm depth for both no-till and conventional till. Soil samples taken June 28 (one month after N fertilization) showed that available N increased significantly both in no-till and conventional till, at both sampling depths and with and without N fertilizer; the increase was much greater with conventional till, than with no-till. With conventiona till, and no N fertilizer, available N under hairy vetch increased by 99% over the month before, while the increase was only 13% with no-till. This indicates that a substantial amount of organic N was mineralized during the first month of the corn season and more mineralization occurred with conventional till, than no-till. This is consistent with results reported by Smith and Rice (5).

If we assume that 50% of the N of the top growth was mineralized during the corn growing season, the hairy vetch would have provided about 60 to 65 kg/ha N from top growth alone (50% of the N values from Table 1). If we assume further that the ratio of N in top growth to N in roots was 4:1, an additional 15 to 16 kg/ha N would have been supplied by the roots assuming also 50% minealization from the roots. This is slightly less than the 90 to

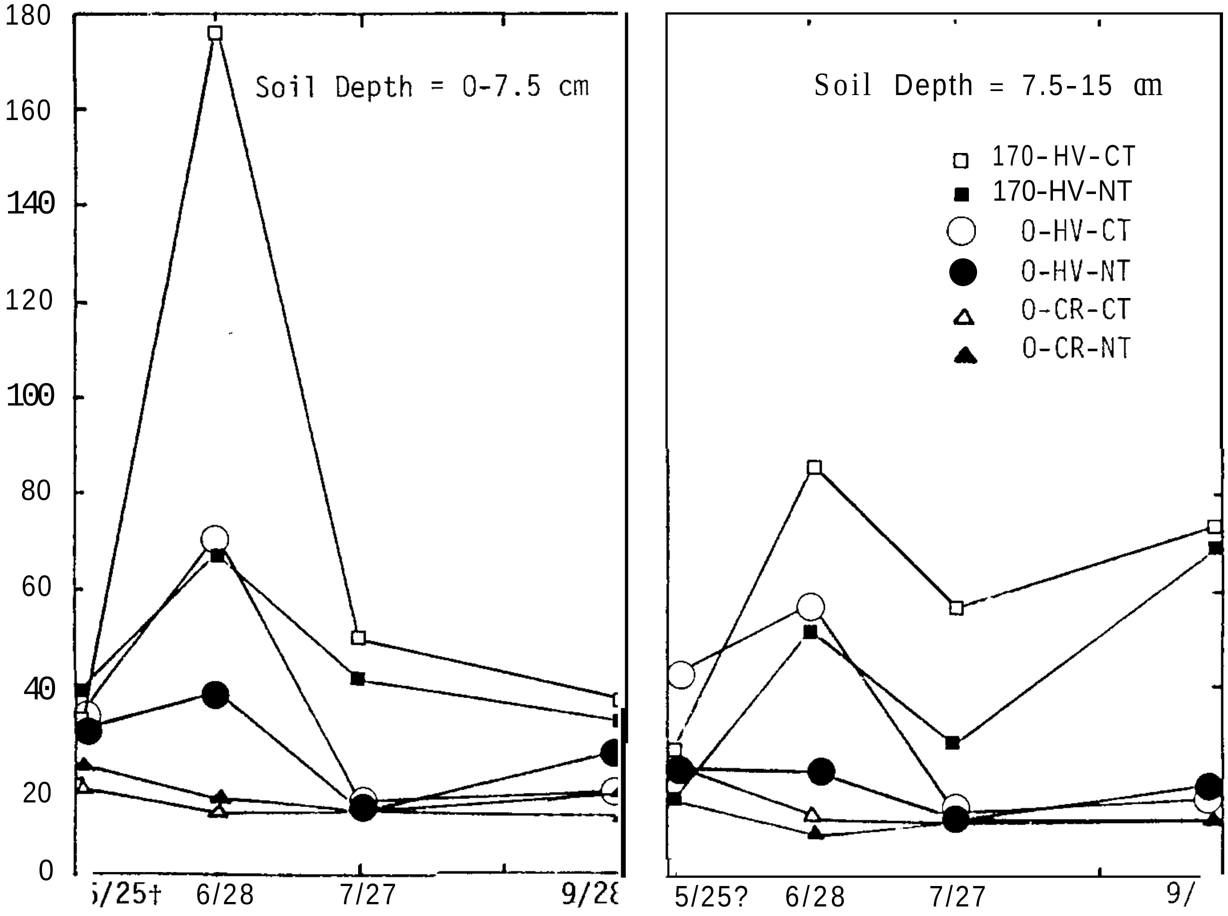

Fig. 1. Available soil nitrogen ($NH_4^+ + NO_3^-$) of no-tillage and conventional tillage, 1984. (HV = hairy vetch? CR = corn residue; 170 and 0 = kg/ha of N fertilizer; †Before N fertilizer applied).

100 kg/ha/yr N estimated by Ebelhar et al. (1) from grain yields and based on fertilizer N equivalent, but it does not take into account mineralization of stored soil organic N. We presently do not have a reliable estimate of that.

Legumes as Mulch

The mulch from killed winter cover crops affects soil temperature, soil moisture, and soil erosion. Maximum and minimum soil temperatures were measured daily at 5-cm depth during the first month after planting the corn. The average maximum soil temperatures, measured both in row and between row, were consistently lower under no-till than conventional till. However, no-till maximum soil temperatures under corn residue, rye, and hairy vetch were 1.9, 1.8, and 3.6 C, respectively, higher when measured in the row slits than when measured between the rows and only 0.7, 0.3 and 1.2 C lower than in the row of the respective cover treatments with conventional tillage. Apparently, the microclimate of the slit of the corn row in no-till is fairly similar to conventional till. The average minimum soil temperatures under no-till were generally not significantly different than under conventional till.

The mulch cover with no-till was effective in conserving soil water, resulting in more available water than with conventional till. Hairy vetch, rye, and corn residue treatments with no-till averaged 3.6, 3.1, and 1.8%, respectively, higher in gravimetric soil moisture content than with conventional till during the first 7 weeks of the season.

Effect on Corn Grain Yield

Corn grain yield without N fertilizer was greater with the legume cover crops than with rye or corn residue, both in no-till and conventional till (Table 3). Yield with hairy vetch was greater than with big flower vetch. The familiar relationship between corn yield, tillage system, and N fertilizer rate discussed by Phillips et al. (4) was apparent in these data. Corn yield was greater with conventional till than no-till where no fertilizer N was applied, but with N fertilizer, no-till corn tended to outyield conventional till corn. The greater yield under conventional tillage with no N fertilizer was thought to be due to the greater N mineralization indicated by Fig. 1. The tendency for greater yield under no-till with N fertilizer applied was probably because soil water was higher under no-till, resulting in more efficient use of the fertilizer N by the corn plants.

Table 3. Effects of cover treatment, N fertilizer rate, and tillage on corn grain yield, 1984.

	Fertilizer N rates, 1984 (kg/ha)					
	0		85		170	
Cover	CT[+]	NT	CT	NT	CT	NT
	Yield of corn grain[+] (Mg/ha)					
Corn residue	4.9	3.1	5.9	5.5	6.2	6.2
Rye	5.1	3.3	6.3	6.4	6.8	7.0
Big flower vetch	6.0	4.0	7.0	7.6	5.6	5.7
Hairy vetch	6.8	6.0	6.3	6.8	7.2	7.6

[+] CT = conventional tillage; NT = no-tillage.

[‡] Based on 15.5% moisture.

Corn appeared to respond well to N fertilizer up to 170 kg/ha N with all tillage and cover treatments except big flower vetch at 170 kg/ha N (Table 3). The decrease in corn yield between 85 and 170 kg/ha fertilizer N on the big flower vetch plots has been shown to be a result of differential erosion of the soil of the experimental area (2).

CONCLUSIONS

When the plots of an 8-year old continuous no-till corn experiment were split into no-till and conventional till, the first year's data showed:

1) With no N fertilization, no-till resulted in lower corn grain yields than conventional till, however, with the 170 kg/ha N rate, grain yields with no-till were generally higher. In both tillage systems, hairy vetch had the greatest influence on corn grain yields compared to other cover treatments.

2) Because of inversion the plow layer, total soil N under conventional till was less than no-till in the 0- to 7.5-cm depth, but was greater than no-till in the 7.5- to 15-cm depth. Available N (NH_4^+ and NO_3^-) was generally greater under conventional till. This was attributed to greater N mineralization.

3) The maximum soil temperature at 5-cm depth measured in the row under no-till with corn residue, rye, and hairy vetch cover, respectively, were 1.9, 1.8 and 3.6 C higher than between rows and only 0.7, 0.3 and 1.2 C lower than where measured in the row of conventional till.

4) Soil water content in the 0- to 15-cm depth under corn residue, rye, and hairy vetch was 1.80, 3.1 and 3.68, respectively, higher with no-till than with conventional till.

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Soil Management
and
Soil Fertility

Soil Management and Fertility for No-Till Production

K. L. Wells and J. T. Touchton

University of Kentucky and Auburn University

No-till production of corn, soybeans, and grain sorghum has increased rapidly during the past 15 years. With development of no-till small grain drills in recent years, a large increase of no-till small grain production is expected. No-till seeding of forages is also expanding.

Recent shifts in tillage management have created concern among producers about the influence these management systems will have on soil productivity and the need for different fertilizer management practices. During the rapid expansion of no tillage in the early 1970's, research data was not available to provide direction for no-till soil management practices. Because of the lack of data, information obtained from researchers as well as progressive farmers received much attention from the farm press without much concern about its adaptability. Farmers in the south were wondering why publicized results from farther north were different from what they were being told, and northern farmers were wondering why no-till practices often performed differently for them as compared to results publicized from the south.

By the late 1970's sufficient information from long-term no-till studies in the Southeast was available to show the effect of long-term no-till production on soil characteristics. It became apparent from this information that the effect of no-till on some soil characteristics was great enough to merit consideration in developing no-till production systems.

EFFECT OF NO TILL ON SOIL PROPERTIES

Moisture Content,

As expected, a mulch reduces evaporation of soil moisture. Studies have shown that evaporation losses from no tillage was much less than that from conventional tillage, particularly in the interval from planting until the crop canopy completely shades the soil surface. Additionally, the mulch increases water infiltration, particularly on sloping surfaces. The net result is about 15 to 258 more available soil moisture during the growing season with no tillage than conventional tillage.

Soil Temperature

The mulch in no-tillage systems acts as an insulation barrier between the soil surface and the atmosphere. As a result, changes in soil temperature are considerably slower with no tillage than conventional tillage. This means cooler soil temperatures in the spring and summer and warmer soil temperatures in late fall with resultant less temperature fluctuation under no tillage. While cooler soil temperatures can be beneficial in mid summer by slowing plant metabolism, they can sometimes cause delays in spring planting. This delay can be greater on soils which have fragipans, hardpans or other barriers that restrict internal drainage and create waterlogged soils. Although the optimum corn planting date is mid-May in Kentucky, research (Herbek et al., 1984) has shown that no-till corn planted on a Zanesville soil (fragipan at about 24-inches) in early June will yield as well as conventionally planted corn in mid-May.

The key point is that no tillage results in cooler soils in the spring than conventional tillage, and while this is no particular problem for normal planting on well-drained soil, planting on water-logged soils should be delayed until they drain and warm in the seeding zone. An area not yet adequately described is the effect that warmer soil in late fall will have no-tilled small grain. Some research is currently underway in Kentucky on this topic.

Redistribution of Organic Matter and Immobile Nutrients

Plants act as a pump in the soil relative to removing minerals and accumulating them in their tops and roots. With conventional tillage, plant residues from the previous crop are mixed to varying degrees with the surface soil to plow depth. As a result, organic matter and minerals are mixed back into the plow layer. In contrast, there is no mixing of crop residues back into the soil with continuous no tillage. All residues from previous crops accumulate at the soil surface, and results in development of a surface mulch layer made up of partially decomposed plant residues. Decomposition of this thin surface layer of organic material produces acids and greatly increases acidity in the top 1 to 2 inches of underlying soil. With conventional tillage, this highly acidic layer would never accumulate at the surface because the source of the acidity (plant residues) would be diluted greatly when plowed and disked into the soil. The same is true for minerals contained in the plant residues. Those which react strongly with soil move very little and accumulate in the surface 1-2 inches in no-tillage systems. Initially, there was some concern that the surface accumulation of nutrients, especially P, would not be available for plant uptake. Research conducted in Kentucky, Georgia, and Virginia has shown, however, that the surface accumulation of nutrients would not result in an insufficient nutrient supply even if fertility levels below the surface 1 to 2 inches were low.

Greater Microbial Activity

As expected, accumulation of organic residues at the soil surface results in greater microbial activity in no-tilled than conventionally tilled soils. Greater numbers of both aerobic and anerobic bacteria have been measured under no-till as compared to conventional till. Even though large numbers of aerobes are present, the relatively large presence of anerobes, together with a higher soil moisture content under no tillage, results in no-tilled soils having a greater potential for loss of plant available nutrients by denitrification and immobilization than conventionally tilled soils.

Residual Soil Nitrogen

Although no tillage can result in greater leaching on well-drained soils and greater denitrification on poorly drained soils, recently published research has shown that the residual soil N content is higher with no tillage. While studies to-date have not indicated the extent to which this buildup of residual soil nitrogen contributes to plant-available nitrogen, they have shown that it is in the organic form, and that nitrogen fertilizer used in crop production results in a greater buildup of residual soil nitrogen. Although much of this increased nitrogen content is not readily available to crops, it does not mean N is lost from the no-till system. Low availability of this labile organic pool of soil N assumedly represents only a diminished nitrification of organic nitrogen reserves due to the soil not being aerated as the case in preparation of a conventional seedbed.

Bulk Density

The no-till practice in itself does not cause soil compaction. Similar machinery traffic is used on conventionally prepared seedbeds even more intensively with on no till. Reported low yields from no-tilled soils as compared to conventionally planted crops appear to result from no-tilling into soils which were already too compact for good root permeability through the soil or soils which already contained traffic pans resulting from moldboard plowing or disking in previous conventional-tillage practices. Reports are quite clear that if compaction problems already exist, no-till planting into such conditions is not likely to produce as well as conventional planting. However, if such conditions are known, no-till planting can be successful if "in-row" subsoilers are used. Touchton and Johnson (1982) reported that no-till soybean yields on Appling and Cedarbluff soils in Georgia were equivalent to yields from moldboard plowed or chisel plowed seedbeds when an "in-row" subsoiler was used with the no-till planter. Subsequent wheat yields drilled into disked soybean residues were better following soybeans planted into moldboard plowed, chisel plowed, or no-till with "in-row" subsoiled than from no-till without "in-row" subsoiling. Touchton (1984) has also reported results showing that "in-row" subsoiling was not likely to be as beneficial on Decatur and Hartsells soils of north Alabama as on the more sandy textured Coastal Plains soils of south Alabama. These studies also showed that use of a starter fertilizer placed into the "in-row" subsoil slit significantly improved yields on these soils with traffic pans as compared to "in-row" subsoiling without use of a starter fertilizer.

OTHER AGRONOMIC CHARACTERISTICS OF NO-TILL

Rooting Habit

There is much greater root activity in the surface 3 inches from no-tilled crops as compared to crops planted in a conventional seedbed. Assumedly, this results from the greater soil moisture content associated with no-tillage.

Effect of Topdressing All Lime and Fertilizer on Crop Yields

Since there is no practical way to incorporate lime or fertilizer into the soil in continuous no-tilled fields, it must be surface applied. Although there has been much concern about the effectiveness of such applications, particularly on acid soils with low residual fertility, several basic studies have been conducted showing them to be effective (Belcher and Ragland, 1972; Singh et al., 1966; Hargrove et al., 1982). This probably results from the greater surface rooting activity of no-tilled crops, making the surface applied lime and fertilizer (and the residual fertility which accumulates at the surface under no-till) more utilizable by the crop. So long as there is rooting activity at or near the surface, topdressed application of relatively immobile nutrients might be viewed simply as a horizontal band, with attendant band efficiency resulting from its use.

Nitrogen Fertilizer Efficiency

There is concern about N efficiency with no-till systems, just as with conventional-tillage systems. The likely routes of inefficiency are the same...leaching, volatilization, denitrification, and immobilization. Soil and climatic characteristics will often be the determining factors as to which route or routes of N inefficiency will be most likely. Such practices as incorporation, split applications, surface broadcasting, band application, use of winter legume cover crops, or use of nitrification inhibitors should be used in terms of the relative merits which have been tested and demonstrated under the various soil and climatic situations found throughout the south.

Since fertilizer N is usually surface applied for no-till, there is a greater potential risk for leaching, volatilization, denitrification, and immobilization. Of the commonly used N sources, the potential risk of surface losses from surface application of urea to no-till corn is greater than from ammonium nitrate or urea-ammonium nitrate solutions (Bandel et al., 1980; Touchton and Hargrove, 1982; McKibben, 1975). In a Kentucky report by Wells et al. (1976) it was indicated that although urea has a greater potential for surface losses, variability of results due to unpredictable rainfall make it difficult to discriminate among these sources for no-till corn.

Subsurface application of N has been shown to improve the efficiency for use by no-till Corn. Assumedly, this practice would lower the risk for volatilization and immobilization. Delayed applications of N give similar increased efficiency (Smith et al., 1984). Touchton et al., (1982) reported success in using crimson clover as a winter cover crop on a Cecil sandy loam soil in Georgia for no-tilling grain sorghum. They showed that if the grain sorghum was not planted until after the crimson clover set seed, the crimson clover would successfully reseed itself, eliminating the need for purchasing cover crop seed in the fall. Additionally, they found that nitrogen fixed by and released from the crimson clover was sufficient to get maximum grain sorghum yields without application of fertilizer N.

Wells (1984) has summarized nitrogen fertilizer management for no-till corn as follows:

> "Study of no-till corn experiments reported to the current time indicates that more efficient use of fertilizer N results from no-till corn than from conventionally grown corn. It should be noted that most data published to date come from the upper south and eastern seaboard areas. This better efficiency is assumedly the result of less moisture stress in no-till corn, which provides the potential for higher yields from dry land corn production at higher levels of fertilizer N use than is generally possible with conventional tillage. Even though use of no-till production techniques increases risks for immobilization, denitrification, and leaching of fertilizer N, results have generally shown that corn yields are equivalent to and often better for no-till than conventional tillage at rates of fertilizer N usage likely to be recommended for commercial production. Although such risks are great on soils likely to be near moisture saturation during the early growing season, delayed or split applications of fertilizer N, or use of the nitrification inhibitor, nitrapyrin, have been shown to be effective in overcoming them for surface N application on such soils. There is some indication that such risks can also be lowered by subsurface application of fertilizer N.
>
> "Studies directed at increasing residual soil N content as a means of compensating for the lower mineralization of soil organic N inherent with no-till, have shown good results. This has involved use of winter annual legumes as cover crops and planting no-till corn into killed legume sods."

Phosphate and Potash Management for No-till

Although there is often much concern over surface application of P and K to no-till crops, particularly on low testing soils studies as previously cited (Singh et al,, 1966; Belcher and Ragland et al., 1982) have shown it to be as effective as incorporation. However, it has been shown that a row application of P and K on soils which were compacted improved yields of corn grain sorghum, and cotton (Touchton, 1984). Sharpe et al., (1984) reported on a study conducted on a Cecil sandy loam soil in Georgia to determine whether. it was necessary to raise a low P testing soil to high before no-tilling. They compared rates of P initially worked into the soil before no-tilling against annual or biannual broadcast application of P for double cropped soybeans and wheat over a 4 year period. They found that an initial application of 114 lbs P/A (260 lbs P_2O_5) was sufficient to maintain maximum wheat and soybean yields for at least 3 years on this low P soil. Annual broadcast application of 57 lbs P/A (130 lbs P_2O_5) either all in the fall before seeding wheat or half in the fall and half before seeding soybeans also maintained maximum yields.

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Influence of Tillage on the Distribution of Soil Nutrients under Continuous Soybean Production

W. L. Hargrove

Agronomy Department, University of Georgia, Georgia Station. Experiment, GA 30212

Soybean production significantly differs from corn production in that soybeans return much less residue to the soil and no fertilizer nitrogen (N) is required for soybean production. However, most studies of fertilization and nutrient uptake under no-tillage have been conducted with corn. In this study the influence of tillage on the distribution of soil nutrients under continuous soybean production was determined.

Materials and Methods

The experiment was initiated in 1981 at the Bledsoe Research Farm in Pike County, Georgia on a Cecil sandy loam, which is a member of the clayey, kaolinitic, thermic family of Typic Hapludults. This study was part of a larger experiment evaluating tillage and residue management practices. For this study, two tillage practices were utilized: no-tillage (fluted coulter), and conventional tillage. The conventional tillage treatment was moldboard plowed to a depth of approximately 12 in, disked twice, and planted. The size of each plot was 15 x 30 ft and the experimental design was randomized complete block with four replications. A cover crop of rye (Secale cereale L.) was planted each fall without tillage using a no-till drill. The soybeans were planted in 30 in rows in May of each year. Seeding rate was 9 seed/ft of row using the cultivars 'GaSoy 17' in 1981 and 'Ransom' in 1982 and 1983. The only fertilizer applied was 100 lbs K/A as KC1 (0-0-60) in November 1981 since soil pH and extractable P levels were adequate.

Soil samples were collected after seed harvest in 1983 at depths of 0 to 3, 3 to 6, and 6 to 12 inches. Soil pH was determined in a 1:l soi1:water suspension. Extractable P, K, Ca, Mg, Mn, and Zn were determined by extracting a subsample of soil from each plot with a double-acid extract. The amount of P in the extract was determined colorimetrically, and the amount of K, Ca, Mg, Mn, and Zn was determined by flame emission or atomic absorption spectrophotometry.

Results and Discussion

The distribution of pH and extractable P, K, Ca, Mg, Mn, and Zn for conventional and no-tillage is shown in Figs. 1, 2, and 3. For no-tillage, the concentration of extractable nutrients was consistently greater in the soil surface than for conventional tillage. However, deeper in the soil profile the concentration of most nutrients was greater for conventional tillage compared to no-tillage.

The accumulation of these nutrients at the soil surface is associated with the surface application of fertilizers and lime without soil mixing and with the return of crop residues to the soil surface rather than incorporation. The impact of surface applications of lime without incorporation is illustrated by the distribution of soil pH with depth (Fig. 1). The divergence of soil pH with depth between conventional and no-tillage is indicative of greater efficiency of incorporated lime in ameliorating soil acidity. The increase in acidity and concomitant decrease in Ca in the soil surface under no-tillage corn production observed by Blevins et al, in Kentucky was not apparent in this study for soybean production where lime but no fertilizer N had been applied.

Results from analyses of whole plant samples or trifoliolate samples collected at this and other sites show that P, K, and micronutrient concentrations are ofter greater for no-tillage soybeans compared to conventional tillage (data not shown). This is easy to reconcile with the distribution of soil nutrients and the observation (made by me and many other researchers) that no-tillage results in a shallower root system.

The seed yield response to tillage is variable and generally depends on rainfall amounts and distribution (see Hargrove et al, this Proceedings) As a result of moisture conservation, no-tillage often results in greater seed yields in years with less than adequate rainfall. It would therefore seem that although continuous no-tillage results in a redistribution and concentration of soil nutrients at the soil surface this is not a disadvantage to soybean growth and seed yield. Lesser seed yields for no-tillage compared to conventional tillage on some soil types is probably related to soil physical limitations and not nutrient availability, per se.

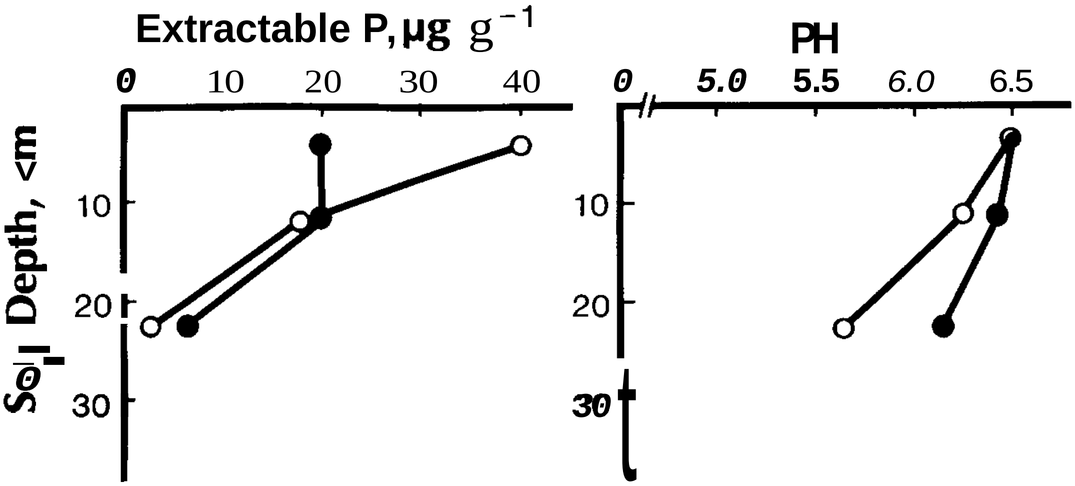

Fig. 1. Distribution of soil pH and extractable P for conventional (●●) and no-tillage (oo).

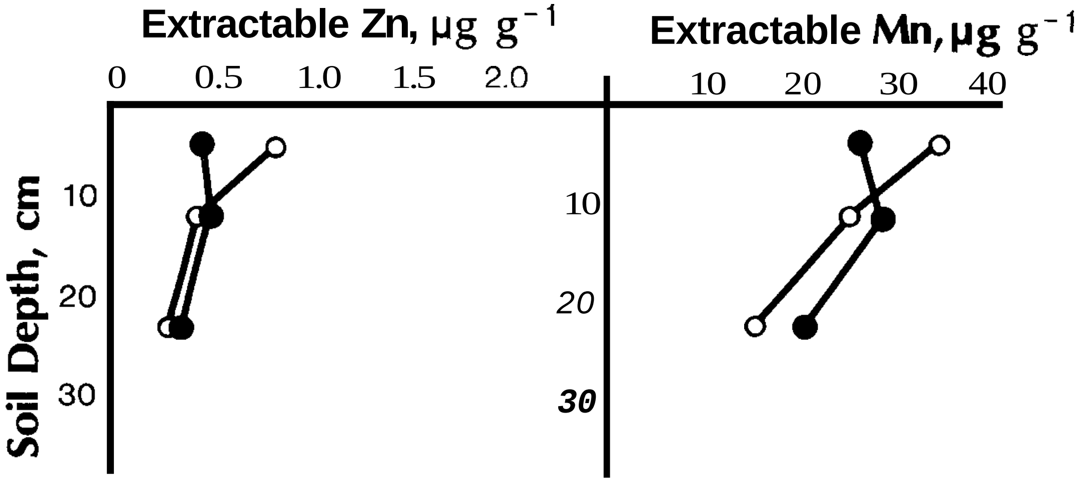

Fig. 2. Distribution of extractable Zn and Mn for conventional (●●) and no-tillage (oo).

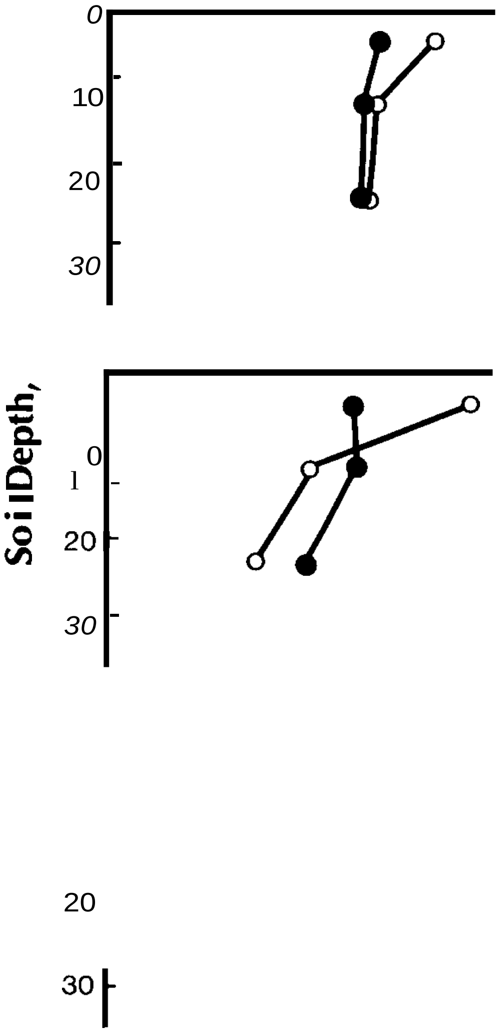

Fig. 3. Distribution of extractable K, Ca, and Mg for conventional (●●) and no-tillage (○○).

Comparisons of Conventional and No-Tillage Peanut Production Practices in Central Georgia

J. M. Cheshire, Jr., W. L. Hargrove, C. S. Rothrock, and M. E. Walker

Departments of Entomology, Agronomy, and Plant Pathology, University of Georgia, Georgia Station, Experiment, GA 30212;
Department of Agronomy, University of Georgia, Coastal Plain Experiment Station. Tifton. GA 31793

Recent efforts by producers to optimize profits and conserve soil and water have resulted in an increasing interest in the use of conservation tillage practices in peanut production systems. There has been additional interest in doublecropping peanuts behind other crops. Seedbed implements consisting of fluted coulters proceeding in-row subsoilers have been used on a limited basis for planting no-tillage (NT) peanuts (technically, precision tillage) into the residues of small grains. This change in tillage may alter soil characteristics and the incidence of soil arthropod pests and soilborne plant pathogens when compared to conventional tillage (CT) peanut production practices. Pests of major concern in peanut cropping systems of the Southeastern U.S. include the lesser cornstalk borer (LCB), Elasmopalpus lignosellus (Zeller) and Southern stem rot (white mold), Sclerotium rolfsii (Sacc.). Comparisons of NT and CT production practices in terms of yields, quality, LCB damage and S. rolfsii incidence were therefore conducted in peanuts planted at the recommended time and also in peanuts doublecropped behind wheat.

Materials and Methods

NT and CT peanut production systems were compared during 1983 at three sites. Wheat was planted in Taylor Co., GA (site 1), Macon Co., GA, (site 2) and Pike Co., GA (site 3) during the Fall of 1982. The soil types were Fuquay sandy loam, Wagram sand and Appling sandy loam at sites 1-3, respectively. During the previous growing season, grain sorghum was produced at site 1 and peanuts were produced at sites 2 and 3. Peanuts were planted in May (monocropped peanuts) and also following wheat harvest in June (doublecropped peanuts). CT and NT plots *of* monocropped or doublecropped peanuts were each arranged in a randomized complete block design with four replicates. Individual plot size was 9.15 x 12.2 m. A two row x 4.6 m section in the center of of each plot was designated for yield and quality measurements, and the remainder of each plot was designated for plant and soil sampling. Paraquat was applied to each cover crop at least one week before planting monocropped peanuts and immediately after planting doublecropped peanuts. CT plots were prepared by moldboard plowing and subsequent smoothing. NT plots were not disturbed. Peanuts (cv. Florunner) were planted (91 cm row spacing) in both NT and CT plots with a two row Brown-Harden Ro-Till (fluted coulter, in-row subsoiler) with conventional planters mounted directly behind each subsoiler shank. Monocropped peanuts were planted on 10 May at sites 1 and 2, and on 6 May at site 3. Doublecropped peanuts were planted on 15 June at site 1, on 14 June at site 2 and on 13 June at site 3.

Weeds were supressed in each NT and CT plot with an at-cracking application of metolachlor + naptalam + dinoseb at 2.2, 3.4, and 1.7 kg/ha, respectively. All plots were treated with 38 kg P/ha and 72 kg K/ha at cracking; and 850 kg $CaSO_4$/ha, 0.6 kg B/ha and 0.14 kg Mo/ha at flowering. Chlorothalonil (1.3 kg/ha) was applied for foliar disease control 6-7 weeks after each planting and on subsequent 10-14 day intervals. Selections of postemergence herbicides and timing of their applications were based on careful monitoring of weed populations in the two tillage systems at each site. Sethoxydin (0.2 kg/ha) was applied for control of large crabgrass in doublecropped peanuts at site 1. Bentazon (1.1 kg/ha) was applied twice for control of yellow nutsedge in both monocropped and doublecropped peanuts at site 2. Paraquat (0.4 kg/ha) was applied between rows (hooded sprayer) of monocropped and doublecropped peanuts at sites 3 for control of mixed weed populations. Each postemergence herbicide application was required in both NT and CT plots.

LCB populations at each site were assessed 6-7 weeks after each planting, and on subsequent 10-14 day intervals. Sampling was conducted by removing two randomly located 40 x 40 x 10 cm deep soil samples which were randomly located over the row in each plot of each replicate. Subterranean plant parts and soil from eacn sample were examined for LCB larvae and their feeding damage. The percent of LCB damaged hulls at harvest was estimated by counting all hulls obtained in the yield sample from each plot and all hulls with damage characteristic to the LCB damage observed during the sampling program.

The densities of S. *rolfsii* sclerotia in soil of NT and CT plots at each site were estimated at planting and at harvest of monocropped and doublecropped peanuts. On each date, 20 soil cores (2.5 x 15 cm deep) were obtained from each plot. Bulked cores were air dried and passed through a 2 mm seive, and 500g of soil from each plot was spread evenly on absorbent paper. 90 ml of 1% methanol was applied as an aerosol to the soil and the sample was placed in a plastic bag. Colonies of S. *rolfsii* on the soil surface were counted after 3 days of incubation at 300°C. Immediately after inverting peanuts at each site, the incidence of S. *rolfsii* on plants was estimated by examining the subterranean parts of 20 randomly selected plants in each plot.

Peanut plants in all plots were inverted with standard digging equipment. The section in the center of each plot designated for yield and quality measurements was transported from the field and placed in a large drying chamber. Dried hulls were removed from the plants with a stationary peanut thrasher. Peanuts at 8.5% moisture were graded (454 g from each yield sample) in accordance with standard Federal-State inspection service procedures. Data from each planting date at each site (peanut yields, quality aspects, soil insect damage and S. *rolfsii* incidence) were subjected to analysis of variance (ANOVA) for a randomized complete block design. ANOVA for a series of experiments was also conducted on yield and quality data combined over the three sites.

Results and Discussion

Yields, seed size, and the percent total sound mature kernels (%TSMK) from monocropped and doublecropped peanuts (Table 1) indicated that NT was a viable peanut production practice under the conditions experienced at sites 1-3. Rainfall at each site was sufficient for initial plant growth during May-June, 1983. Drought conditions at sites 1-3 during July and August, resulted in extremely slow plant growth and peanut pod development until adequate rainfall resumed in September (irrigation was not available). Totals for rainfall measured during July and August were 8.6, 8.7 and 10.1 cm at sites 1, 2 and 3, respectively. The longest period without rain (29 days) occurred during August at site 1. Yields from monocropped peanuts at each of sites 1-3 were higher in NT than in CT, but no significant differences were detected from analysis of individual experiments. A 52% higher yield in NT as compared to CT in monocropped peanuts at site 1 was not significant as a result of considerable variation between replicates which corresponded closely to variation in LCB damage. Quality measurements from NT and CT monocropped peanuts were similar, except for a significantly higher seed size and %TSMK in NT at site 1. Yields from doublecropped peanuts were similar in NT and CT at sites 1 and 3. A 47% higher peanut yield in NT as compared to CT (significant at the 0.09 level) may have been influenced by considerable variation in LCB damage between replicates. This difference also may have been enhanced by competition from a severe yellow nutsedge infestation in CT. Differences in quality aspects of doublecropped peanuts included a significantly higher ($P<0.05$) %TSMK in NT at site 2 and significantly higher ($P<0.1$) seed size and %TSMK in NT at site 3.

Table 1. Yield and quality measurements from no-tillage (NT) and conventional tillage (CT) peanuts produced in monocropping and doublecropping production schemes.

		Monocropped peanuts			Doublecropped peanuts		
Site	Tillage	Yield (kg/ha)	Seed size (g/100)	%TSMK	Yield (kg/ha)	Seed Size (g/100)	%TSMK
1	NT	3923	44.2	65.5	2130	40.3	58.8
	CT	2584	40.1**	62.a**	2309	42.2	56.3
2	NT	2808	42.9	70.3	2186	41.4	64.5
	CT	2533	41.4	68.0	1491*	42.0	59.3**
3	NT	4013	43.6	69.8	2897	41.5	64.5
	CT	3346	43.5	65.5	2443	36.0*	58.3*
Means over Sites 1-3:							
	NT	3581	43.5	68.5	2404	41.1	62.6
	CT	2821**	41.7	65.4**	2081*	40.1	58.0*

* indicates significant differences between tillage treatments at the 0.1 level, ** indicates significant differences at the 0.05 level, F-test.

The analysis of data combined over sites (Table 1) indicated that yields and %TSMK were significantly higher in NT than in CT in monocropped peanuts ($P<0.05$) and in doublecropped peanuts ($P<0.1$). The pronounced differences in yields between NT and CT may have resulted from the drought conditions which prevailed during this study. The dead wheat residues in the NT systems may have reduced soil temperatures and increased soil moisture retention compared to CT. Other research has shown that yields and quality from NT and CT peanuts can be expected to be similar under conditions optimal for plant growth.

Yields from doublecropped NT and CT peanuts at sites 1-3 were lower than corresponding yields from monocropped peanuts (Table 1). ANOVA on data combined over sites indicated that yields in NT and %TSMK in CT were significantly lower ($P<0.05$), and seed size and %TSMK in NT, and yields in CT were significantly lower ($P<0.1$) in doublecropped peanuts as compared to monocropped peanuts (differences are not denoted in Table 1). Although the yields obtained from these plantings were low, further research is needed in central Georgia to determine whether doublecropping will be a viable peanut production practice in situations of adequate rainfall or on farms with irrigation.

Soil sampling at each site indicated a general increase in LCB populations throughout July and August, but populations diminished during September. Population densities were extremely variable in both NT and CT plots throughout each site. The only significant difference ($P<0.1$) in measurements of LCB damage between NT and CT was a lower number of damaged hulls in monocropped NT peanuts at site 1. The percentage of damaged hulls in monocropped peanuts at each of sites 1-3 was lower in NT than in CT, but extreme variations between replicates prevented the detection of significant differences. Drought conditions caused a delay in pod development in doublecropped peanuts until rains resumed and LCB populations decreased in September. Numbers of damaged hulls were therefore lower in doublecropped peanuts as compared to monocropped peanuts. Wireworms detected in September in samples from doublecropped peanuts at sites 2 and 3 resulted in hull damage estimates which included both LCB and wireworm damage. The similarities in LCB damage in NT and CT at sites 1-3 suggest that LCB management needs will be similar in NT and CT peanut systems.

Table 2. Hull damage caused primarily by lesser cornstalk borer larvae in no-tillage (NT) and conventional tillage (CT) peanuts produced in monocropping and doublecropping production schemes.

Site	Tillage	Monocropped peanuts		Doublecropped peanuts	
		No. damaged hulls/m row	% damaged hulls	No. damaged hulls/m row	% damaged hulls
1	NT	23.4	6.4	19.8	8.8
	CT	35.1*	14.7	19.0	8.1
2	NT	37.7	14.2	21.6	11.1
	CT	42.0	17.1	12.8	10.1
3	NT	44.6	12.5	36.3	14.3
	CT	45.0	14.8	21.3	9.3

* indicates significant differences between tillage treatments at the 0.1 level, F-test.

Low populations of S. rolfsii were detected at sites 2 and 3 at planting. Sclerotia were detected in soil at harvest in doublecropped NT peanuts at site 1, and in NT and CT of both planting dates at sites 2 and 3 (Table 3). Higher S. rolfsii populations were detected at sites 2 and 3 (peanuts following peanuts) than at site 1 (peanuts following grain sorghum). No significant differences in densities of sclerotia or percentages of infected plants were detected between NT and CT of either monocropped or doublecropped peanuts at sites 1,2 or 3. The presence of surface residues in the NT systems at sites 1-3 did not increase either S. rolfsii populations or the incidence of the disease on plants.

Table 3. Densities of S. rolfsii sclerotia in soil and incidence of the disease at harvest of no-tillage (NT) and conventional tillage (CT) peanuts produced in monocropping and doublecropping production schemes[1].

Site	Tillage	Monocropped peanuts		Doublecropped peanuts	
		No. sclerotia/ 500g soil	% infected plants	No. sclerotia/ 500g soil	% infected plants
1	NT	0	2.5	0.5	0
	CT	0	1.2	0	0
2	NT	3.8	22.0	0.2	6.0
	CT	3.0	17.0	1.8	10.0
3	NT	0.8	7.5	2.2	13.8
	CT	0.5	3.8	2.0	8.8

[1] No significant differences were detected between tillage treatments.

The findings of this study indicate that no-till peanut production is feasible. Under the drought conditions at sites 1-3, NT resulted in higher average yields than CT in both monocropped and doublecropped peanuts. Comparisons of LCB and S.rolfsii populations in the NT and CT systems suggest that current management - needs for these pests will be similar in NT. Research is however needed to allow development of optimal management techniques for NT peanut cropping systems.

Acknowledgement

We express our sincere thanks to Mr. George T. Smith for providing land and assisting in planting and inverting peanuts at site 1, and to Mr. William Brown for providing land for site 2.

Tillage and Residue Management Effects on Soil Physical Properties

D. S. NeSmith, W. L. Hargrove; D. E. Radcliffe, and E. W. Tollner

Agronomy Department. Georgia Station, Experiment. GA 30212: Agronomy Department, University of Georgia, Athens.
GA 30602; Agricultural Engineering Department, Georgia Station, Experiment. GA 30212

In 1984, 2.2 million acres of soybeans (Glycine max) were planted in Georgia, approximately 39% of which were double-cropped. With double-cropped soybeans, time often becomes an important factor at planting. Efforts to manage the previous crop residue in the least amount of time have led to the development of a variety of approaches, the most popular of which is burning and disking. Other tillage practices used range from conventional tillage with a moldboard plow to the no-tillage system.

Although extensive research has been conducted in the area of tillage practices, it remains unclear how various tillage and residue management practices affect soil physical properties, especially in Ultisols with poor structural development such as found in the Coastal Plain. The objective of this research was to determine the effects of tillage and residue management on soil moisture, temperature, and bulk density under double-cropped soybean production.

Materials and Methods

The study was conducted at the Southwest Georgia Branch Experiment Station near Plains, Georgia. The soil was a Greenville sandy clay loam (clayey, kaolinitic, thermic Rhodic Paleudult). Wheat had been grown on the area the previous fall. A strip-split, randomized block experimental design was used. Individual plot size was 30 ft x 60 ft. and there were four replications. The main blocks were split into burned and nonburned residue and the tillage treatments were then stripped across these blocks. Tillage practices were no-tillage, disk tillage, and conventional tillage. The no-tillage treatment consisted of direct planting of the soybeans with a fluted coulter planter. The disk tillage consisted of four passes with a disk-harrow prior to soybean planting. This resulted in tillage to a depth of about 3 in where residue was left and 4 in where it was burned. Conventional tillage treatments were moldboard plowed to a depth of 12 in and disked tilled before soybeans were planted. Soybeans were planted in early June and were irrigated three times (1" each time) in the first two weeks to ensure a stand. Three additional applications were made in September during a period of moisture shortage.

Bulk density was determined three times during the season from soil core samples (5.4 cm diameter x 5.9 cm length core). The measurements were taken at planting, one month after planting, and after soybean harvest. Most measurements were made in the soil surface (0-10 cm), but post harvest sampling consisted of 0 to 4 in, 8 to 12 in, and 16 to 20 in measurements. At each date, two samples per plot were taken and bulk density was calculated on a dry weight basis.

Soil gravimetric water content was measured periodically during the season, and converted to a volumetric basis using the measured bulk density. The surface was the primary concern, but samples were also taken from other depths.

Soil temperature was measured approximately 3 times per week for the first 8 to 10 weeks. After this time, the soybean canopy had closed and there were no longer differences between treatments. The temperatures were taken at 3:00 p.m. with thermocouple-type thermometers placed 1 in into the soil. There were four measurements per plot and the mean of these was recorded.

An analysis of variance was conducted on the data, and where differences in treatments were found, Fisher's LSD was used to separate the means.

Results and Discussion

Surface (0 to 4 in) bulk density throughout the growing season was significantly greater in the burned no-tillage, nonburned no-tillage, and nonburned disk tillage treatments than in the other treatments (Fig. 1). There was little change within the no-tillage and nonburned disk treatments, so that a compaction problem at the beginning of the growing season persisted throughout the entire season. Visual observations revealed that the high densities had an adverse effect on soybean root growth. The area was disk tilled in the fall prior to wheat planting. This may have compacted the soil and no-tillage or disk tillage in the spring did not eliminate the problem. The burned disk tillage treatment had a lesser density in the surface, but Fig. 2 shows it was similar to the burned no-till, nonburned no-till, and the nonburned disk tillage treatments at the 8 to 12 in depth. This was probably a result of the straw removal allowing the disk to penetrate deeper in the burned treatment.

The post harvest bulk density measurements (Fig. 2) showed that conventional tillage, burned or not, seemed to eliminate the high bulk density in the upper 12 in. There was a trend for the nonburned plow treatment to have a lower density than any of the other treatments in the upper 12 in. This is probably a result of the incorporation of organic material throughout the profile. There was little or no difference between the treatments at 12 to 16 in.

Soil water content in the surface was generally greater under the no-tillage and nonburned disk tillage treatments (Fig. 3). The presence of mulch was probably the most important factor responsible for the greater moisture content of these treatments. Fig. 4 corresponds to the last sampling date in Fig. 3. On this date, soil water content was measured in 6 in increments to a depth of 2 ft. All treatments had a greater water content than the burned conventional and nonburned tillage treatments, especially in the 8 to 16 in zone. This is probably a result of poor soybean rooting at soil depths of 8 to 16 in under the no-tillage and disk tillage treatments. Much better root growth was observed with the conventional tillage soybeans and as a result, moisture was probably taken from the 8 to 16 in depth. Under no-tillage and disk tillage, the roots were primarily confined to the upper 6 in due to compaction problems.

Temperature measurements were made only on the nonburned treatments and were similar to the results of other researchers (Fig. 5). Soil temperature was generally highest under the conventional tillage treatment (bare surface) and lowest under no-tillage which had the greatest amount of residue on the surface. There was little or no difference between treatments near the end of the season, due to canopy closure and shading by soybeans.

Soybean seed yields are shown in Table 1. The burned no-tillage and burned disk tillage treatments resulted in inferior yields relative to the othe treatments. The greater soil densities with disk and no-tillage probably contributed to the reduced yields for the burned treatments. It is interesting to note, however, that the no-tillage treatment with mulch resulted in yields which were not significantly different from the plowed treatment. This is probably a result of moisture conservation and lower surface soil temperatures where the mulch was present.

Although these results are from only one year of data, some preliminary observations have been made. No-tillage and disk tillage treatments had high bulk densities in the upper 6 in. Soil water contents were greatest and soil temperatures were lowest in the nonburned no-tillage treatment. This was probably due to the wheat residue that was present. The burned disk tillage treatment (the most common practice for double-cropped soybean production in the Coastal Plain) resulted in poor yields.

Table 1. Soybean seed yields.

Tillage Treatment	Residue Management		
	Nonburned	Burned	Mean
	Yield, bu/A		
Moldboard plow	30.6	30.4	30.5
Disk	28.8	26.1	27.5
No-Tillage	27.6	22.7	25.2
Mean	29.0	26.4	27.7
LSD .05	NS	4.8	NS

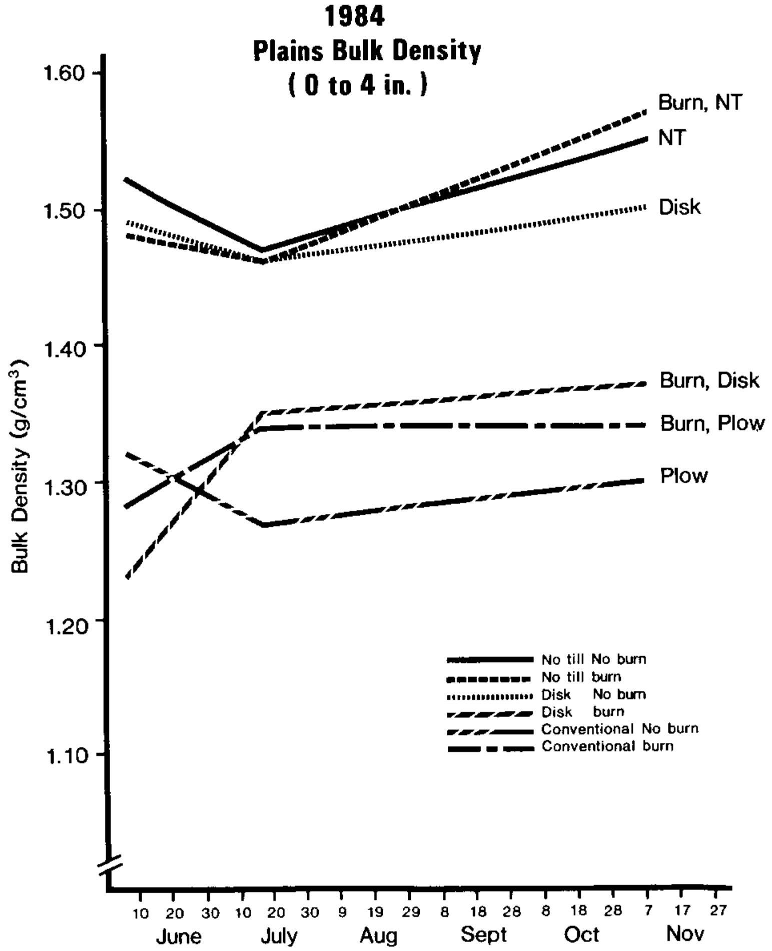

Fig. 1. Surface soil bulk density over time.

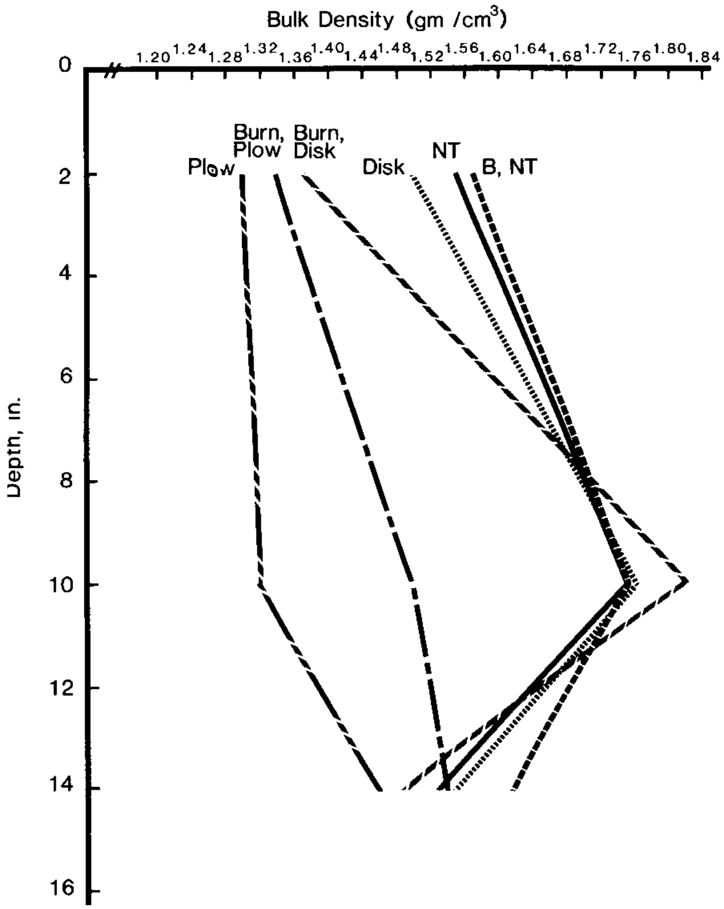

Fig. 2. Bulk density at harvest time.

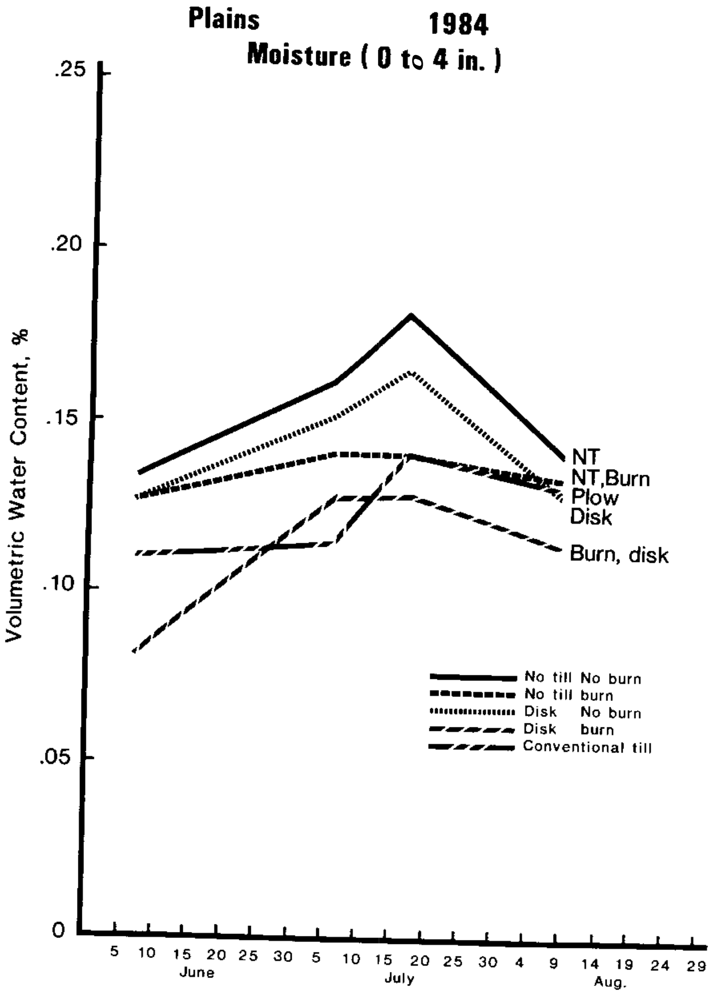

Fig. 3 Surface soil water content over time.

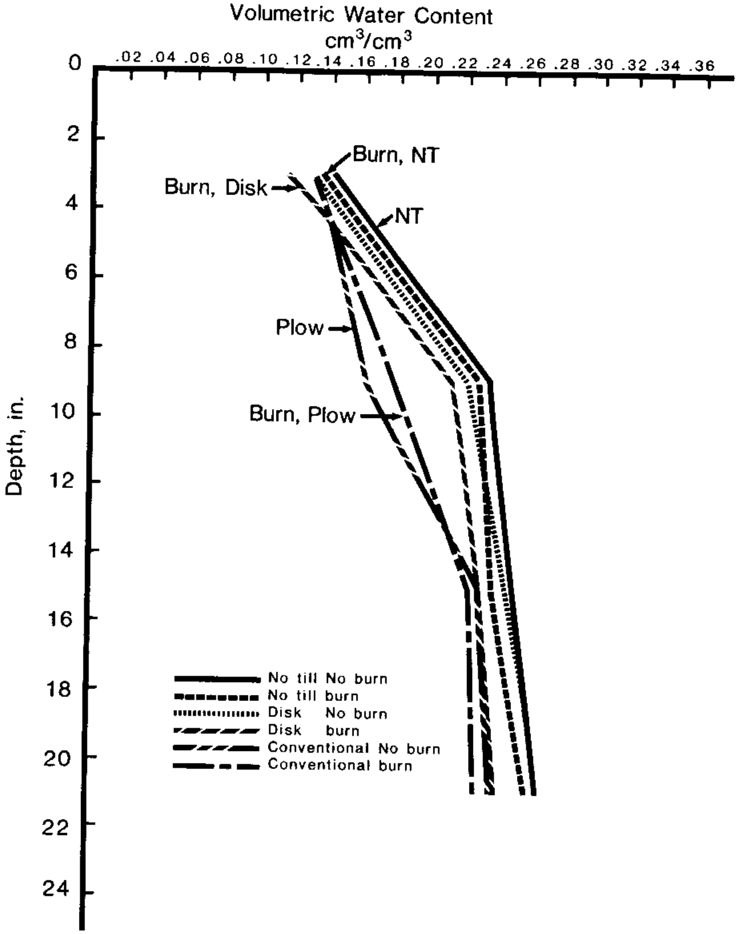

Fig. 4. Soil water content at R-2 soybean growth stage.

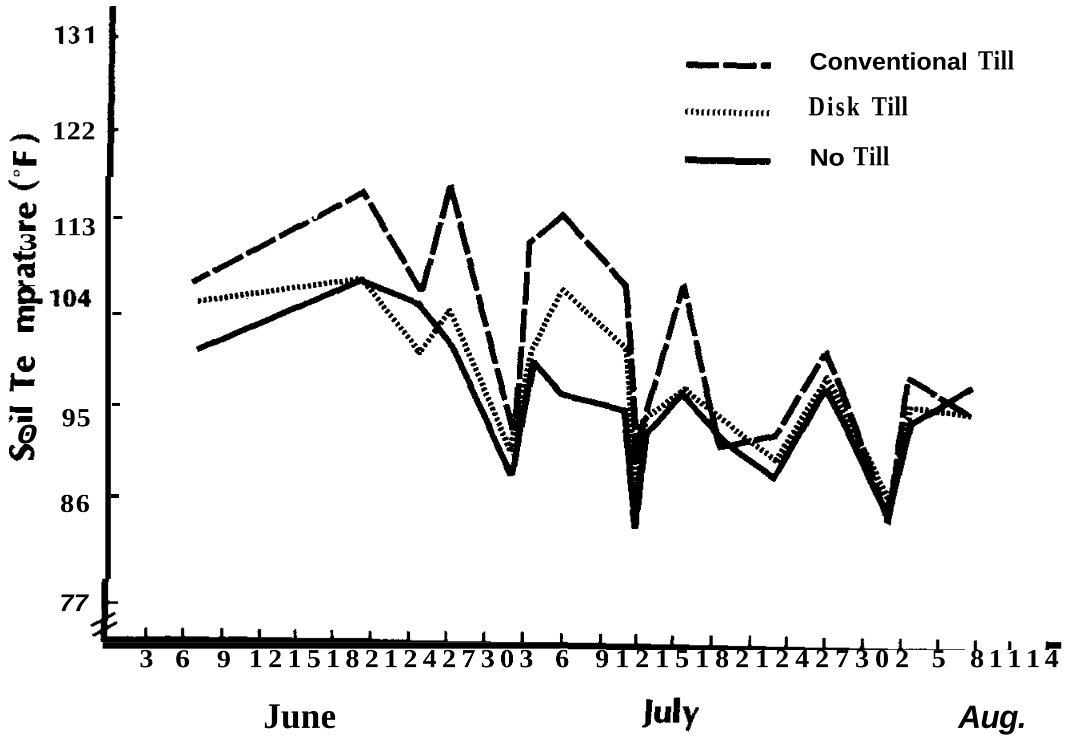

Fig. 5. Surface soil temperature before canopy closure as influenced by tillage.

Calcium, Magnesium, and Potassium as Affected by Tillage and Cropping System

Ruben A. Ortiz and R. N. Gallaher

Department of Agronomy, IFAS, University of Florida, Gainesville, FL 32611

INTRODUCTION

Higher soil Ca and Mg levels have been reported in no-tillage systems compared with conventional-tillage (Hargrove et al., 1982, Ferres, 1984). Blevins et al. (1977) found no significant effects in exchangeable Ca under different tillage methods. Triplett and Van Doren (1969), and Ferrer (1984) pointed out that soil K levels in the first 5.0 cm were greater for no-tillage treatments. In contrast, Hargrove et al., (1982) showed lower K concentrations in no-tillage compared to conventional-tillage. The purpose of this study was to evaluate soil extractable Ca, Mg, and K as affected by tillage and cropping system in a 7 year-old multiple cropping experiment.

MATERIALS AND METHODS

The experiment was conducted at Green Acres Agronomy farm near Gainesville, Florida on an Arrendondo loamy sand, a member of the loamy, silicious, hyperthermic family of grossarenic Paleudults. The field study started in 1976 included cropping systems of oat (Avena sativa/soybean (Glycine max L. Merr.) versus oat/grain sorghum (Sorghum bicolor L.). Cropping systems were split plots radomized within whole plots of four tillage variables. The whole plots were in a randomized complete block design with four replications and included no-tillage versus conventional-tillage with and without in-row subsoiling. Soil samples were taken in 12 increments to a depth of 80 cm for laboratory analyses of Ca, Mg, and K extracted by two methods, Mehlich I and Neutral Normal Ammonium Acetate.

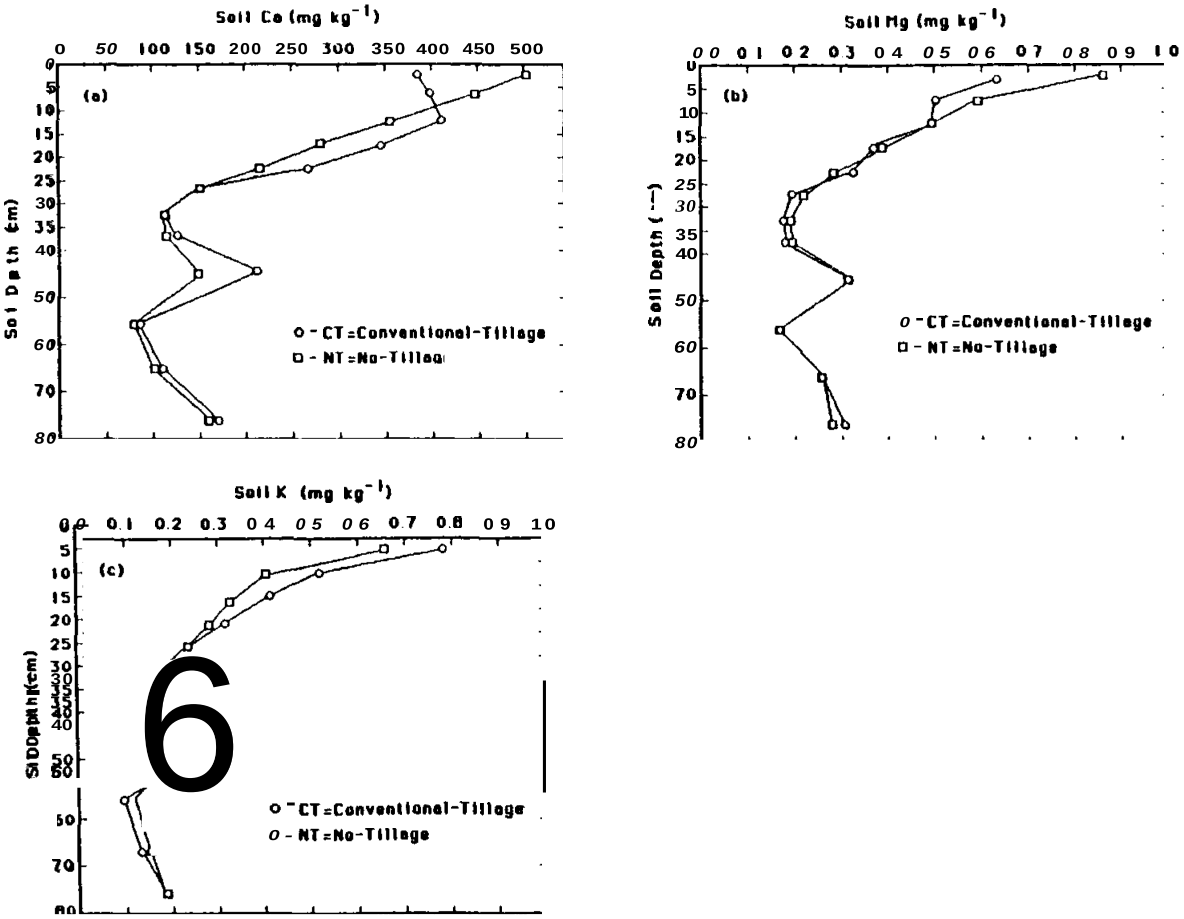

Fig. 1. Extractable Ca, Mg, and K as affected by tillage.

RESULTS AND DISCUSSION

Tillage

Tillage influenced Ca to a depth of 25 cm. Higher Ca contents were observed in no-tillage through a depth of 10 cm as opposed to conventional-tillage which showed more Ca content from the 10 to 25 cm depth. This can be explained by soil mixing and Ca dispersion during conventional plowing operations (Fig. la). Magnesium content was also higher in no-tillage at the 0-10 cm depth (Fig. lb).

Greater soil K concentration was observed in conventional-tillage at the 0–15 cm depth. Old root channels in the soil may be acting as capilar pathways, resulting in leaching of K from no-tillage plots (Fig. lc).

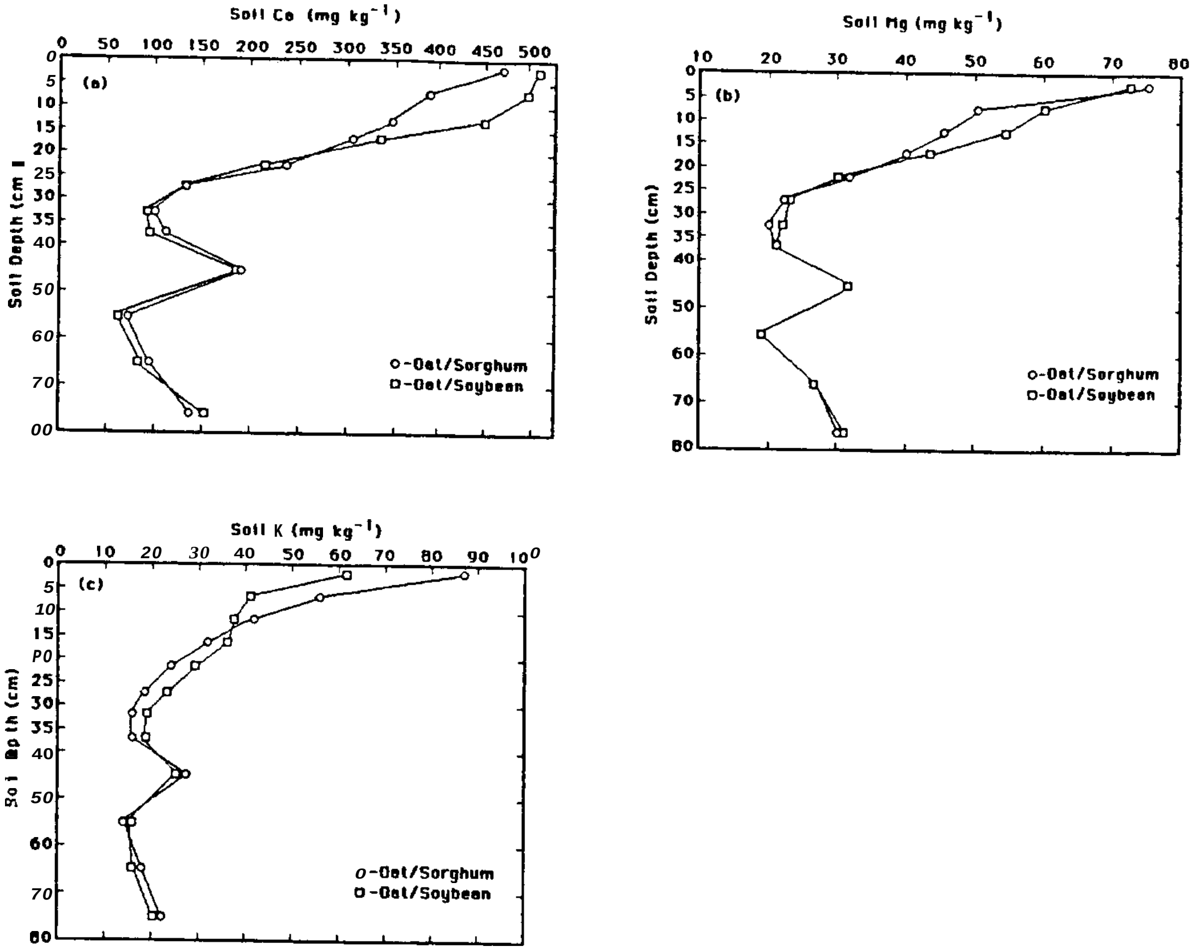

Fig. 2. Extractable Ca, Mg, and K as affected by cropping system.

Cropping System

Higher Ca and Mg contents were found in the oat/soybean soil surface compared to the oat/grain sorghum cropping system. These results indicate a greater Ca and Mg return and more nutrient conservation in the oat/soybean system (Fig. 2a and 2b).

However, more soil K was observed at the 0–10 cm depth in the oat/sorghum compared to the oat/soybean cropping system. A reverse effect occured at the 20–30 cm depth which indicates K is being taken out from the lower depths and accumulated in the soil surface by the sorghum system (Fig. 2c).

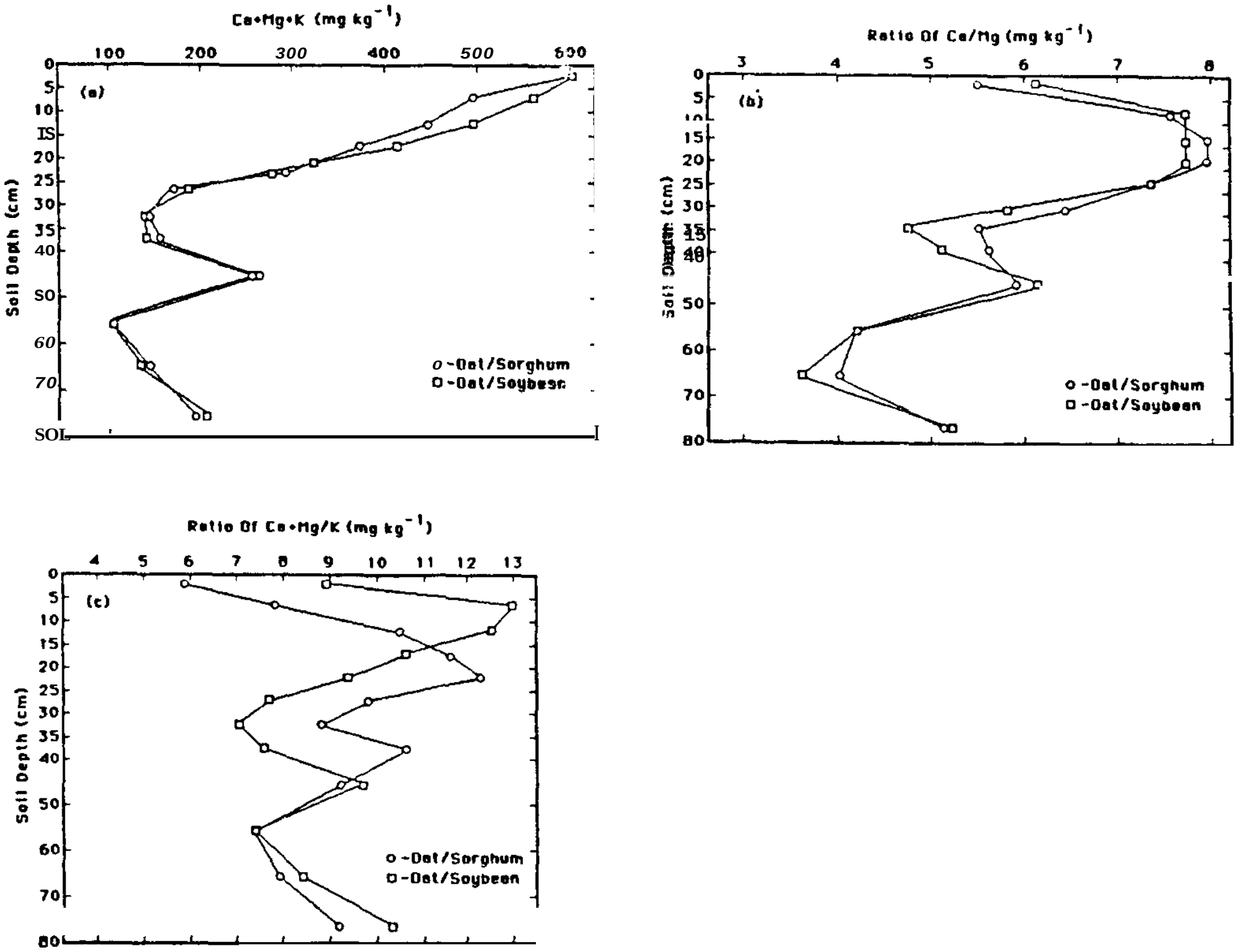

Fig.3. Total extractable Ca+Mg+K and the Ca/Mg and Ca+Mg/K ratios as affected by cropping system.

Total Ca+K+Mg and the Ca/Mg, and Ca+Mg/K Ratios

The total extracted Ca+K+Mg and the ratios of extractible Ca/Mg and Ca+Mg/K were also calculated. In the oat/soybean system there was a higher total extractible Ca+K+Mg in the soil surface, indicating a greater conservation of these elements by this cropping system. The Ca/Mg and Ca+Mg/K ratios of extractible nutrients were higher in the oat/soybean system in the 0–10 cm depth. In contrast, a reverse effect was observed at the 10–15 cm, and 25-40 cm depths for the Ca/Mg ratio, and 20-40 cm depth for the Ca+Mg/K ratio (Fig. 3a, 3b, and 3c). Therefore, there was more Ca in relation to Mg and more Ca+Mg in relation to K. As a result, Ca and Mg were taken up from lower depths and deposited in the surface by the oat/soybean cropping system.

CONCLUSIONS

Tillage affected Ca, Mg, and K in the 0 to 15 cm soil depth. Higher Ca and Mg contents were found in no-tillage compared to conventional-tillage treatments at the 0-5 cm depth. Soil K was higher in conventional-tillage than in no-tillage treatments at 0-15 cm depth. There was a trend for higher Ca and Mg content over the conbined 0-15 cm depth in no-tillage compared to conventional-tillage treatments. The oat/soybean cropping system showed more Ca and Mg in the soil surface than the oat/sorghum cropping system. A reverse effect occured for soil K; the ratios of the total extractible Ca+Mg+K, Ca/Mg, and Ca+Mg/K were higher in the oat/soybean compared to the oat/sorghum cropping system at the 0-15 cm depth. Factors such as tillage, cropping system, crop nutrition, and root system influenced soil Ca, Mg, and K content.

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Penetrometer Measurements in Conventional and Minimum Tillage

D. E. Radcliffe and R. L. Clark

University of Georgia College of Agriculture, Athens, GA 30602

S. NeSmith and W. L. Hargrove

Georgia Experiment Station. Experiment, GA 30212

G. W. Langdale

USDA. Watkinsville, GA 30677

Introduction

In 1984, over 2 million acres of soybean [Glycine max (L.) Merr.] were grown in Georgia and nearly 40% of this acreage was double cropped with wheat. Under these conditions, it is important to minimize the time delay between harvest of the winter wheat and planting of soybeans. To this end, many farmers have reduced spring tillage operations to disking or adopted minimum-tillage systems. Fall tillage prior to planting wheat is usually disking. These combinations of tillage systems have led to a number of potential problems, one of which may be compaction. Others have shown that a pan can form just below the depth of disking. In the southeast where the depth of freezing may be shallow, organic matter is low, and non-swelling clays predominate, a pan formed by fall disking may persist through the next growing season if it is not broken up by spring tillage. The purpose of this study was to determine if there was evidence of compaction in the tillage zone of conventional and minimum tillage systems.

Materials and Methods

Two ongoing experiments involving conventional and minimum tillage in double-cropped soybeans were examined. One experiment, located at the Southwest Georgia Branch Experiment Station, Plains, involved different spring tillage systems and residue management, including burning. Only the nonburned portion of the experiment was examined in this study. The three spring tillage treatments were moldboard plow followed by disking, disking alone, and no-tillage. Fall tillage for all treatments was disking. Soybeans were planted in early June and were irrigated three times (1 inch each time) in the first two weeks to ensure a stand. Three additional applications were made in September during a period of moisture stress. The soil was a Greenville sandy clay loam (clayey, kaolinitic, thermic Rhodic Paleudult). Wheel traffic during tillage, spraying, and harvest operations was not confined to designated rows.

The second experiment, located at the Southern Piedmont Conservation Research Center, Watkinsville, involved different spring tillage systems and 3-year combinations of rotations between summer crops of soybean and grain sorghum (Sorghum bicolor (L.) Moench). Only the continuous soybean rotation was examined here. The three spring tillage treatments were disking with an offset disk harrow, no tillage, and chisel tillage in which a chisel was attached to a no-till planter so that in-row subsoiling occurred to a depth of about 7 inches Soybeans were planted in early June and there was no supplemental irrigation. The soil was a Cecil sandy clay loam (clayey, kaolinitic, thermic Typic Hapludult). All spring and summer wheel traffic was confined to alternating rows.

To measure compaction in the tillage zone in each experiment, a tractor-mounted hydraulically driven penetrometer was used. This unit drives a standard ASAE cone (0.8 inch base diameter) into the soil and records the force required, which when divided by the cross sectional area of the base of the cone gives soil mechanical impedance in units of pressure (bars). A micro-computer records mean mechanical impedance for each one-inch depth increment and enters this on a floppy disk. In order to measure soil mechanical impedance in each plot, four transects of readings were made perpendicular to the rows. On each transect, two rows were straddled and a series of five readings were taken at half the row spacing so that measurements alternated, between-row midpoints and in-row, producing two in-row and three between-row readings per transect. In the Watkinsville experiment where wheel traffic was controlled, the transect was centered over the non-traffic area so that the between-row readings could be subdivided into traffic and non-traffic readings. At each point, mechanical impedance was recorded with depth down to 12 inches. After the penetrometer readings were made, each plot was sampled for gravimetric water content.

Results and Discussion

Plains Experiment

Penetrometer measurements were taken at Plains on August 28 and 29. The soybeans were at approximately the bloom stage of growth at this point and the soil moisture levels were similar in the various treatments. Mean mechanical impedance was low near the surface for all treatments, but below 2 inches the readings in the no-till and disk treatments increased more rapidly than in the plow treatment (Figure 1). The no-till and disk means reached a maximum at about 8-9 inches and decreased slowly below this depth. The maximum readings are in the neighborhood of 20 bars which is high enough to reduce root growth rates. The depth of maximum mechanical impedance in these treatments is a little below the depth of disk tillage and indicates that a pan may be formed by this practice. The absence of such a maximum in the plow treatment indicates that spring plowing may destroy the pan. The difference between means was statistically significant at the depths between 5 and 9 inches below the surface. Between-row means showed a similar pattern, but due to the variability introduced by uncontrolled wheel traffic fewer of the differences were statistically significant.

Although the differences in yield were not significant, there was a trend for the plowed treatment to yield slightly higher than the disk and no-till treatments (table 1). This trend could be due to the presence of a **pan** in the last two treatments that reduced root penetration below the 6-inch depth.

Table 1. Soybean yields

Location	Tillage Plow	 Disk	 No-till	 Chisel
	----------bu/A----------			
Plains	30.6	28.8	21.6	
Watkinsville		19.0	18.0	19.3

Watkinsville Experiment

Penetrometer measurements were made at Watkinsville on August 14 which also corresponded to the bloom stage of growth in these earlier planted soybeans. As at Plains, there was little difference in gravimetric soil contents between treatments, but the soil moisture content was less than in the Plains experiment and penetrometer readings were higher at Watkinsville. Mean mechanical impedance in-row was much lower in the chisel treatment than in the no-till and disk treatments, especially between 5 and 9 inches of depth (figure 2). These differences were statistically significant only between the 3 and 6 inch depths due to a strong interaction caused by very high readings in one replication of the no-tillage treatment. However, it appears that the spring chisel treatment, like the plow treatment at Plains, does a good job of breaking up a pan that may be formed during fall tillage.

Due to the lack of irrigation and extremely droughty conditions in the latter part of the 1984 growing season, soybean yields at Watkinsville were very low and there were no significant differences between treatment means.

Since wheel traffic during the three years of the Watkinsville experiment had been confined to designated inter-rows, we were able to contrast between-row traffic and non-traffic readings. The mean mechanical impedance for these two positions are shown in figure 3 for the no-till treatment and in figure 4 for the disk treatment (the between-row patterns for the no-till and no-till chisel were similar). In both treatments, traffic caused higher readings in the top six inches and this effect seemed to be greater in the disk treatment. The differences were statistically significant down to the 5 inch depth. As with the in-row readings, a maximum occurs at about 7 inches indicating that a pan may be present. Below 6 inches, the highest readings occur in the non-traffic positions and these differences are significant statistically between 10 and 12 inches of depth. This may be due to a slight lowering of the surface elevation in the traffic inter-rows. Displacing the traffic curves down one inch causes them to coincide roughly with the non-traffic curves below 6 inches. This also reduces, but does not eliminate, the differences in the top 6 inches.

Conclusions

In both experiments mean mechanical impedance was high in no-tillage and disk tillage systems especially between 5 and 9 inches below the surface. This is interpreted as evidence of a pan formed by fall disk tillage. Use of a moldboard plow or chisel in the spring appears to break up the pan. In the Watkinsville experiment, wheel traffic had a significant effect on mechanical impedance.

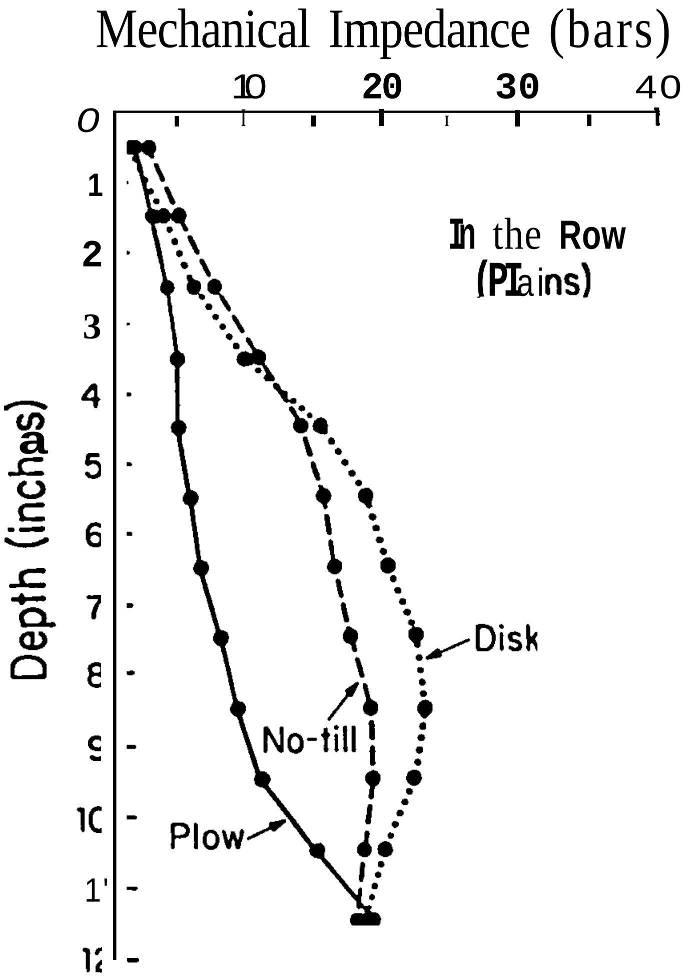


Figure 1. Mean mechanical impedance in-row with depth for three tillage treatments at Plains, Ga.

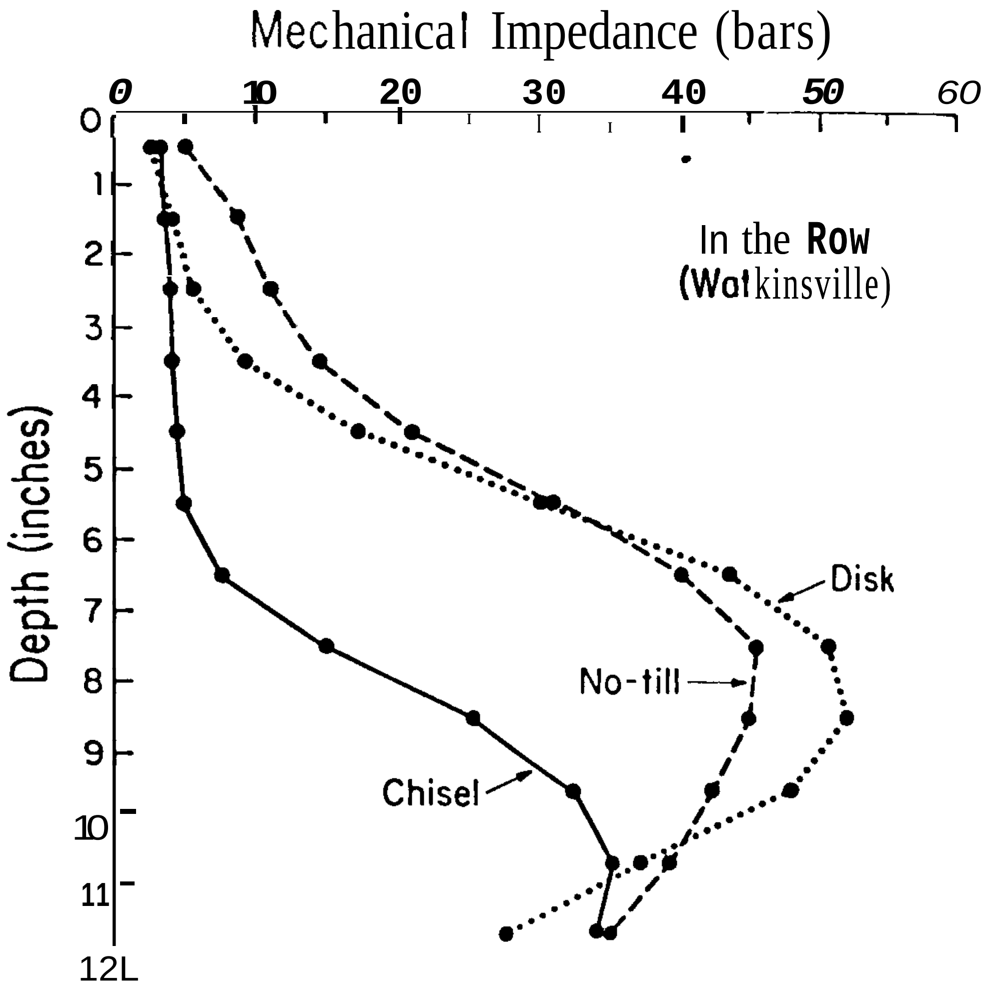


Figure 2. Mean mechanical impedance in-row with depth for three tillage treatments at Watkinsville, Ga.

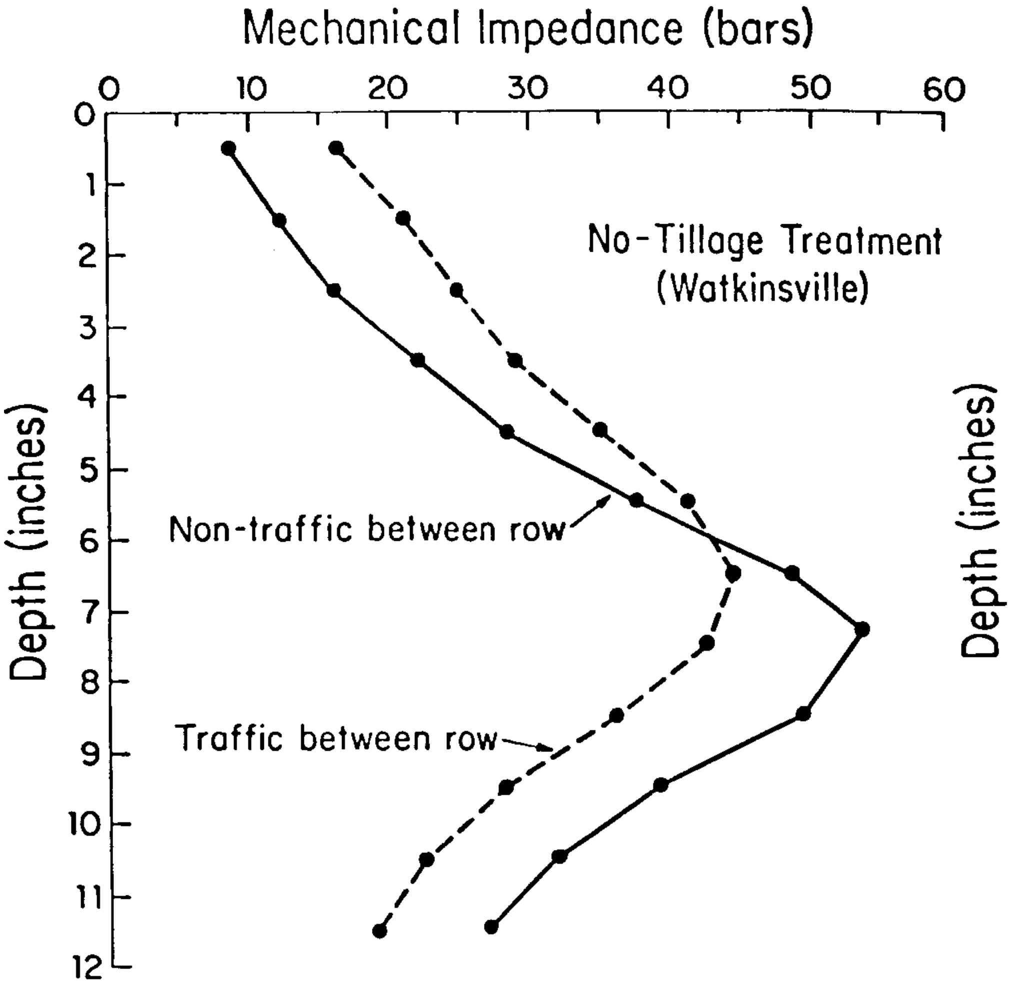


Figure 3. Mean mechanical impedance with depth in the no-till treatment for traffic and non-traffic between-row positions at Watkinsville, Ga.

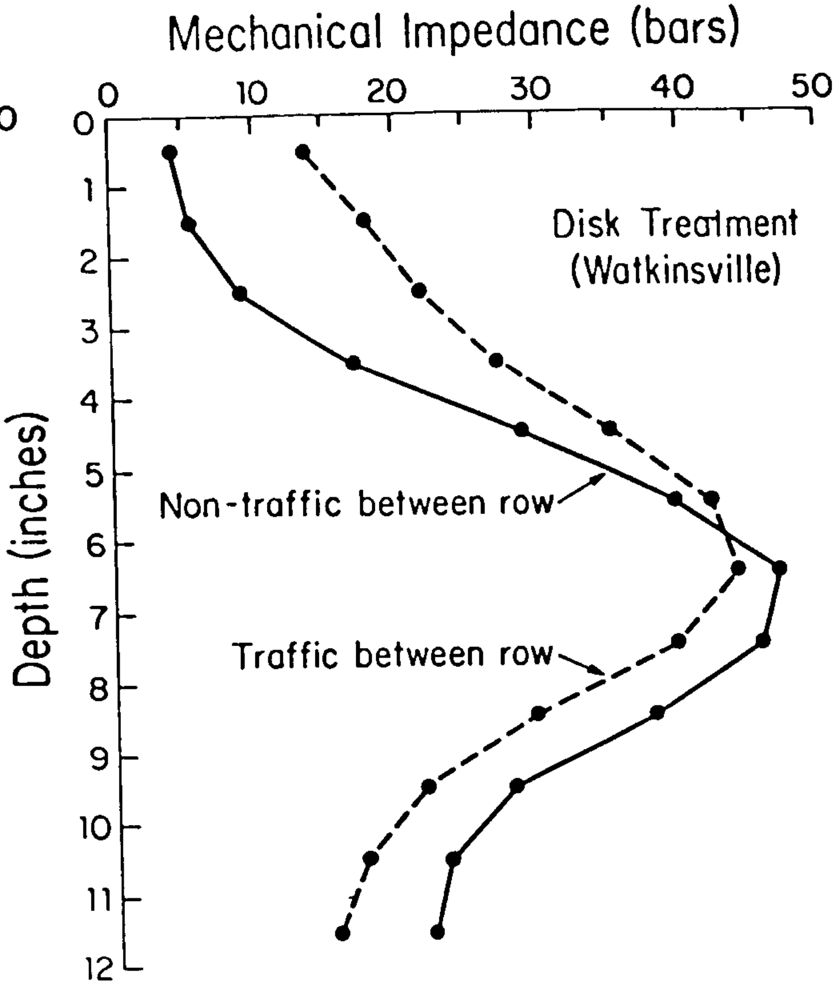


Figure 4. Mean mechanical impedance with depth in the disk treatment for traffic and non-traffic between-row positions at Watkinsville, Ga.

Decomposition of Clover and Wheat Residues under Different Tillage Systems on Severely Eroded Soil

Scott W. Thompson, H. F. Perkins; and G. W. Langdale

Agronomy Department, University of Georgia College of Agriculture, Athens, GA 30602. USOA, Watkinsville, GA 30677

INTRODUCTION

Tillage methods that allow crop residues to remain on the soil surface in multiple cropping systems are becoming more widespread. Multiple crop canopies and residues protect Southern Piedmont lands from even moderate soil erosion during the vulnerable soil erosion period (April-August). Return of residues not only reduces soil erosion but increases water storage capacity and returns nutrients to the soil. The recent use of cool season legumes to supply residue cover of the surface and biologically fix N is even more important in conservation tillage systems. In view of a lack of information on crop residue decomposition in conservation tillage systems on eroded Southern Piedmont soils an investigation was initiated to determine rate of decomposition and N release from clover and wheat residues under minimum tillage and conventional tillage systems.

MATERIALS AND METHODS

The investigation was conducted under natural conditions at the Southern Piedmont Conservation Research Center on severely eroded Cecil series (Typic Hapludults). Above ground portions of Coker 747 wheat (Tritrium aestivum L.) and Tibbee crimson clover (Trifolium incarnatum were harvested at or near maturity and dried. Grain was removed from the wheat. Crop residues of 25 g each of wheat and clover were placed in separate 0.25 mm mesh nylon bags (15x23 cm). Bags were placed in grain sorghum (Sorghum bicolor L.) plots on June 10, 1983 on a severely eroded (2.5-5.0 cm topsoil mixed with subsoil) site under conventional tillage (monocrop, disked Fall and Spring and cultivated) and minimum tillage coulter) treatments.

The site was previously used for low management fescue and native grass and had one season of crimson clover grown in minimum tillage treatments. Grain sorghum was seeded May 17, 1983 at a rate of 400 kg ha^{-1} and was approximately 15 cm tall at initiation of study. All residue samples were placed between stalks of grain sorghum to prevent disturbance by implement traffic. Samples in minimum tillage treatments were seated in the residue to approximate natural conditions. Conventional tillage plots received 90 kg ha^{-1} N from NH_4NO_3 but minimum tillage plots were not fertilized with N. Weeds were controlled with a combination of Paraquat and Atrazine herbicides. Bags containing residues were retrieved at random at two week intervals. Samples were dried and N was analyzed by standard TKN methods.

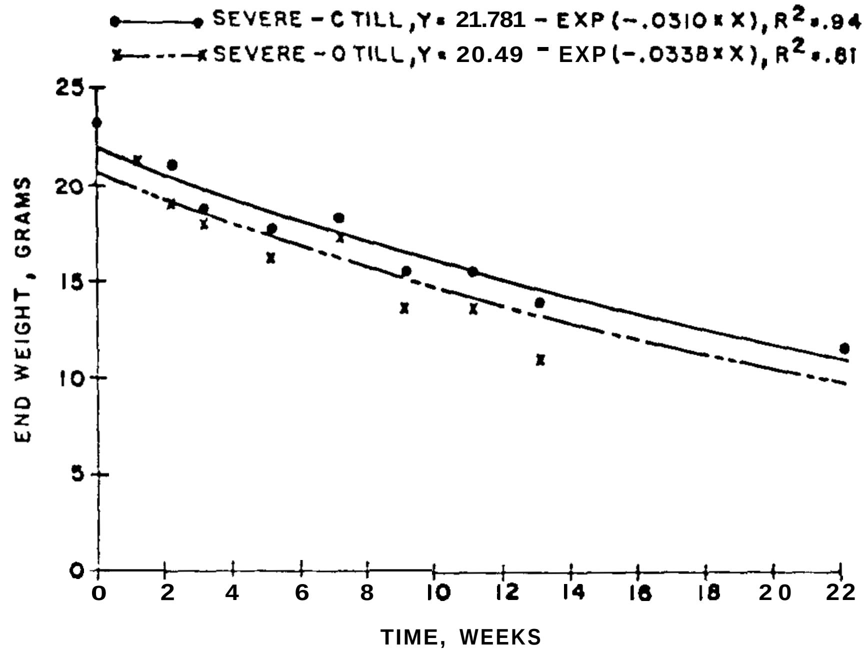
RESULTS

Dry weight and N loss of clover and wheat residues during 22 weeks of decomposition on eroded soils are presented in Figs. 1 and 2. The symbol "c" refers to conventional and "o" refers to minimum tillage as described in Material and Methods.

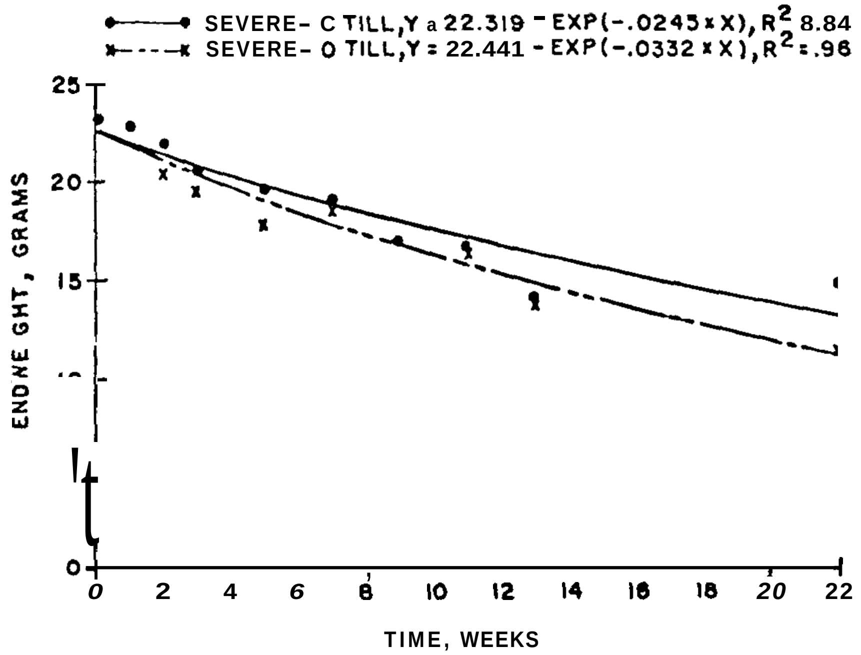
Weight loss of clover residue under conventional ("c") and minimum tillage ("o") systems decreased (R^2=0.94* and 0.81*, respectively) following application in early June (Fig. 1). There were no significant differences between rate of decomposition under conventional and minimum tillage. Similar results were obtained with wheat where conventional and minimum tillage systems resulted in R^2 values of 0.84* and 0.96*, respectively. Approximately 50% of each residue decomposed during the course of the grain sorghum growing season.

Loss of N from clover and wheat residues during the 22 week period of study is shown in Fig 2. A reduction of N occurred in conventional (R^2=0.88*) and minimum tillage (R^2=0.75*) systems although tillage systems were not significantly different. There was no effect of time or tillage system on loss of N from wheat residues.

Nitrogen losses in clover residues appear to be directly related to weight losses. The continuous release of N during summer months supplies most of the N requirement for non-irrigated grain sorghum. The use of a crimson clover and grain sorghum sequence in conservation tillage modes provides the potential to restore soil productivity on severely eroded Southern Piedmont lands.



WEIGHT LOSS, CLOVER RESIDUE 1983



WEIGHT LOSS, WHEAT RESIDUE 1983

Figure 1. Weight loss during decomposition of residues on severely eroded soils under different tillage systems.

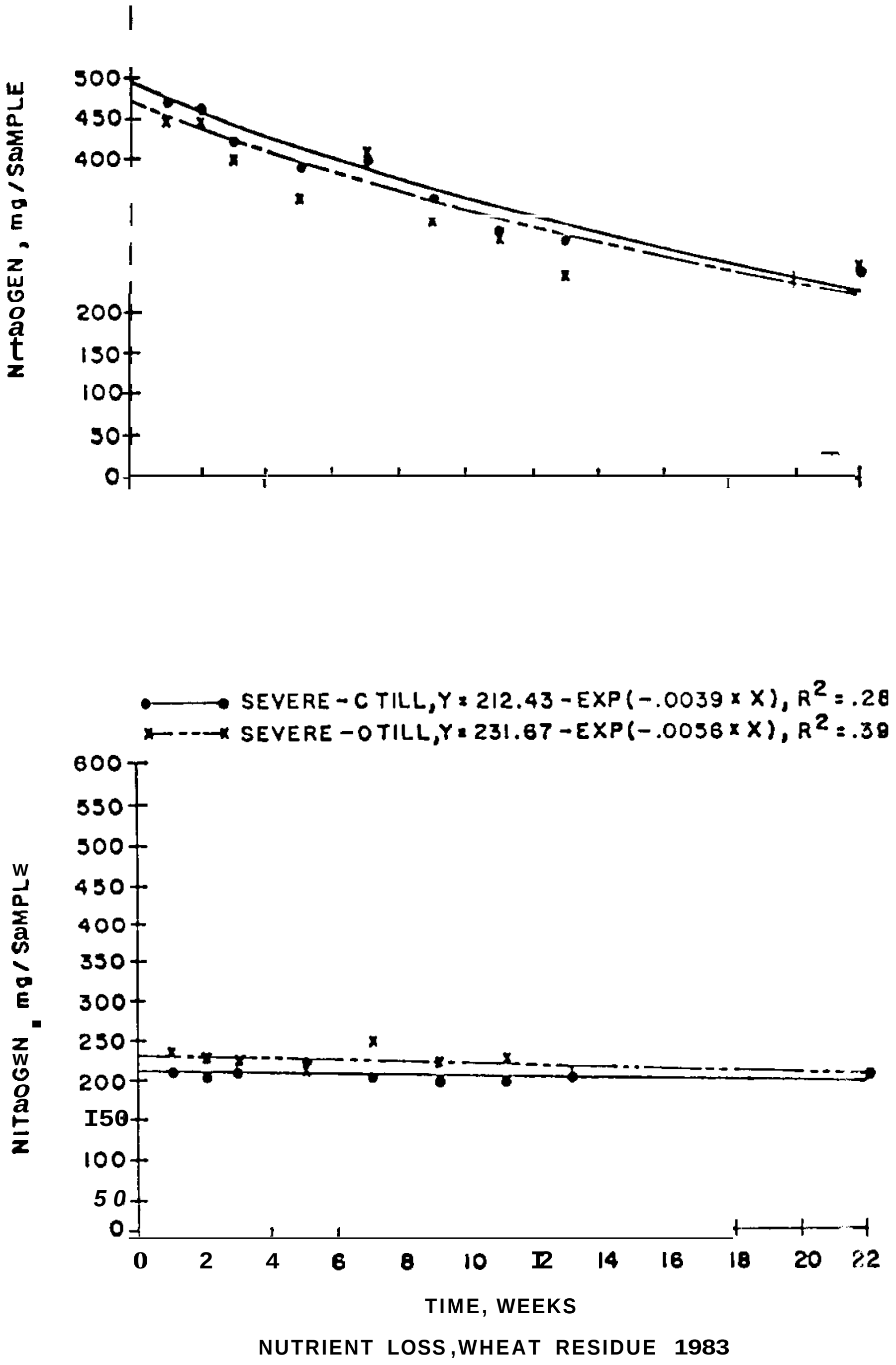


Figure 2. Nitrogen loss during decomposition of residues on severely eroded soils under different tillage systems.

Tillage and Cropping Sequence Effects on Yields and Nitrogen Use Efficiency

F. M. Hons, R. G. Lemon, and V. A. Saladino

Texas Agricultural Experiment Station and Texas A&M University

Conservation tillage practices have rapidly been adopted over the past decade, especially in the southeastern and midwestern United States. Because of cost effectiveness, improved moisture storage, etc., certain conservation tillage practices may be adaptable to portions of the southwestern United States. Fertilizer requirements for conservation tillage may be different from conventional practices, particularly in drier regions. The objectives of the reported study were to determine the effects of several cropping sequences of grain sorghum, wheat, and soybeans and conventional and no-ti11 practices on crop yields and N use efficiency.

Materials and Methods

Several cropping sequences receiving varying N rates were established on a Ships clay - Norwood silt loam intergrade in Burleson county in 1983 (Table 1). The statistical design was a split plot within randomized complete blocks (4 replicates) with sequence serving as the main plot and tillage-fertilizer combinations constituting split plots. The study was organized so that each crop in each sequence was represented every year. Wheat-soybeans were doublecropped while the sorghum-wheat-soybeans sequence represented 3 crops produced every 2 years. Cultivars used were NK Pro 812 wheat, Funks G522DR sorghum, and Ransom soybeans. Wheat was planted in early December following the soybean harvest, while sorghum was planted in late March and soybeans in late May or early June subsequent to wheat harvest. No-till treatments were planted with a no-till drill, while conventional treatments were planted with a standard row planter. Herbicides used were propazine on sorghum and alachlor on soybeans. Paraquat was added along with the above herbicides for burn-down on no-till plots. Wheat received no herbicide. Nitrogen treatments for wheat were split into 2 topdress treatments and were applied in mid-December and mid-February. Nitrogen as NH_4NO_3 was knifed into beds of conventional sorghum in late February, while N treatments for no-till sorghum were surface broadcast following sorghum emergence in April. Each plot was 12.2 x 4 in. Row spacing for sorghum and soybeans was 1 m, while wheat was planted on 18 cm centers. Yield samples for corn and sorghum were cut from 3 m of the middle 2 rows of each plot, while a 12.2 x 1 m swath from the center of each plot was used to estimate wheat yields. Grain samples from each plot were ground, dried, and digested for total Kjeldahl N. Results from 1984 will be presented, as appropriate tillage treatments had been established for one full year prior to the 1984 cropping year. Results were statistically analyzed by analysis of variance and reyression techniques.

Results and Discussion

Cropping sequence influenced the yields of all crops in 1984, while tillage effects varied with the specific crop and cropping sequence. Hard red winter wheat production was affected by cropping sequence, with continuous wheat producing the most grain, followed by the wheat-soybean doublecrop and the sorghum-wheat-soybean doublecrop (Table 2 and 3). Wheat yields from the sorghum-wheat-soybean sequence were analyzed separately from the other sequences since wheat in this sequence relied only on residual nitrogen applied to sorghum. Residual nitrogen following sorghum was generally not sufficient for optimal wheat yields and N rates corresponding to the other wheat sequences were applied to wheat in this sequence in 1985. The winter of 1983 and spring of 1984 were unusually dry. Monocrop wheat produced the highest yields probably because of greater available soil water as compared with doublecrop treatments. Tillage treatment did not significantly influence wheat yields with continuous wheat or the wheat-soybeans doublecrop,. but no-till did increase wheat yields in the sorghum-wheat-soybeans rotation. Soybeans normally are not harvested in this location until late November. Since the winter and spring were unusually dry, little difference in soil moisture storage would be expected between tillage treatment in the wheat-soybeans doublecrop. Sorghum is harvested by mid-July and presents a greater potential for differences in soil water storage from early fall rains that might be attributed to varying methods of residue management.

Cropping sequence influenced grain sorghum yields in 1984, with continuous sorghum producing significantly more grain than the sorghum-wheat-soybean rotation (Table 4). Conventional tillage sorghum outperformed no-ti11 sorghum when averaged across cropping sequences. Nitrogen treatments were topdressed on no-ti11 sorghum, while N was subsurface knifed in conventional tillage plots. No rainfall was received for six weeks after topdressing the no-till plots, resulting in poorer early season growth and nitrogen uptake and demonstrates that surface applying N for no-ti11 warm season crops may not be practical under drier climatic conditions.

A significant cropping sequence x tillage interaction was noted for soybeans. Therefore, tillage means were compared within cropping sequence (Table 51. The wheat-soybean doublecrop produced the greatest mean yield, followed by continuous soybeans and the sorghum-wheat-soybean rotation. No-till increased yields, though not statistically, in the first two cropping sequences and significantly improved yields in the sorghum-wheat-soybean rotation. **It** was noted that both wheat and soybeans following sorghum have decreased yields as compared to other cropping sequences.

Applied N increased grain yields of both wheat and sorghum. Continuous wheat responsed to applied N more than wheat in the wheat-soybean doublecrop, presumably due to differences in available soil water (Fig. 1). Nitrogen applied to no-ti11 wheat was also more effective in improving grain yield as compared to conventional tillage plots (Fig. 2). Conventional tillage sorghum utilized applied N more effectively than no-ti11 sorghum in 1984 (Fig. 31. Some of the difference was attributed to topdressing versus knifing the added N, as previously discussed. Conventional tillage sorghum produced greater yields than no-till, even with no applied N, implying that nutrient cycling may be significantly slower under no-till conditions. Applied N was a more important determinant of grain yield in continuous as compared to rotational sorghum (Fig. 4), implying greater soil water available to the monocrop or greater depletion of other nutrients by the doublecrop rotation.

Conclusions

1) Cropping sequence influenced the yields of all crops studied.
2) The effect of tillage on crop yields varied with crop and cropping sequence.
3) Cropping sequence and tillage also altered crop response to applied N.

Table 1. Cropping sequences and nitrogen fertilization rates.

Crop Sequence	N Applied to:	N Rate, kg ha $^{-1}$
Continuous Wheat	Wheat	0, 34, 68, 102
Wheat-Soybeans	Wheat	0, 34, 68, 102
Continuous Soybeans	-----	-----
Sorghum-Wheat-Soybeans	Sorghum	0, 45, 90, 135
Continuous Sorghum	Sorghum	0, 45, 90, 135

Table 2. Cropping sequences and tillage effects on wheat grain yields, 1984.

Treatment	Grain yield
	kg ha^{-1}
Sequence	
Continuous wheat	3688 a†
Wheat-soybean doublecrop	2610 b
Tillage	
No-till	3244 a
Conventional till	3054 a

† Values within a treatment parameter followed by the same letter are not different by LSD (0.05)

Table 3. Tillage effects on wheat grain yields in sorghum-wheat-soybeans cropping sequence, 1984.

Tillage Treatment	Grain yield
	kg ha^{-1}
No-till	2531 a†
Conventional till	1691 b

† Values followed by the same letter are not different by LSD (0.05).

Table 4. Cropping sequence and tillage effects on grain sorghum yield, 1984.

Treatment	Grain yield
	kg ha^{-1}
Sequence	
Continuous sorghum	5087 a†
Sorghum-wheat-soybeans	4512 b
Tillage	
Conventional till	5044 a
No-till	4555 b

† Values within a treatment parameter followed by the same letter are not different by LSO (0.05).

Table 5. Crop sequence x tillage interaction on soybean yields, 1984.

Sequence	Tillage	Grain yield
		kg ha^{-1}
Wheat-soybeans	Conventional	3722 a†
	No-till	3493 a
Continuous soybeans	No-till	3501 a
	Conventional	3388 a
Sorghum-wheat-soybeans	No-till	3434 a
	Conventional	2844 b

† Values within a crop sequence followed by the same letter are not different by LSO (0.05).

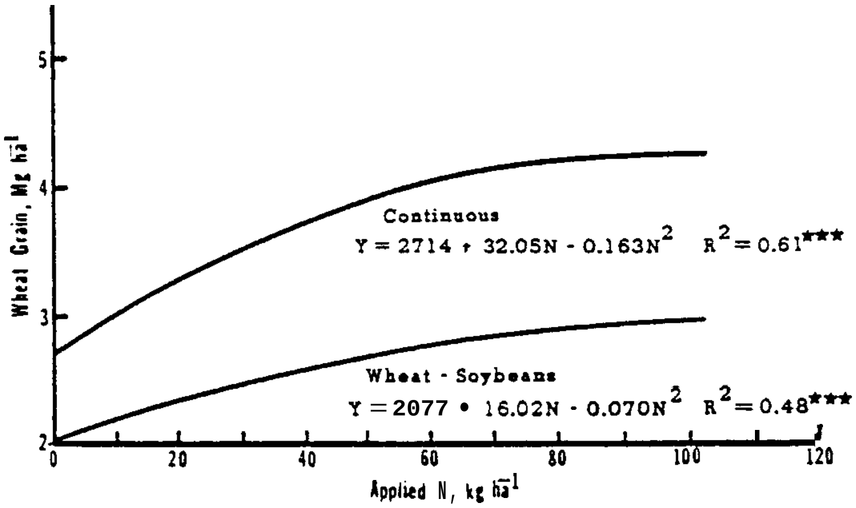


Figure 1. Applied N effect on wheat yields in monocrop and doublecrop sequences.

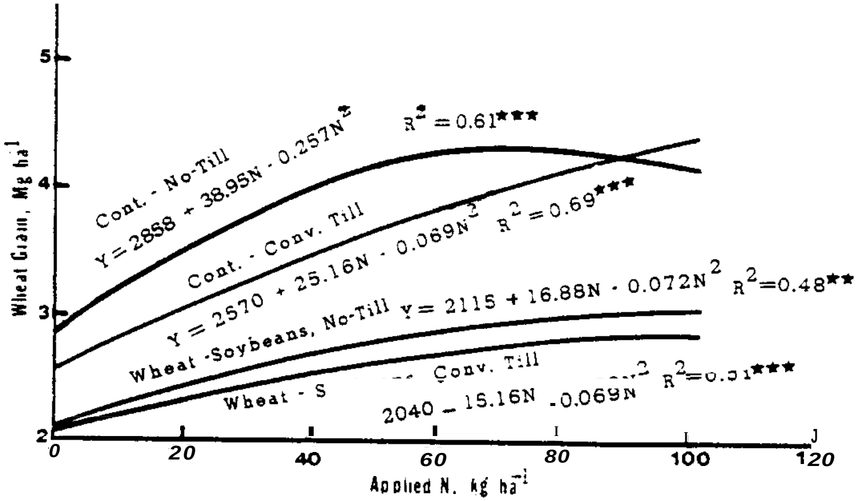


Figure 2. Wheat response to applied N as modified by crop sequence and tillage.

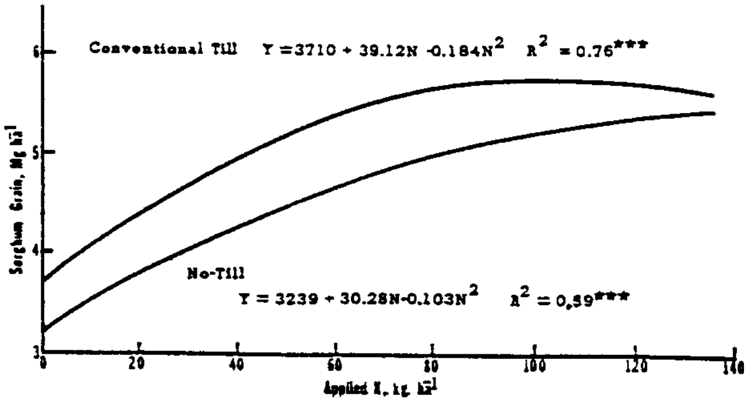


Figure 3. Tillage effect on the response of sorghum to applied N.

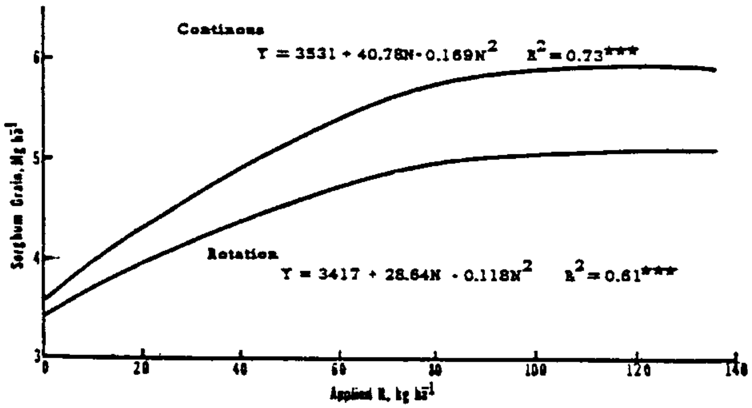


Figure 4. Effect of crop sequence on the response of sorghum to applied N.

Surface Lime Influence on No-Till Alfalfa Grown in an Acid Soil

J. E. Rechcigl, D. D. Wolf, R. B. Reneau, Jr., and W. Kroontje

Virginia Polytechnic Institute and State University, Blacksburg. VA 24061

ABSTRACT

Soil acidity is believed to be a major cause of limited root penetration and low yields for alfalfa (Medicago sativa L.). Alfalfa was seeded into an orchardgrass sod (Dactylis glomerata L.) to evaluate the influence of surface applied limestone on alfalfa growth under acidic soil conditions. Alfalfa was no-till planted in April of 1981 and 1982 on an Ernest silt loam soil (fine-loamy, mixed, mesic Aquic Fragiudult). Dolomitic agricultural limestone was surface applied at 0 or 6.7 kg ha^{-1} either **6** or 18 months before planting (April 1981 or 1982) or at planting. Yield (from 1982 through 1984) increases, greater than 2 fold, resulted from surface application of limestone. Time of lime application (6 months or 18 months prior to planting or at planting) had no influence on yields. Roots were more prevalent at the 1.0 and 1.5 meter depths as a result of surface lime application than without lime. Soil pH (0 to 10 cm depth) ranged from 6.2 to 6.9 in the surface limed plots as compared to 5.3 to 5.6 in the unlimed plots, regardless of time of lime application. The pH averaged 5.1 at and below the 45 cm depth irrespective of lime application. Aluminum levels ranged from 21 at the 0 to 5 cm depth to 186 mg kg^{-1} at the 145 to 150 cm depth on unlimed plots. Lime application reduced Al levels by 2 to 20 fold in the upper 15 cm, but had no influence on A1 levels at depths of 95 cm and greater. Calcium levels were elevated in the top 15 cm as a result of lime application and then decreased with increasing depth. This study indicates that no-till alfalfa may be grown on acid soils containing high Al, without lime incorporation prior to seeding, provided surface lime is applied.

INTRODUCTION

No-till farming is becoming increasingly popular as a conservation practice. In addition to conserving valuable top soil, no-tillage methods save the producer time and machinery cost. No-till practices for corn (Zea mays L.) and soybeans (Glycine max, Merr.) are well established and widely accepted; however, no-till establishment procedures for small-seeded legumes such as alfalfa (Medicago sativa L.) are only now being developed.

No-till alfalfa is recommended only if the soil pH is above

6.5. Extreme acidity in subsoils has been shown to be harmful to alfalfa because of shallow rooting, resulting in drought susceptibility, and poor use of subsoil nutrients.

Studies by the authors have shown yield increases in alfalfa on acidic soil by plowsole application of lime. There is also some evidence that alfalfa roots may penetrate acidic subsoils, in the absence of plowsole lime when surface limed. In the latter study alfalfa roots penetrated soil to 84 cm, where the pH was 4.1 and the exchangeable A1 was 225 mg kg-^{1}.

Liming studies with alfalfa have used conventional tillage practices where lime if needed is incorporated during preplant field operations. The objective of this paper is to evalute the influence of surface lime application on alfalfa growth when no-till planted in acidic soil conditions.

MATERIALS AND METHODS

'Arc' alfalfa was no-till planted into orchardgrass (Dactylis glomerata L.) in an Ernest silt loam soil (fine-loamy, mixed, mesic Aquic Fragiudult) at the Agronomy Research Farm near Blacksburg, VA. Plantings were made in the third week of April 1981 and 1982. A contact herbicide was applied the day before planting. A no-till drill was used to place the seed at a 2.5 cm depth in 20 cm rows at a rate of 16.5 kg ha^{-1}. Dolomitic agricultural limestone was surface applied either 6 or 18 months before planting (April 1981 or 1982) or at planting. A randomized complete block design included four replications. Harvests and fertility programs were selected to maintain productive stands.

Composite soil samples were collected from 0 to 5, 5 to 10, 10 to 15, 45 to 50, 95 to 100, and 145 to 150 cm depths. Soil samples were air dried and crushed to pass a 2-mm sieve. Soil pH, Ca, and KC1 exchangeable A1 measurements were then conducted.

Plant samples from 3 harvests in 1984 were dried at 65°C for 12 h and ground in a stainless steel mill to pass a 20-mesh sieve. Nitrogen, Ca, P, Al, and Mn were then determined.

Trenches were excavated in limed and unlimed plots planted in April 1982 to measure the depth of root penetration. Roots were measured at the 0.1, 0.5, 1.0, and 1.5 meter depth utilizing the foil method by counting root intersections on a 21 by 28 cm grid. Roots were then sampled and washed 10 times in distilled water to remove soil contaminants and tested qualitatively for A1 using the Quinalizarine method.

RESULTS AND DISCUSSION

Surface limed plots had an average pH of 6.8 in the surface 5 cm, in comparison to 5.5 for unlimed soil. The pH decreased with increasing depth regardless of lime application. There were no differences in pH values between limed and unlimed plots at depths of 45 cm or greater, the average being 5.1. Exchangeable A1 ranged from 21 to 186 mg kg^{-1} at increasing depths in unlimed soils. Surface application of lime reduced the A1 by 2 to 20 fold in the top 15 cm. At depths of 95 cm and greater there were no significant differences in A1 concentration between limed and unlimed plots. Aluminum increased with increasing depth regardless of lime application. Time of lime application *(6,* 18 months prior to planting, or at planting) did not affect A1 levels in the soil. Calcium ranged from a low of 271 to a high of 870 mg kg^{-1} for unlimed and limed plots, respectively in the top 15 cm. Time of lime application resulted in no changes in soil Ca levels.

Roots were more prevalent at the 1.0 and 1.5 meter depths in surface limed plots in comparison to the unlimed plots (Fig. 1). Roots penetrated to the 1.5 meter depth under acidic conditions. This is in agreement with earlier work conducted by the authors, who showed alfalfa roots penetrated to the 152 cm depth in a Tatum clay loam soil (Typic Hapludult, clayey, mixed, thermic) in the presence of 225 mg kg^{-1} exchangeable A1 when surface limed.

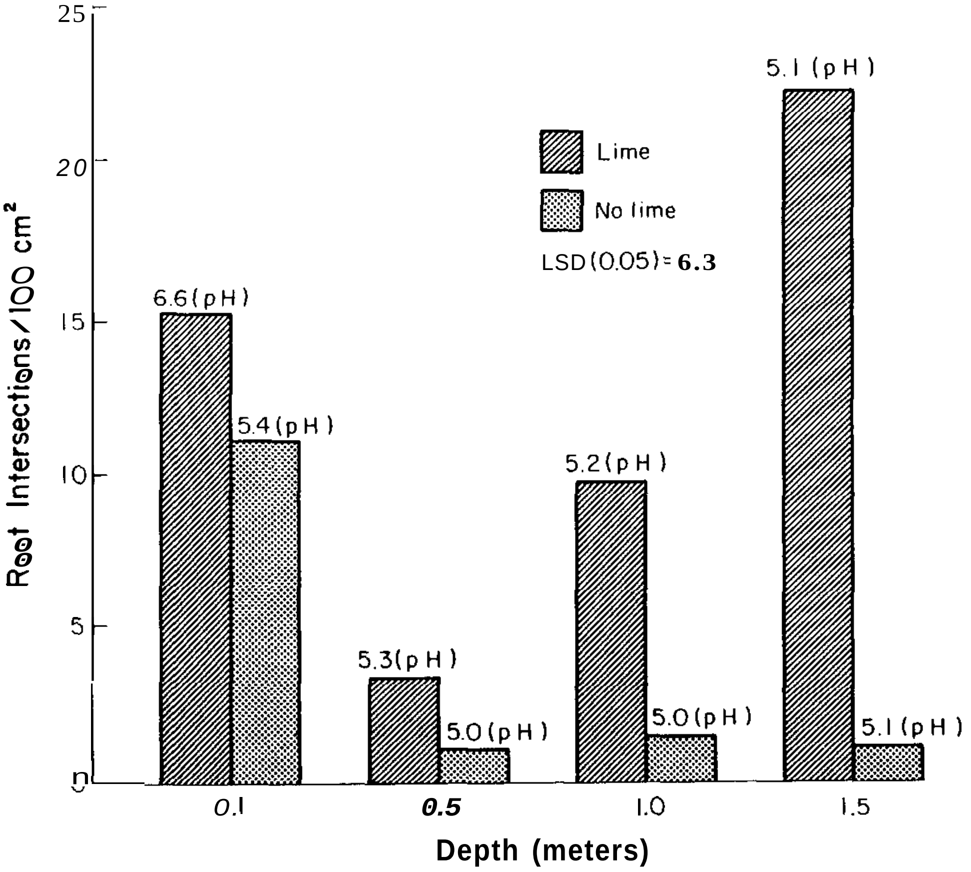


Fig. 1. Influence of surface lime on alfalfa root abundance at various soil depths. Numbers above each bar indicate pH values at different depths.

Whereas the findings of other investigators reported stunting of roots in nutrient solutions with as little as 1 mg kg^{-1} Al. At the 0.5 meter depth, roots were reduced in comparison to other depths regardless of lime application, due to the presence of a fragipan. Roots which penetrated the fragipan branched at greater depths.

Alfalfa roots from treatments with and without surface lime were tested by the Quinalizarine method to detect the presence of A1 on the root surface. Whitish roots from unlimed soil changed to red-violet indicating the presence of A1 at all depths. In contrast, surface roots (0 to 15 cm) from plots that received surface lime appeared blue under comparable conditions indicating absence of A1 at the 0 to 15 cm depth. At depths greater than 15 cm, all roots appeared red-violet indicating the presence of Al.

Alfalfa yields were increased by surface application of lime (Table 1). The 1981 planting of alfalfa showed a 2 to 3 fold yield increase from surface lime application compared to the unlimed plots. The time of lime application whether applied immediately before planting or 6 or 18 months before planting did not influence yields. In the 1982 alfalfa planting there were 3 and 2 fold yield increases in the 1983 and 1984 harvests, respectively, due to surface-lime application. Again, there were no differences in yield due to time of lime application. Rainfall after spring planting may have benefited lime response but different results might occur with late August planting. When rainfall after planting is limited, then lime application 6 to 18 months before planting might be necessary.

Table 1. Influence of rate and date of surface applied agricultural limestone on alfalfa yield. Alfalfa was no-till planted in 3rd week of April of 1981 and 1982.

Date of planting	Lime application		Year of alfalfa harvest		
	Rate	Date	1982	1983	1984
	Mg ha^{-1}		----Yield (Mg ha^{-1})----		
Apr. 1981	0.0	--	2.0	4.9	5.0
	6.7	Apr. 1981	6.1	10.0	10.6
	6.7	Aug. 1980	6.8	11.3	10.3
Apr. 1982	0.0	--	--	2.6	4.3
	6.7	Apr. 1982	--	8.0	10.5
	6.7	Aug. 1980	--	7.6	8.9
$LSD_{(0.05)}$			1.8	3.7	3.6

Yield increases were related to increased root penetration. Increased root penetration may enable the plants to obtain needed nutrients and water. This is in agreement with the previous work of the authors who reported increased yield with increased root penetration as a result of plowsole lime application.

There were no differences between limed and unlimed plots for Ca, P, Al, and Mn in tissue (Table 2). There were trends showing Mn levels to be increased in the tissue in the absence of lime, though not in the toxic range. Nitrogen was increased by lime application. In the absence of lime, N averaged 29 g kg^{-1}, while in the presence of lime, N averaged 32 g kg^{-1}. Soil acidic conditions may reduce N fixation and limit N needed for root and top growth. A reduced level of N fixation in the unlimed soil may also account for decreased root penetration resulting in reduced yields. The present study demonstrated that surface application of lime may be adequate for the growth of alfalfa in acidic soils, with the most important factor being the benefit to symbiotic N fixation.

Table 2. Influence of rate and date of surface applied agricultural limestone on nutrient concentration and calculated nitrogen uptake of alfalfa herbage. Data are average of 3 hay harvests in 1984.

Date of planting	Lime application		Nutrient concentration					N Uptake[+]
	Rate	Date	N	Ca	P	Al	Mn	
	Mg ha^{-1}		-----g kg^{-1}-----			mg kg^{-1}		kg ha^{-1}
Apr. 1981	0.0	--	28.9	12.7	4.4	157	91.3	105
	6.7	Apr. 1981	32.7	11.7	4.3	131	67.7	246
	6.7	Aug. 1980	32.3	11.9	4.4	221	76.9	231
Apr. 1982	0.0	--	29.6	12.5	4.2	132	89.8	75
	6.7	Apr. 1982	32.1	11.5	4.2	147	61.0	227
	6.7	Aug. 1980	32.1	12.1	4.5	156	70.4	188
	$LSD_{(0.05)}$		2.6	NS*	NS	NS	NS	96

*NS Not significant at the 0.05 level

[t] N Uptake = N concentration x yield

Tillage and Traffic Effects on Soil Compaction in an Oat-Soybean Double-Cropping System

L. Vazquez, D.L. Myhre, R. N. Gallaher, and E. A. Hanlon

IFAS, Department of Soil Science, and Department of Agronomy, University of Florida

INTRODUCTION

Growers and scientists have observed that soybean yields (*Glycine max* (L) Merrill) decrease after the second or third year of a continuous soybean **no**-tillage system (Gallaher, 1984; Gebhardt and Minor, 1983; Lindeman, Randall, and Ham, 1982; Thurlow, Elkins, and Hiltbold, 1984; and Touchton and Johnson, 1982). Decreased soybean yields under a no-tillage system may be an indirect effect of increased soil compaction. From an agronomic viewpoint, soils or soil layers are considered to be compacted, 1) when the air-filled porosity is low enough to restrict aeration, and 2) when soil pores are so small as to impede root penetration or reduce drainage (Hillel, 1980). Penetrometer resistance measurements give an indication of compacted layers (pans) and relative resistance to root penetration (Volk, 1953). Previous research in Florida has shown that penetrometer resistance under soybean rows was about 2.0 MPa less in subsoiled plots than in control plots at the 15 to 20 cm depth during the growing season (Rhoads, 1978).

MATERIALS AND METHODS

A soybean ['Bragg'/oat (*Avena sativa* L.)] multiple cropping tillage experiment was initiated in 1976 near Gainesville, Florida, and continued through 1984, when soil compaction was investigated, The experimental design was a randomized complete block with four replications. Each plot was 10 m long and consisted of 12 rows spaced 76 cm apart. Rows were located in the same position each year. Tillage treatments were applied to the same plots each year and consisted of 1) minimum tillage (MT), 2) minimum tillage plus subsoiling (MTPS), 3) conventional tillage (CT), 4) conventional tillage plus subsoiling (CTPS). Minimum tillage plus subsoiling in conventional plots were imposed with an in-row subsoil no-tillage planter. Conventional tillage plots were tilled to a depth of 15 cm with a rototiller and planted with the no-tillage planter. Subsoiling was performed to a depth of 33 cm. Soil probe resistance readings were made with a recording penetrometer (Carter, 1967) to a depth of 60 cm at five horizontal positions in a perpendicular transect across four soybean rows. Three soil probe resistance readings were taken at each position forming an isosceles triangle about 5 cm on each side. Root-pull resistance readings were taken by a method described by Gallaher (1984).

RESULTS AND DISCTJSSION

Soil probe resistance increased up to 2.5 to 3.5 MPa at a depth of about 30 to 40 cm, depending on treatment and position. At the 10 cm depth and the traffic position, CT treatment lowered soil probe resistance 0.33 MPa below the MT treatment (Fig. 1). Shaded areas indicate where statistical difference was present. At the no-traffic position, however, this reduction was as high as 1.25 MPa. Tractor wheel passage positively increased soil probe resistance masking the benefit of tillage. Under the no-traffi.c position at the 35 cm depth, an increase in soil probe resistance of 0.29 MPa was observed.

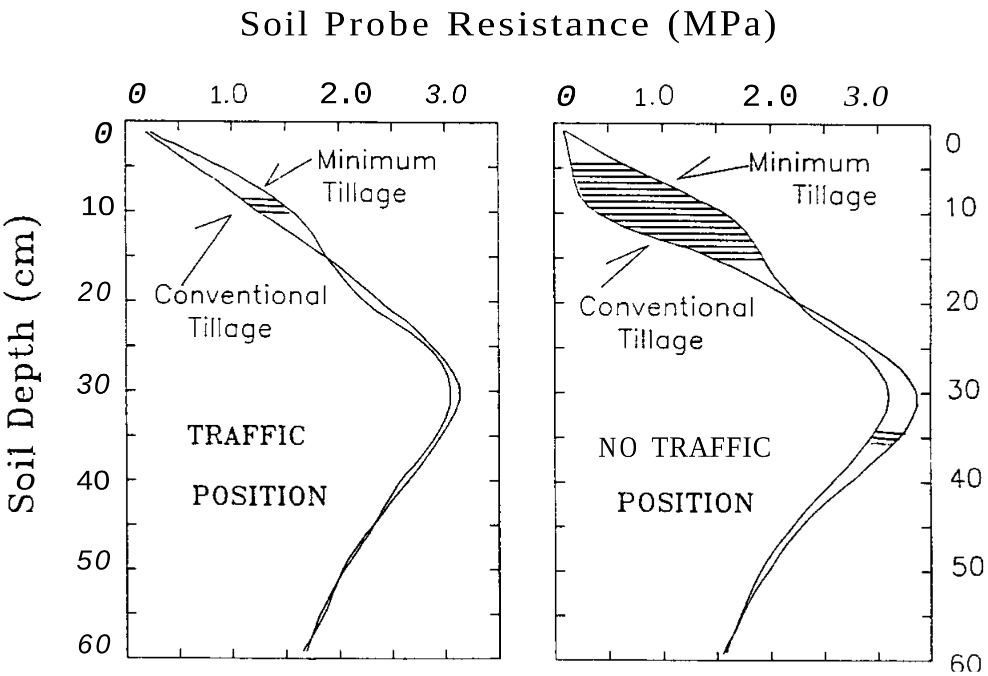


Fig. 1. Soil probe resistance (MPa) comparing minimum tillage vs. conventional tillage in relation to soil depth, traffic, and no-traffic positions. Cross-hatched areas indicate where statistical differences occur.

Subsoiling affected both vertical and horizontal soil probe resistance readings (Fig. 2). Subsoiling reduced soil probe resistance at the traffic, no traffic, and drill positions. Subtracting values of MT from MTPS, a reduction in soil probe resistance at the traffic position was observed between the 25 and 35 cm depths with a maximum difference of 0.71 MPa at the 30 cm depth. At the no traffic position, a maximum difference of 0.65 MPa was observed at the 25 and 30 cm depths. The effect of in-row subsoiling decreased with lateral distance from the drill position. Maximum subsoiling effect was observed at the 20 cm depth in the drill position (-1.85 MPa difference) hut subsoiling reduced soil probe resistance from 5 to 30 cm depths. Figure 2 shows a 0.29 MPa increase in soil probe resistance in the drill at the 45 cm depth due to the passage of the subsoiler. A similar, but not equal, pattern was observed by subtracting values of CT from CTPS (Fig. 3). At the drill position, tillage masked the subsoil effect in the top 10 cm depth. Since subsoiling reduced soil probe resistance near the surface to the 30 cm depth, deeper roots may be expected and more attachment of the plant to the soil may result. It may be necessary to fertilize according to increase nutrient availability where roots are actively growing.

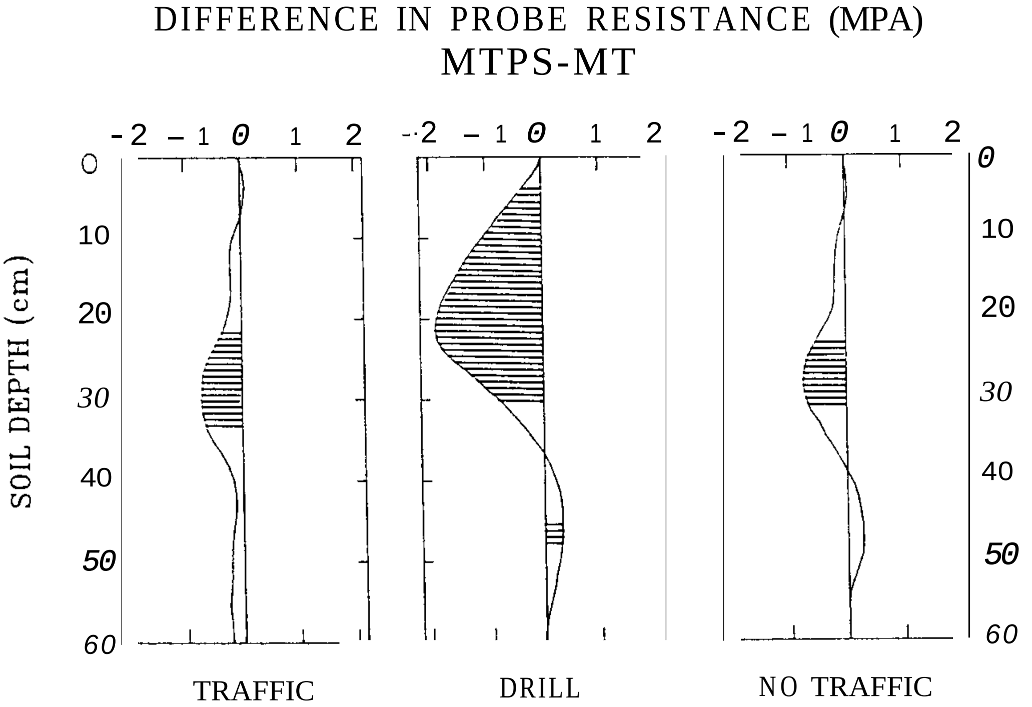


Fig. 2. Differences in soil probe resistance (MPA) as a result of subtracting values of minimum tillage from minimum tillage plus subsoil.

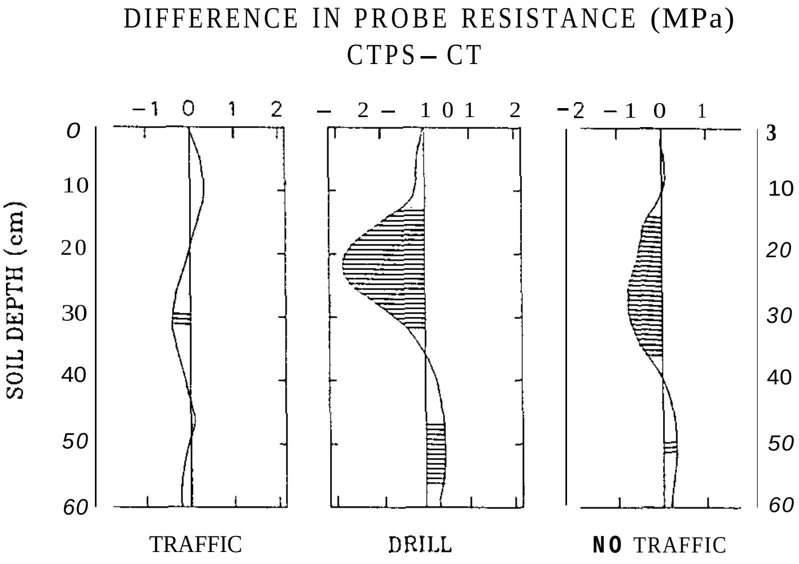


Fig. 3. Differences in soil probe resistance (MPa) as a result of subtracting values of conventional tillage from conventional tillage plus subsoil.

For CTPS and MTPS, a reduction of soil probe resistance occurred at the drill position compared with the traffic position (Fig. 4). Contrasting soil probe resistance between drill and traffic, the drill position under CTPS had lower values from the 5 to 30 cm depths and higher values from the 35 to 60 cm depths. Respective maximum differences of 2.1 MPa and 0.47 MPa at the 20 and 45 cm depths were found. Under MTPS, the drill position had lower soil probe resistance values at the 5 to 25 cm depths and higher soil probe resistance values from the 35 to 50 cm depths, with maximum respective differences of 1.69 MPa and 0.48 MPa at the 20 and 40 cm depths.

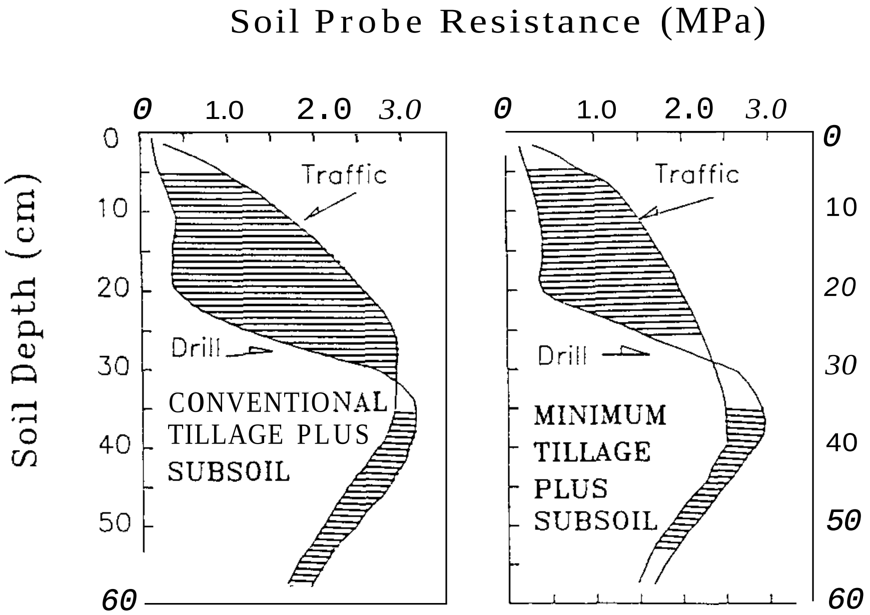


Fig. 4. Soil probe resistance (MPa) comparing traffic versus drill (row) positions.

The resistance (kPa) or force necessary to pull roots from soil varied among treatments (Table 1). Selecting the MT treatment as the control, both tillage (CT) and subsoiling (MTPS) increased the force, 0.31 and 0.97 kPa, respectively, needed to pull roots out of the soil. The differences in forces corroborates the reasoning that root growth pattern was influenced by mechanical disturbance of the soil. Subsoiling masked the effect of tillage on root pull measurements.

Table 1. Root-pull resistant values (kPa) of soybean plants.

	Subsoil		
Tillage	With	Without	
	------- k Pa --------		
MT	3.09	2.12	*[1]
CT	2.73	2.43	N.S.[2]
	*	*	

[1] * = significant at the 5% level of probability.

[2] N.S. = non-significant.

Note: Comparisons made between subsoiling treatments keeping tillage constant **or** between tillage treatments keeping subsoiling constant.

SUMMARY AND CONCLUSIONS

The tillage action in CT reduced soil probe resistance in the upper 15 cm of soil when compared to MT. This reduced resistance, however, was negated due to traffic passage and persisted only in the no-traffic position. Location of traffic activity was not as critical in MT as in CT since MT plots exhibited uniform, increased soil probe resistance with depth regardless of traffic, drill, or no-traffic position.

High soil probe resistance was found at 30 cm in both CT and MT, exceeding the 2.0 MPa limit for normal soybean root growth. This 30 cm compacted zone was eliminated by in-row subsoiling but passage of the tool created another compacted zone at 35 cm depth and horizontally as far as 30 cm away.

Root-pull readings suggested that subsoiling resulted in deeper-rooted plants than in non-subsoiled plots.

The evidence strongly suggests that decreased soybean yields under MT are an indirect effect of increased soil compaction. This adverse effect may be counteracted by in-row subsoiling, providing the presence of a soil compaction layer has been determined by soil probe resistance measurements.

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Mehlich I Extractable Soil Calcium, Magnesium, and Potassium in an Oat/Soybean Doublecropping System as Affected by Tillage and Time

Suzanne Dyal and R. N. Gallaher

Department of Agronomy, IFAS. University of Florida, Gainesville, FL 32611

INTRODUCTION

The reason for this research project was to study the change in soil test of available nutrients over time as affected by tillage in an oat (Avena sativa)/soybean (Glycine max L. Merr.) doublecropping system. There have been conflicting reports of tillage influence on nutrients in the past and this may be due to a diurnal fluctuation of available nutrients in the soil. If this is the case, the time of sampling would be an important factor in interpreting the results of tillage comparison studies. The purpose of this study was to determine the influence of tillage and time of year on soil extractable Ca, Mg, and K in an oat/soybean double cropping system.

MATERIALS AND METHODS

The experiment was set up as a randomized complete block design with four replications. The four tillage treatments are no tillage (NT) and conventional tillage (CT) plus and minus subsoiling. The oat/soybean doublecropping system is located at the Green Acres agronomy farm, 12 miles west of Gainesville, FL. Samples are taken approximately monthly and sampled at the 0–20 cm and 20–40 cm depths over a 24 month period. The data to be discussed includes soil samples taken from September 6, 1983 to December 12, 1984. The Melich I (double acid) method of soil testing was used and the data on Ca, Mg, and K will be presented for the average of no–tillage versus conventional tillage treatments.

RESULTS AND DISCUSSION

Calcium in both CT and NT decreased over time at the 0–20 cm soil depth (Fig 1). Dolomitic limestone was last applied in the Fall of 1976. Calcium and Mg, at the 0–20 cm soil depth in the NT plots were higher than in CT plots (fig. 1&3)however, Ca and Mg at the lower soil increment of 20-40 cm was higher in the CT plots (fig. 2&4). This is due to the plant roots in the NT plots mining soil nutrients from the lower depths and depositing them on the surface in crop residues. Old root channels in the NT plots can cause excessive leaching at this lower level. The Ca/Mg ratio at both soil increments shows that Ca is higher in relation to Mg in the CT plots (fig. 5&6). There is more available Mg for the plants in the NT plots as compared to Ca.

Potassium at the 0-20 cm depth is not different in either tillage treatment but, NT is slightly higher at the 20-40 cm depth than for CT (fig. 7&8). Due to incorporation and mixing of the residue in CT, K could be released more readily and be utilized by the plant or leached out of the soil causing K to be lower. The NT treatment could possibly hold or conserve K better than the CT treatment. There is no difference between tillage treatments in the Ca+Mg/K ratio at the 0-20 cm depth, however, a seasonal fluctuation is observed in both tillage treatments associated with each cropping system (fig. 9). Potassium is higher at the very end and beginning of each crop life cycle in relation to Ca+Mg, showing its higher availability during this time. It seems from the data so far that K is favored over Ca+Mg in residue release. Calcium and Mg are more available for plant use during the time periods, as shown on the graph, where the slope is positive. At the 20-40 cm soil depth, CT is higher in all the cropping systems for the Ca+Mg/K ratio (fig. 10). Calcium and Mg contents are favored in the CT plots compared to K. In the NT plots, K is held more efficiently than in the CT plots at the lower soil depth. The total extractable Ca+Mg+K decreased over time at the 0-20 cm depth in both tillage treatments (fig. 11). The NT treatment was higher in the CT plots at the 0-20 cm depth because of the mining effect of the roots in NT. The nutrients are pulled up and left on the surface, depleting the lower depths. The CT plots are higher in Ca+Mg+K at 20-40 cms due to the mining effect in the NT and more leaching (fig. 12).

CONCLUSIONS

Magnesium and Ca were higher at the 0-20 cm soil depth for NT due to roots drawing up these nutrients and leaving them on the surface. Magnesium and Ca were lower at the 20-40 cm depth in the NT rather than the CT plots because of leaching due to old root channels and also mining effect of roots in the NT plots depleting the lower depths. Potassium is conserved more in relation to Ca+Mg in NT compared to CT. Further study may confirm that K is favored over Mg and Ca in residue release.

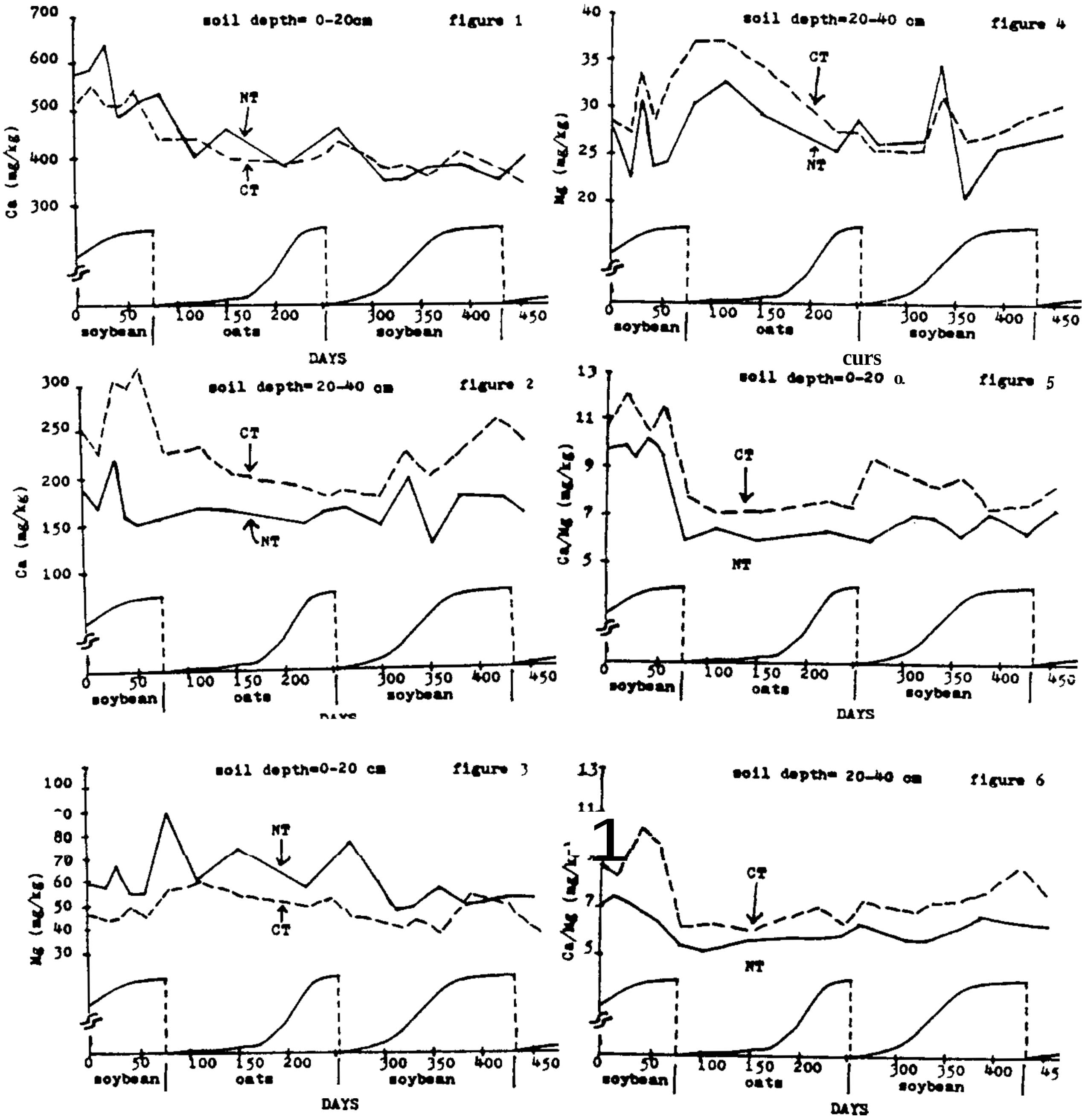

Figure 1-6. Extractable soil Ca, and Mg, and the Ca/Mg ratio as affected by tillage, time, and soil depth in an oat/soybean double cropping system. CT= Conventional tillage, NT= No tillage.

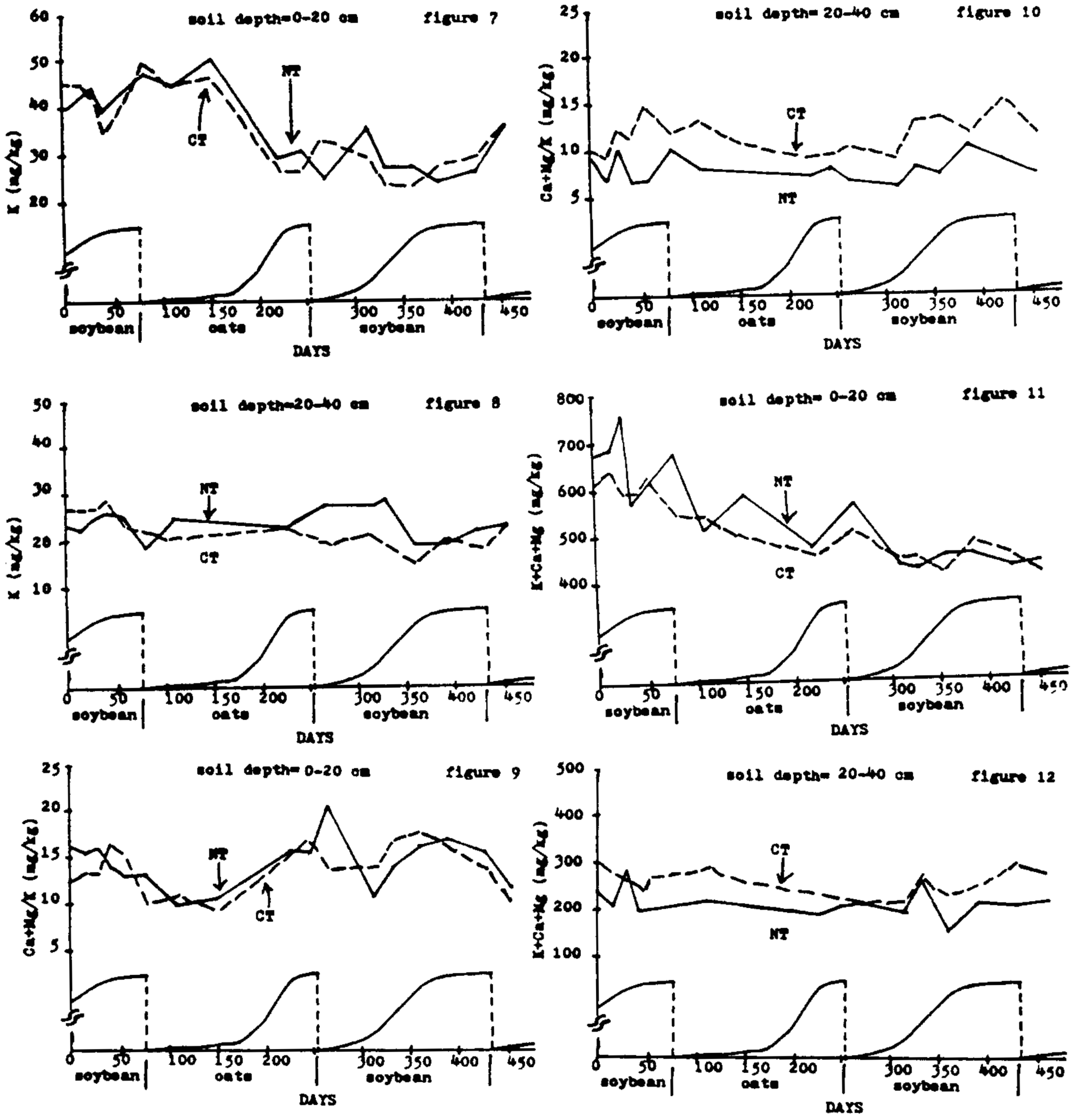

Figure 7-12. Extractable soil K, Ca+Mg/K ratio and the total extractable Ca+Mg+K *as* affected by tillage, time and soil depth in an oat/soybean double cropping system. CT= Conventiona tillage, NT= No tillage.

Nitrogen Recovery by No-Till and Conventional Till Corn from Cover Crops

J. J. Varco, W. W. Frye, and M. S. Smith

Department of Agronomy, University of Kentucky, Lexington, KY 40546-0091

A significant portion of the N required by corn can be supplied by legume cover crops. Based on N fertilizer equivalents in pounds per acre, the following estimates of N input to corn from legume cover crops have been reported: 100 from a mixed cover of hairy vetch and spring oats (Mitchell and Teel, 1977), 120 to 180 from hairy vetch (Flannery, 1982), and 80 to 90 from hairy vetch (Ebelhar et al., 1984). Frye et al., (1985) have shown that hairy vetch cover resulted in the highest grain yields and economic returns compared to cover treatments of rye or corn residue only; all were in combination with 90 lb N/acre. Thus, legume cover crops can be considered a viable substitute for a portion of the fertilizer N needs of corn. In order to take full advantage of the legume N and to make judicious N fertilizer recommendations in terms of rates and time of application, more information on the behavior of this system is needed. Therefore, the objective of this study was to determine the pattern of uptake and recovery of N from ^{15}N-labeled legume and non-legume cover crop residues under no-till and conventional till management.

MATERIALS AND METHODS

A field experiment was initiated in the spring of 1984 within a long-term no-till corn experiment that has been in progress since 1977. A thorough description of the established experiment was given by Ebelhar et al. (1984). In 1984, a tillage variable was incorporated into the long-term study by plowing half of each plot, resulting in tillage treatments of no-till and conventional till.

Microplots (2x3 m) were established on plots with cover treatments of corn residue, rye, and hairy vetch, all with 0 N fertilizer. In situ rye and hairy vetch were removed from the microplots and replaced with the same amounts of ^{15}N-labeled residues (Table 1).

Whole corn plant samples were taken by randomly cutting 3 plants within the microplot at day 42, 77, and 126 after planting. The plants were dried at 65°C, weighed, ground, and analyzed for total N. Percent ^{15}N in each sample was determined with a mass spectrometer, and by the use of appropriate formulas the recovery of N from the labeled residues was determined.

Table 1. Dry matter quantity of labeled residues added and N content.

Cover Crop	Quantity	N Content
	lb/acre	lb/acre
Hairy vetch	3030	110
Rye	1360	23

RESULTS AND DISCUSSION

The quantity of N removed by corn was dependent on the cover treatment and tillage (Fig. 1). Plowing the soil resulted in greater N uptake (accumulation) for all cover treatments. This suggests that mineralization of the residues and/or soil organic N was greater when the soil was plowed.

An estimate of the differential quantity of N accumulated by corn with a hairy vetch cover over a cover of corn residue for both tillage treatments is shown in Fig. 2. It is apparent that there is an additional quantity of N in the hairy vetch system which can be attributed to its capacity to biologically fix atmospheric N_2. This additional N is released from both the hairy vetch residue and the soil which, over time, has reached a greater equilibrium soil N content. At harvest, the apparent contribution of N from hairy vetch to corn was 70 and 50 lb/acre for conventional till and no-till, respectively.

Grain yields are presented in Table 2. Plowing the soil resulted in greater yields for the corn residue and rye cover treatments, while with hairy vetch there was no significant difference between tillage treatments. The ratio of yield over total N removed for all treatments was near one, except for plowed hairy vetch, which was less than one (Table 2). This implies less efficiency of the greater quantity of N accumulated in the plowed hairy vetch system compared to the other treatments. This is probably due to low available soil moisture in 1904 limiting utilization of this N. Ratios near one indicate an average utilization of N, but ratios less than one suggest that something other than N was limiting. An indication of increased productivity when hairy vetch is used as a cover crop can be seen when one takes the ratio of yield with hairy vetch cover for each tillage treatment over the corresponding tillage treatment of corn residue cover. Ratios of 1.36 and 1.92, resulted for conventional till hairy vetch/corn residue and no-till hairy vetch/corn residue, respectively. Thus, by the use of a hairy vetch cover crop, grain yield was 36 and 92% greater than corn residue alone for conventional till and no-till, respectively.

Table 2. Effect of tillage and cover treatment on grain yield and yield/lb N removed.

Cover Treatment	Tillage	Grain Yield*	Yield/lb N Removed
		bu/acre	
Hairy vetch	CT+	110 a‡	0.76
	NT	102 a	0.99
Corn residue	CT	81 b	1.10
Rye	CT	80 b	1.10
	NT	53 c	0.96
Corn residue	NT	52 c	0.99

4 Adjusted to 15.5% moisture.

\+ CT = conventional till; NT = no-till.

‡ Means followed by the same letter are not significantly different at the 5% level of probability based on LSD.

By employing labeled residues we were able to estimate the recovery of N by corn, from the residues (Table 3). It is apparent that turning under the residue by plowing resulted in a greater quantity of N recovered. Mixing the soil with the residue resulted in a more intimate contact between residue and soil, thereby increasing the quantity of residue decomposed. Although in the no-till system less of the residue is likely to decompose, the remaining residue on the soil surface protects the soil from erosion.

Table 3. Total recovery of cover crop N by corn as influenced by tillage.

Cover Crop	Tillage	Total N Recovered
		%
Hairy vetch	CT*	34 a+
Rye	CT	26 b
Hairy vetch	NT	18 c
Rye	NT	18 c

4CT = conventional till; NT = no-till.

\+ Means followed by the same letter are not significantly different at the 5% level of probability based on LSD.

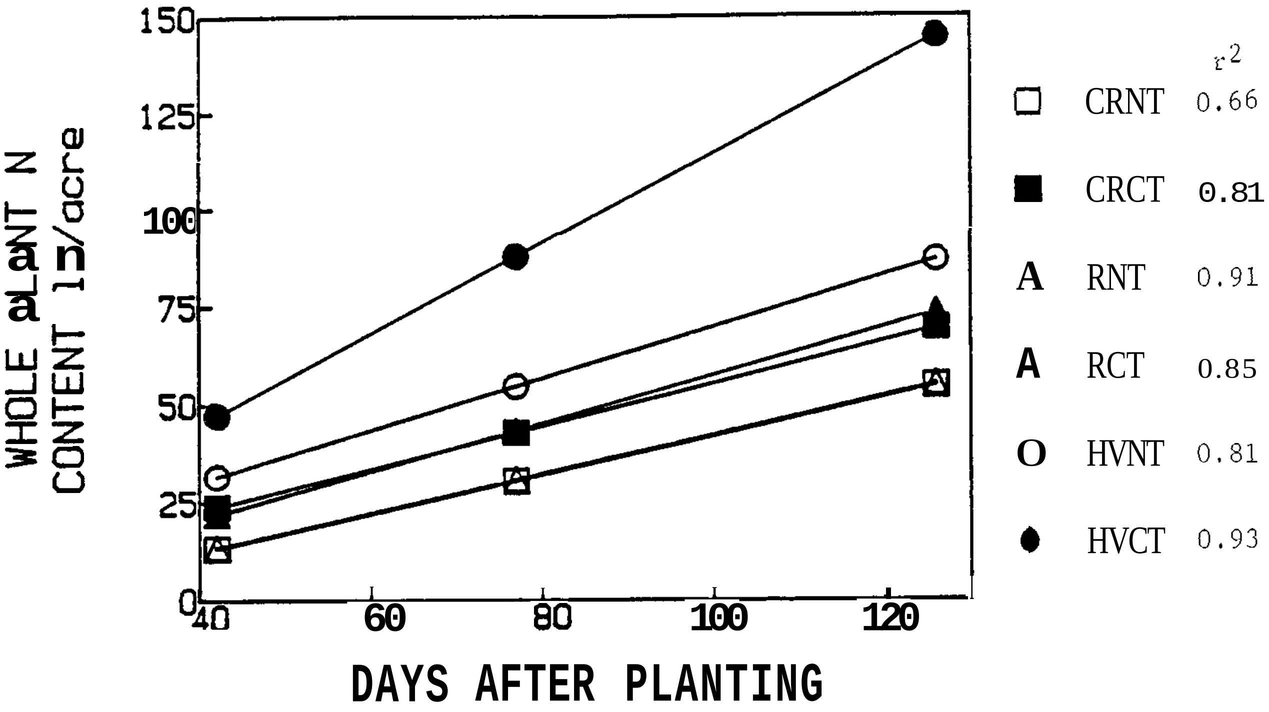

Fig. 1. Nitrogen uptake by corn as influenced by cover treatments of corn residue (CR), rye (R), and hairy vetch (HV), and conventional till (CT) and no-till (NT) management.

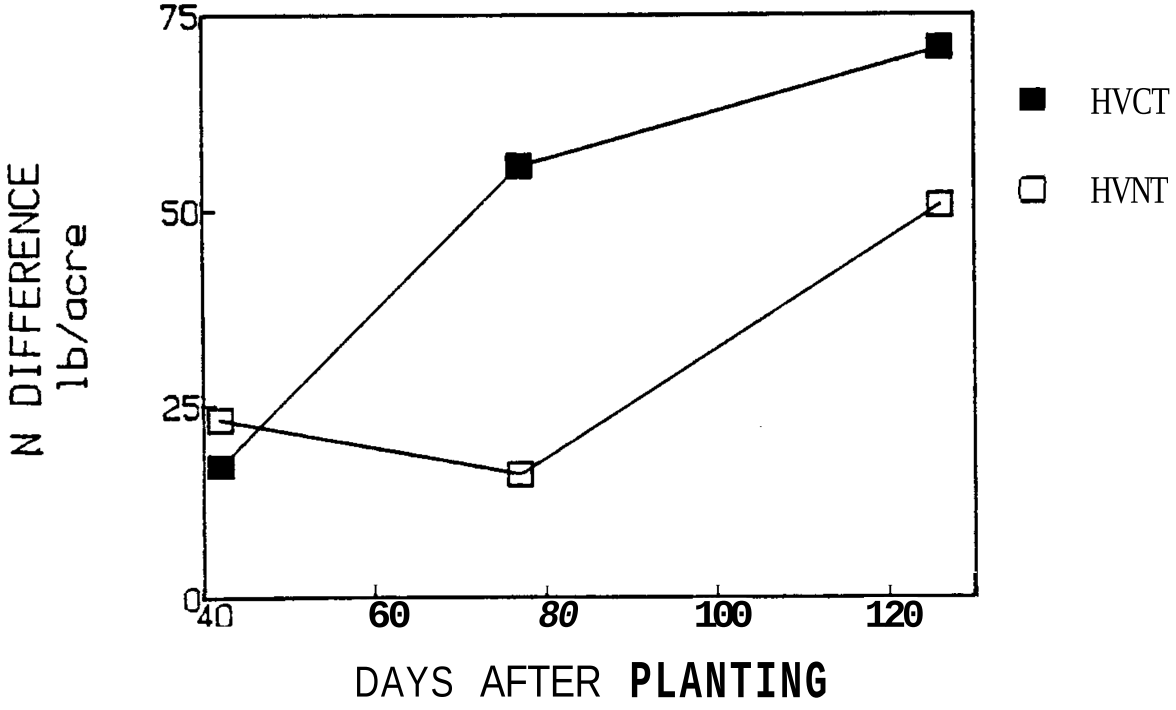

Fig. 2. Nitrogen uptake by corn planted into hairy vetch (HV) residue, in excess of N accumulated by corn planted into corn residue (CR), as influenced by conventional till (CT) and no-till (NT) management.

SUMMARY

Turning the residues under by plowing resulted in a greater quantity of N accumulated by corn compared to no-till. As measured by the use of ^{15}N-labeled residues, more residue N was recovered by the conventionally grown corn. These effects are the result of a more enhanced mineralization of N from the residue and soil organic matter with conventional till. Although N removal and recovery of hairy vetch residue N were greater with conventional till, N efficiency by no-till corn was greater due to more available moisture. Also with the no-till system, the residue remaining on the soil surface will provide protection against soil erosion.

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No-Tillage Corn and Grain Sorghum Yield Response to Anhydrous Ammonia

John A. Baldwin and Raymond N. Gallaher

Department of Agronomy. IFAS. University of Florida, Gainesville. FL 32611

INTRODUCTION

Nitrogen is the largest and most expensive fertilizer component used in growing corn (Zea mays L.) and sorghum (Sorghum bicolor L. Moench) in the United States. Anhydrous ammonia is one of the least expensive sources of available N for agronomic crops. Multi-cropping systems utilizing bahiagrass (Paspalum notatum Flugge) sod followed by temperate corn or grain sorghum (4,5,6,7,9) have been studied. Limited studies have included the use of no-tillage subsoil planting into grass sods (7,9). Many research reports have been published on the use of various N sources for use in no-tillage cropping systems (1,2). However, there is limited research when utilizing anhydrous ammonia as the primary source of N for producing corn or grain sorghum in bahiagrass sod (3). Nitrogen management in no-tillage systems has been shown to be more critical due to slower mineralization, higher immobilization and potentially greater losses by leaching and denitrification of NO_3(l,2). The objective of this study was to determine the effect of anhydrous ammonia as the sole source of N in no-tillage plus subsoil planted grain sorghum and tropical corn into bahiagrass sod.

METHODS AND MATERIALS

Two separate experiments at three locations were planted during 1983 and 1984. The experiments were in randomized complete block designs with 6 replications, one testing Pioneer brand 'X304C' tropical corn and the other testing DeKalb 'DK59' grain sorghum planted into 15 year-old bahiagrass (cv.'Pensacola') sods. Location one was planted on June 9, 1983 on a Kershaw fine sand (thermic, uncoated Typic Quartzipsamment) an excessively drained sand and location two was planted on June 23, 1983 on a Chiefland fine sand (loamy, siliceous, thermic, Arenic Hapludalf). The third location was planted on May 29, 1984 on an Arrendondo fine sand (loamy, siliceous hyperthermic grossarenic Paleudult).

The plots were 8 rows, 76 cm wide, and 12.2 m in length. The plots were planted with an in-row subsoil planter with anhydrous tube attached to the subsoil shank. No irrigation was provided at any location. an application of 0.67 kg a.i. Carbofuran (2,3-Dihydro-2,2-dimethyl-7- benzofuranyl methylcarbamate) 15G (Furadan) was applied in front of the press wheel at planting. Ten days prior to planting, an application of 0.84 kg a.i. glyphosate (isopropylamine salt of N-(phosphonomethyl) glycine) (Roundup) plus 1.9 L of X-77 surfactant/95 L of water was applied in a spray volume of 26 L/ha at 2.8 kg/cm. This was done to suppress the bahiagrass sod prior to planting.

All plots were fertilized with a broadcast application of 80 kg K/ha 25 kg S/ha, and 12 kg Mg/ha just prior to planting. Sources of K, S, and Mg were K_2SO_4:$MgSO_4$ (K-Mag) and KCl (Muriate of Potash). Nitrogen was applied at planting under the row and injected on the subsoil shank at a 25 cm depth. Nitrogen rates were randomized and replicated six times at 0, 56, 112, 168, and 224 kg N/ha. On July 10 at one location and on July 26 and 27th at the other two locations, 0.05 kg a.i. paraquat (l,l'-Dimethyl-4,4'-bipyridinium ion) plus 0.5 L X-77/95 L of water was direct sprayed to further suppress the sod. The plots were harvested on the following dates at the three locations: September 12, 1983; September 26, 1983; and September 9, 1984.

RESULTS AND DISCUSSION

The corn showed a grain response to the 56 kg N/ha rate at locations one and three and to the 112 kg N/ha rate at location two (Table 1). The grain to residue ratio was similar at all locations showing significant response to the 56 kg N/ha rate. The corn grain to residue ratio averaged over the three locations increased 280% over the control. Two locations responded to the 56 kg N/ha for grain, residue, and whole plant dry matter yields due to insufficient rainfall during the silking to ear fill period. Grain yield decreased with increasing rate of N at one location where rainfall was limiting. This physiological response of corn to drought stress has been reported previously (8). Dry matter yield for corn residue and whole plant increased up to the 168 kg N/ha rate at location two. The number of ears/ha responded to the 56 kg N/ha level at location one and two; however the response was to the 224 kg N/ha rate at location three (Table 2).

Grain sorghum dry matter yield for grain and whole plant showed a response at the 56 kg N/ha rate for two locations (Table 3). Location three responded to the 112 kg N/ha rate for grain and whole plant yield. All three locations responded to the 112 kg N/ha rate for residue dry matter yield.

In summary, the rate of anhydrous ammonia as applied in this experiment had a positive effect on most components measured. Insufficient rainfall and distibution of rainfall effected corn yields more than sorghum yields.

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TABLE 1. **Corn response to no-tillage in-row subsoil planting into bahia grass sod as influenced by rates of anhydrous ammonia and location**

	Location			
N Treatment	1	2	3	average
kg N/ha	Grain yield kg DM/ha			
0	240	240	260	250
56	1170	1480	1760	1470
112	1080	2690	2240	2000
168	1120	3250	2220	2200
224	680	3580	2540	2270
LSD.05	423	860	577	
	Residue Mg DM/ha			
0	1.55	1.12	1.28	1.32
56	2.62	2.97	2.82	2.80
112	2.72	3.29	3.50	3.17
168	3.14	4.30	3.46	3.63
224	2.64	4.31	4.23	3.73
LSD.05	.75	.98	.82	
	Whole Plant Mg DM/ha			
0	1.79	1.35	1.54	1.56
56	3.79	4.45	4.58	4.27
112	3.80	5.97	5.74	5.17
168	4.25	7.54	5.69	5.83
224	3.32	7.80	6.77	5.99
LSD.05	1.02	1.57	1.23	
	Grain/residue			
0	.15	.19	.24	.19
56	.45	.52	.61	.53
112	.38	.77	.64	.60
168	.36	.82	.68	.62
224	.27	.83	.62	.57
LSD.05	.15	.23	.14	

TABLE 2. Agronomic variables of no-tillage in-row subsoil planting into bahia grass sod as influenced by rates of anhydrous ammonia and location

	Location			
N Treatment	1	2	3	average
kg N/ha	Plants/ha			
0	44470	48420	22420	38440
56	39450	52290	27790	39840
112	39450	54150	30490	41360
168	37660	54870	26900	39810
224	39450	55230	30130	41600
LSD.05	NS	NS	4650	
	Ears/ha			
0	13630	27970	13270	18290
56	30840	40890	24570	32100
112	29050	45900	29770	34900
168	28690	50930	26000	35200
224	25100	51290	32640	36340
LSD.05	9750	9540	5530	
	Ears/Stalk			
0	.29	.59	.29	.39
56	.77	.81	.75	.78
112	.74	.85	.75	.78
168	.78	.92	.80	.83
224	.64	.93	.90	.82
LSD.05	.22	.25	.23	
	Shelling %			
0	.78	.55	.72	.68
56	.76	.68	.77	.74
112	.78	.72	.77	.76
168	.77	.75	.77	.76
224	.70	.73	.76	.73
LSD.05	NS	.05	NS	

TABLE 3. Grain sorghum response to no-tillage in-row subsoil planting into bahia grass sod as influenced by rates of anhydrous ammonia and location

	Location			
N Treatment	1	2	3	average
kg N/ha	Grain yield kg DM/ha			
0	510	200	510	410
56	1920	770	1870	1520
112	1860	1080	2830	1920
168	2220	1480	3140	2280
224	2500	1380	1880	1920
LSD.05	604	478	616	
	Residue Mg DM/ha			
0	1.58	2.08	0.69	1.45
56	2.96	4.64	2.14	3.25
112	3.65	5.86	3.02	4.16
168	3.85	5.76	2.99	4.20
224	4.30	6.41	2.32	4.34
LSD.05	.54	1.21	.52	
	Whole Plant Mg DM/ha			
0	2.09	2.29	1.20	1.90
56	4.89	5.42	4.00	4.77
112	5.52	6.98	5.85	6.11
168	6.06	7.24	6.13	6.47
224	6.80	7.79	4.20	6.26
LSD.05	.91	1.49	.96	
	Grain/residue			
0	.32	.11	.75	.39
56	.64	.17	.89	.57
112	.51	.19	.95	.55
168	.58	.25	1.05	.63
224	.60	.21	.84	.55
LSD.05	.18	.06	NS	
	% Grain			
0	24	08	41	24
56	39	14	47	33
112	34	17	48	33
168	36	20	51	36
224	37	17	45	33
LSD.05	10	05	04	
	Plants/ha			
0	128680	88580	66350	94540
56	157950	93960	76030	109310
112	102000	96830	83030	93950
168	181610	97190	76390	118400
224	185060	106160	60610	117280
LSD.05	11800	5940	14990	

No-Till Corn Response to Starter Fertilizer and Starter Placement

D. L. Wright

Extension Agronomy, University of Florida

Higher farm profits are necessary for many farms to stay in business over the next several years. Higher crop yields are the key to reducing cost per unit of production and increasing farm profit. Increased yields cannot be attained by adjusting fertilizer rates alone but will come from placement that improves nutrient availability in a more intensively managed cropping system. Better nutrient use through placement does not necessarily mean that fertilizer rates can be reduced but that an increase in yield or other favorable results can be obtained from the same amount of nutrients. Several researchers have recorded the positive benefits of nutrient placement especially from close placement at planting (Follett et al. 1981; Richards 1977).

Corn is the primary crop to which starter fertilizer (usually N-P combinations) is applied. Besides having improved utilization of phosphorus (P) placed close to the seed, less P is fixed because of reduced soil contact when applied in a band.

When planting no-till corn, residue may vary from little, if planting behind soybeans, to several tons of dry matter from rye or clovers. The factors that most influence P uptake in no-till corn is (1) temperature and, (2) soil compaction. Phosphorus absorption and diffusion to the roots is slower at low soil temperatures (Epstein, 1971). Large amounts of surface residue and higher soil moisture levels can reduce soil temperatures 3-5^{o}C or more. High nutrient concentrations close to the developing plant can help overcome the slow root development and low P uptake. untilled or no-till planted soils generally have a higher bulk density (more compaction) than tilled soils, and nutrient availability is depressed because of less root exploration. Close placement or starter fertilizer use under these conditions will normally result in plant growth and yield responses.

These studies were conducted under an intensive management system where high rates of nutrients were broadcast, unless it was a variable before planting (50 lbs/A of N, 100 lbs/A P_2O_5, 150 lbs/A K_2O) and then starter fertilizer was applied in a band in or near the row. Each study was planted at 30,000 plants per acre and irrigated when soil water pressures reached 20 centibars. Two sidedress applications of N were made to bring total N application to 240 lbs/A. Minor elements and sulfur **(S)** were applied at planting in a band near the row and an additional S application was made to bring the total application to 25 lbs/A.

Applications of starter fertilizer to crops should be expected to result in yield increases. However, there are other benefits to using starter fertilizer besides increased yields. One that is important in the Southeast is earlier maturity of corn when grain sorghum or soybeans are to be planted as the second crop in late summer. A week to 10 days earlier planting on the second crop results in much better growing conditions than when the weather is cooler. Also, prices may be 20 or 30 C/bu higher. Table 1 shows that placement of fertilizer is helpful in decreasing grain moisture for earlier harvest.

Table 1. Band and broadcast fertilizer influence on corn grain moisture (Quincy).

lbs/A 5-10-15	Band (Fertilizer Placement) Broadcast % H_2O on July 1	
	Band	Broadcast
250	33.1	37.0
500	33.1	36.9
750	36.8	42.7
1000	35.7	37.6

Placement of ammonium polyphosphate near the seed in addition to the normal fertilization program resulted in quicker dry down and higher yields (Table 2).

In studies conducted on sandy loam soils, surface and 2" X 2" placement of starter fertilizer near the row at planting have resulted in best yields and quickest dry down of early planted corn. Similar results have been obtained with dry fertilizer when surface banded in or near the row.

Table 2. Starter placement influence on corn no-tilled into clover under irrigation (Quincy, 1984).

Placement of Starter (10-34-0)	Grain H_2O 7-20-84	Yield bu/A
Control	97.0	141.8
In furrow	67.0	107.1
2" x 2"	44.3	171.1
Surface	44.9	169.5
2" below seed	66.9	122.1
5" below seed	90.9	115.4
8" below seed	87.7	138.7

Stalk rot developed prior to maturity.

Early dry down and higher yields by proper placement are advantages of using starter fertilizer. Other factors that result from using starter fertilizer are increased early season growth (Table 3), 7 to 10 days earlier silking and tasseling and less time in the vegetative growth stage which results in lower ear and plant heights at harvest in most cases (Tables 3 and 4).

Table 3. Starter placement influence on corn no-tilled into clover under irrigation (Quincy, 1984).

Placement of Starter (10-34-0)	Height			Yield bu/A
	plant (in.) (4-19-84)	plant (ft.) 7-20-84	ear 7-20-84	
Control	5.2	9.7	3.7	141.8
In furrow	6.3	9.5	3.4	107.1
2" x 2"	7.0	10.0	4.0	171.7
Surface	6.2	9.7	3.4	169.5
2" below	6.3	9.6	3.6	122.1
5" below	5.0	9.7	3.8	115.4
8" below	4.5	9.8	3.7	138.7

stalk rot developed prior to maturity.

Where monoammonium phosphate was used as a starter fertilizer banded on the surface of the row after an initial broadcast application of 1000 lbs/A of 5-10-15, grain yields were increased by 14 bu/A and final ear and plant heights were lower.

Table 4. Influence of starter fertilizer on irrigated corn yields (Quincy, 1981).

	MAP (11-53-0)	No starter
Grain bu/A	219.7 a	205.7 b
Ear ht. ft.	4.1 a	4.5 b
Plant ht. ft.	9.8 a	10.3 b

Starter fertilizer has been shown to be beneficial to no-till corn on soils that vary from medium to high in P even if an initial broadcast application is made. Benefits may not only be increased yields, but earlier maturity, lower ear placement, less time needed for irrigation, and a better chance for successful double cropping.

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Soil Nitrogen Recovery by No-Till Corn Using Nitrogen Balance and Isotope Methods

J. E. Espinosa, J. H. Grove, C. W. Rice, M. S. Smith, and K. L. Wells

Agronomy Department, University of Kentucky, Lexington, KY 40546

Fertilizer nitrogen (N) efficiency in no-till cereals production has proven to be reduced at lower N rates relative to conventional tillage using current fertilization practices. Some of the processes that appear to induce the additional losses are denitrification, volatilization and, perhaps most importantly, immobilization. In a typical no-till situation the layer of organic residue that accumulates on the surface of the soil is responsible for accentuating these processes. This type of residue generally has a high C:N ratio that induces inorganic N assimilation into organic N.

One way of measuring N fertilizer efficiency is to evaluate plant N uptake in quantitative terms. The amount of fertilizer N taken up depends on various factors, such as the type of crop, root distribution, type and amount of fertilizer, N distribution in the profile, temperature and rainfall. (Broadbent 1984).

The uptake of N coming from fertilizer can be measured by different methods. A popular one is the difference or N balance method which makes the assumption that the N derived from fertilizer is equal to the total uptake of the fertilized crop less the N taken up by the unfertilized control. Another method. and possibly the best, is the use of isotopically labeled N fertilizer to determine the fraction of total plant N resulting from fertilizer addition. When the two aforementioned methods are compared, results may or may not be equal. The purpose of this paper is to share the authors' observations when comparing these two procedures on two no-tillage corn trials and to suggest an operative mechanism that explains our observations. The field experiments were conducted primarily to evaluate plant uptake of N fertilizer and fertilizer N efficiency for different methods of N fertilizer placement.

The experiments were conducted on two different soils, a Donerail silt loam (Typic Argiudoll) located near Lexington, Ky. and a Pope silt loam (Fluventic Dystrochrept) at Quicksand, Ky during 1983 and 1984. The Pope

The investigations reported in this paper **(No.** 85-3-88) are published with approval of the director, Kentucky Agricultural Experiment Station.

soil, though well drained, contains a subsurface water table. All residues were left on the surface and a winter annual cereal cover crop was grown on the Donerail soil.

On the Donerail soil three different methods of N placement at planting time, including broadcasting, surface banding, and subsurface band placement, were evaluated against an unfertilized control. All treatments but the control received one application of 112 kg N/ha as ^{15}N depleted ammonium nitrate at planting.

For the Pope soil the N placement treatments were broadcasting versus subsurface banding. Both treatments received an application of 90 kg N/ha as ^{15}N depleted ammonium nitrate. An unfertilized control was included as well.

For both soils the subsurface band treatment consisted of a trench 3 inches wide and 3 inches deep located 3 inches to the side of the corn row. The fertilizer was applied to the bottom of the trench and covered. The surface band consists of a 3 inch wide fertilizer application to the soil surface 3 inches to the side of the corn row. Planting dates varied according to spring time conditions (Table 1). Whole plant tissue samples were acquired just prior to harvest at both locations (Table 1) and separated into grain and stover for analysis.

Table 1. Planting and harvest dates and growing season weather data from 1983 and 1984 at both locations.

Location	Soil		Date of		Rainfall			Average Daily Temp.		
	Series	Year	Planting	Harvest	June	July	Aug.	June	July	Aug.
					cm			°C		
Lexington	Donerail	1983	31 May	5 Oct.	8.6	2.6	4.1	22.1	26.6	21.2
		1984	22 May	26 Sept.	12.3	9.4	3.4	24.4	22.1	24.4
Quicksand	Pope	1983	5 May	12 Oct.	5.2	5.8	12.5	22.2	25.5	26.1
		1984	18 May	6 Nov.	1.0	12.8	11.8	23.9	23.3	24.4

Weather station data for the months June–August indicated that the 1983 growing season was generally hotter and drier than that for 1984. The Lexington site was generally drier than the Quicksand site both years. Because of this latter fact a total of 18.0 cm of irrigation water was applied from 15 July to 23 August, 1983 and 3.8 cm on 25 July, 1984 at the Lexington location.

The effect of the ^{15}N depleted ammonium nitrate application for different placement methods was evident when the atom % ^{15}N was determined (Table 2). The atom percentage of ^{15}N decreases as the fertilizer is placed in a concentrated band close to the row. The highest percentage of ^{14}N in harvested plant tissue was found for the subsurface band treatments for both soils and both years.

Table 2. Soil and fertilizer N recovery by no-till corn at both locations for both production years.

Placement Treatment	Total N Uptake	atom % ^{15}N Stover	Grain	Fertilizer N Recovery By: Balance	Isotope	Diff.+	Grain Yield
	Kg/ha	%		Kg/ha			
			Donerail - 1983				
Cntrl*	98	0.370	0.373	--	--	--	4830
Brdcst	128	0.289	0.290	30	28	2	5900
Srf Bnd	145	0.250	0.261	47	47	0	6030
Sbsrf Bnd	142	0.240	0.247	44	49	-5	6310
$LSD_{0.05}$		0.024	0.027			$LSD_{0.10}$	1170
			Pope - 1983				
Cntrl	43	0.363	0.367	--	--	--	3590
Brdcst	70	0.302	0.287	27	13	14	5850
Sbsrf Bnd	83	0.246	0.242	40	27	13	6880
$LSD_{0.05}$		0.015	0.027			$LSD_{0.10}$	1000
			Donerail - 1984				
Cntrl	54	0.365	0.366	--	--	--	4110
Brdcst	110	0.298	0.253	56	29	27	6470
Srf Bnd	110	0.277	0.263	56	30	26	6070
Sbsrf Bnd	140	0.257	0.243	86	43	43	6620
$LSD_{0.05}$		0.035	0.026			$LSD_{0.10}$	980
			Pope - 1984				
Cntrl	32	0.365	0.366	--	--	--	3290
Brdcst	88	0.267	0.271	56	23	33	7980
Sbsrf Bnd	95	0.260	0.239	63	31	32	8350
$LSD_{0.05}$		0.015	0.048			$LSD_{0.05}$	1200

+ Diff. = Fertilizer N (balance method) - fertilizer N (isotope dilution method) = Fertilizer Induced Soil N Recovery.

Cntrl = unfertilized control; Brdcst = broadcast; Srf Bnd = surface band; Sbsrf Bnd = subsurface band.

Total N uptake for the unfertilized controls was less on the Pope soil as compared to the Donerail soil. Control plot grain yields for the Pope reflected the lower native N supply, averaging 3440 kg/ha. Comparable yields on the Donerail averaged 4410 kg/ha.

Additionally, all the N treatments increased the total N uptake. Banding was generally superior to broadcasting in increasing total N uptake and N fertilizer recovery as calculated by both the balance and isotope dilution method in both soils for both years (Table 2). The data indicate that N fertilizer uptake was improved when the fertilizer was located close the row and was the best when the fertilizer was located below the mulch layer, presumably because immobilization was avoided. Yields were generally improved by subsurface banding, which outyielded broadcast N anywhere from 2 to 18%

Even though the trend for N fertilizer recovery by corn is the same when calculated either by the balance method or the isotope dilution method, the actual recovery was generally very different where both methods were compared. In the Donerail soil the calculated fertilizer recovery by the two methods was essentially equal in 1983 (Table 2). In 1984 the fertilizer recovery by the difference method is double that of the isotope dilution method on this soil.

Fertilizer N recovery by the difference method may be expected to be higher than the isotope dilution method because the fertilized plants can develop a larger root system that can explore more soil (Broadbent, 1984). This could be described as fertilizer induced recovery of soil N. In 1983, N fertilized corn grown on the Donerail soil recovered little, if any, additional soil N. Soil N availability as measured by the control was higher than for any other location-year. A lack of sub-surface soil moisture may have played a significant role as well. Irrigation to the soil surface probably stimulated proportionately equal recovery of soil and fertilizer nitrogen. In 1984 there was not as large a moisture constraint and the application of N appears to have stimulated greater recovery of soil N from the Donerail soil. Yields were not greatly different between the two years.

In the Pope soil the recovery of N fertilizer was larger where calculated by the difference method in both 1983 and 1984, though overall uptake and N fertilizer recovery was greater in 1984. In this case there was not a soil moisture constraint because of the subsurface water table. Yields in 1984 were superior to those for 1983 at this location. Recovery of fertilizer N. as calculated by the isotope dilution method, averaged 26% of that applied for both treatments both years. When comparable treatments are considered, the no-till corn grown on the Donerail soil recovered 33% of the applied N. Fertilizer induced recovery of soil N was quite substantial on the Pope soil and accounted for 15 to 35% of the total uptake recorded at harvest.

Yield increases to subsurface placement over broadcasting were generally much less in 1984 (average + 3.5%) than in 1983 (average + 12.3%). When comparing the two soils the yield response to subsurface placement was greater on the Pope soil (average + 11%) than the Donerail (average + 5%), in keeping with the poorer native soil N supply in the former. The response pattern may be related to a substitution of fertilizer N placed proximal to the developing plant for the native soil N that is acquired when N fertilizer is broadcast. This substitution appears to be most important in dry years. It is interesting to think that a major benefit of N fertilizer is to stimulate recovery of soil N. The data also suggests that subsurface N placement at planting may be more beneficial on droughty soils and/or soils with a diminished capacity to supply soil N.

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Plant Nutrient Availability Following Chemical Site Preparation for Conservation Land Use Development

L. L. Goodroad and A. E. Smith

Agronomy Department Unlversity of Georgia. Georgla Station, Experiment, GA 30212

The harvest of marketable timber from sloping, eroded soils in the Piedmont and upper Coastal Plain has increased the need for systems to revegetate these areas with economically important species while conserving the soil. Conservation of the soil, on sloping land, is probably best achieved through reforestation or conversion to perennial forage species for grazing. Mechanical site preparation for reforestation or conversion to grazing land is expensive and generally promotes soil erosion from the hillsides. Chemical site preparation could allow for safe, effective, and efficient systems for land-use conversion. Results have indicated that up to 95% of the trees found in the woodland sites can be killed by aerial application of herbicides. The standing-dead trees conserve soil during reforestation and/or aerial seeding with forage species. Tebuthiuron was found to be an effective herbicides for site preparation].

Significant plant nutrient losses can occur during ecosystem conversions. The efficiency of establishing pastures or improved forest land following the application of tebuthiuron will be increased by conserving the plant nutrients already present. This study was conducted to determine the plant nutrient status of a site near Williamson, Georgia, treated with tebuthiuron, burned, and seeded with tall fescue.

Materials and Methods

The site is described in detail elsewhere in the proceedingsl. To determine the nutrient content and availability of various components of the ecosystem, we sampled soils and surface litter and established experimental plots to determine the effects of added phosphorus (P) on tall fescue growth and survival.

We established transects in three areas in the treated site to sample surface litter and soils. This allows us to sample similar areas to reduce variation between samplings. In each transect, we sampled surface litter (1 m^2) and soils (0 to 15 cm) from ten areas in Sept. 1983. The site was burned in November 1983 and the soils and ash sampled to determine nutrient release due to burning.

Replicated plots were established near the sampling transects to determine the effect of added P on tall fescue growth. Phosphorus treatments were 0, 10, 20 and 40 kg P/ha as concentrated superphosphate.

Available nutrients in the soil were determined by double acid extraction (0.05 N HC1 in0.025 N H_2SO_4). Plant and litter samples were digested in a mixture of nitric and perchloric acids for P, K, Ca and Mg analysis and in sulfuric acid for N analysis. Carbon was determined using a Leco combustion furnace. Soil pH was determined in 0.01 M CaCl.

Results and Discussion

Table 1 contains data on the nutrient status in the three transects of the Williamson site before and after burning (just prior to the aerial seeding of fescue). The soils of all three transects have low levels of available nutrients except for NO_3-N. Nitrate-N is expected to be mobile in these soils and would be leached from the rooting zone before significant plant uptake occurred. Phosphorus appears to be the most limiting plant nutrient. Burning generally improves plant nutrient availability (Table 1). Our visual observations were that there was better germination and growth of fescue in burned compared to unburned area which may be due to the slight increase in available nutrients.

Table 1. Effect of Chemical Site Preparation and Burning on Soil Plant Nutrient Status

	Pre-Burn			Post-Burn		
Site	1	2	3	1	2	3
Carbon (%)	1.48	0.92	0.86	1.87	1.32	1.42
NH_4 (ppm)	14	9	9	8	8	15
NO_3 (ppm)	24	24	7	32	34	8
P (ppm)	1	5	4	2	8	6
K (ppm)	87	49	17	101	53	30
Ca (ppm)	351	191	39	498	246	83
Mg (ppm)	63	24	5	110	28	12
pH	4.7	4.6	4.3	4.9	4.8	4.4

We further explored the release of plant nutrients from litter by sampling surface litter from 1 m^2 areas prior to burning. Litter weights and nutrient contents are presented in Table 2. The actual quantity of nutrients in the litter is low so the release of plant nutrients due to burning would be small. Chemical analysis of the ash (Table 2) showed that its composition is similar to the litter. The quantity of ash was not sufficient to obtain estimates of the amount on the surface.

The fescue plots were sampled for dry matter production and chemical composition (Table 3). The addition of P fertilizer significantly increased yield and P content of the fescue. From this data, it is evident that increasing P availability would benefit the establishment of vegetation at this site.

Table 2. Plant Nutrient Content of Litter and Ash

	Pre-Burn 1	Pre-Burn 2	Pre-Burn 3	Ash 1	Ash 2	Ash 3
Weight[1] (kg m^{-2})	1.8	2.7	3.1	-	-	-
N (%)	-	-	-	0.75	0.89	0.87
P (%)	0.05	0.06	0.05	0.06	0.09	0.08
K (%)	0.10	0.08	0.05	0.11	0.11	0.10
Ca (%)	0.21	0.38	0.52	0.82	0.68	0.51
Mg (%)	0.09	0.07	0.04	0.11	0.11	0.10
Carbon (%)	30	43	41	29	44	46

[1] Estimates of nutrient content (kg ha^{-1}) in the litter can be made using the following equation: litter weight (kg/m^2) x nutrient content (%) x 10 = nutrient content (kg ha^{-1}).

Table 3. Effect of Phosphorus Fertilizer on Growth and P, K, Ca and Mg Content of Tall Fescue

Treatment	Yield	P	K	Ca	Mg
kg P ha^{-1}	g m^{-2}	%			
Check	126 b[1]	0.14 c	3.6 a	0.35 a	0.32 a
0	151 b	0.15 cb	3.5 a	0.32 ab	0.28 b
20	164 b	0.18 b	3.3 a	0.30 b	0.27 b
40	207 a	0.23 a	3.3 a	0.34 ab	0.27 b

[1] Values followed by different letters are significantly different (P = 0.05) according to the Duncan's Multiple Range Test.

The standing trees and stumps prevent economical fertilizer applications making the conservation of plant nutrients necessary. While P is likely the nutrient limiting plant growth, N losses as nitrate could be significant. The potential release of nutrients by burning the surface litter is small because of the limited quantities present. The role of the surface litter in reducing erosion may ultimately be more important. Chemical site preparation appears to be more economical than mechanical site preparation. Additional advantages may be gained by managing the surface litter and rapid revegetation of the sites.

Soil Erosion
and
Soil Productivity

Chemical Site Preparation for Conservation Land-Use Development

A. E. Smith and L. L. Goodroad

Agronomy Department, University of Georgia, Georgia Station, Experiment, GA 30212

The potential for biological resource production in the upper Coastal Plain and Piedmont regions of the humid southeastern United States continues to deteriorate due to accelerated soil loss in response to mechanical methods used for land-use conversion. The purpose of this research was to develop chemical methods of site preparation for a safe, effective, and efficient conversion of land-use from woodland to grazing land. Aerial application of 3.6 kg/ha tebuthiuron pellets killed approximately 90% of the woodland-tree species. A good stand of tall fescue ('Ky 31') resulted from an aerial seeding following a fall burn of the treated site. Herbicide residue remaining in the soil resulted in significant damage to loblolly pine seedlings planted one year after herbicide application. Fescue seedlings and established plants were tolerant of the herbicide residue.

INTRODUCTION

The continued decrease in profitability of row-crop farming in the Piedmont and Upper Coastal Plains regions has promoted increased harvests of the economical timber from the privately owned forest acres. The remaining hardwood species dominate the harvested sites resulting in a land-use of little economical value to the landowner. Revegetation to economical species by natural succession is extremely slow due to competition from remaining species following the selective harvests. In 1978, periodic surveys of permanent sample plots in the Piedmont region indicated a significant change in forest types, particularly the loss of southern pine land to hardwood-woodland. It was determined that 58% of the loblolly and slash pine acreage harvested between 1961 and 1972 were occupied by hardwood species in 1978.

There is an increasing interest by landowners in the development of economical land-use systems for these woodland acres by: 1) conversion to grazing land following harvest of the valuable timber; **2)** preparation of the sites for natural and/or artificial reforestation; or **3)** preparation of land for use as agroforestry. The rolling topography, and high average annual rainfall, which commonly occurs as intense rainstorms, result in optimum conditions for high rates of soil erosion from unprotected land. Conservation of the soil, on the sloping land, is probably best achieved through reforestation or conversion to perennial forage species for grazing.

During land-use conversion, intensive site preparation not only affects the ecosystem more than any other management practice, it also can determine the success or failure of vegetation establishment. Once used only on flat terrain and on sites with high growth potential, intensive site preparation is now being used on sloping, previously eroded sites in the Piedmont and upper Coastal Plain regions as a means of converting commercially unproductive stands to productive forest types. Intensive site preparation for planting to forage and forestry species has included the mechanical methods of: 1) brush chopping - a bulldozer towing a straight-blade rolling chopper that falls the residual vegetation before breaking it into small pieces; 2) shearing and windrowing - standing vegetation is sheared to ground level with a V. blade and the debris is windrowed and burned; 3) bedding on the contour - following shearing and windrowing the vegetation, terrraces are developed on the contours. These methods are very expensive for the owner of small tracts of land who has to hire the site preparation. Additionally, intensive site preparation by mechanical methods results in substantial sediment losses from sloping sites.

There is a need for the development of systems for converting the vegetation on the woodland acres to species that are economically important while conserving the soil and preserving the nutrients in the ecosystem. Chemical site-preparation could allow for safe, effective, and efficient systems for land-use conversion.

METHODS AND MATERIALS

The research site was a 36 hectare tract of land located 3 miles west of Williamson, Georgia. The merchantable timber was harvested from the site during the summer of 1982. The remaining woodland species were predominantly sweetgum, oak, and some pine (Table 1). The herbicide, tebuthiuron, was aerially applied to the site on March 7, 1983 using a Meterate attachment on a fixed-wing aircraft. Tebuthiuron was applied to the site at a rate of 3.6 kg/ha as 40% pellets. The major soil type on the 36-hectare research site is a sandy clay loam of the Cecil series.

Research on this site was directed toward converting the land to pasture by seeding to forage species. Approximately 31 hectares of the treated site were burned on several occasions during the first 2 weeks in October. Approximately 60% of the site had a good cover of leaf ash. 'Regal' Ladino white clover and 'Kentucky 31' tall fescue were aerially seeded into the ash on October 29, 1983 at rates of 7.2 kg/ha and 18 kg/ha, respectively. The tall fescue seed-lot was 1-yr old and tested to be 90% free of the endophyte fungus.

During the first of March of 1984 and 1985, approximately 500 improved Loblolly pine seedlings were planted across the treated site to determine the influence of residual tebuthiuron on pine seedling establishment.

Vegetation surveys, forage samples, and soil samples were periodically obtained from the treated site and chemically analyzed for forage quality and nutrient content.

RESULTS AND DISCUSSION

Mechanical-site preparation for land-use conversion to reforestation or conversion to grazing land is expensive for the private landowner and generally the use of bulldozers promotes soil erosion from the hillsides. This research program was established to develop a method for chemical-site preparation that would result in a safe, effective, and efficient system for land-use conversion. It was determined that the standing-dead woodland species should help protect the soil during the establishment ***of*** the introduced crop.

Tebuthiuron was found to be an effective herbicide for this use when applied as a pellet formulation and is presently registered for this use by the Environmental Protection Agency. The pellet formulation and the properties of tebuthiuron preclude drift during aerial application and minimize the risk of off-site damage. The pellets were evenly and precisely distributed through a Meterate method of aerial application by fixed-wing aircraft. The pellets deposited on the soil surface are disintegrated by the first significant rainfall and the herbicide is moved into the soil. Subsequent rainfall moves the herbicide into the root zone to be absorbed by the roots of woody species. Following translocation in susceptible species, **it** inhibits photosynthesis. The chemical properties of this herbicide result in its persistance in the ecosystem allowing for a long-term control of brush species.

Data from this research has indicated that oak, pine, elm, maple, and poplar tree-species are relatively susceptible to tebuthiuron applications and red cedar and sweetgum are considered to be fairly tolerant to the herbicide treatments. Data from our research also indicate similar results (Table 1). The mode of action for tebuthiuron in killing the trees was for a sequential series *of* defoliations before the tree finally dies. Some species of trees and especially trees of larger size were defoliated by August following the March application and would refoliate the next spring indicating viable trees. However, many of these trees were determined to be dead by September 9, 1984.

Table 1. Influence of 3.6 kg/ha tebuthiuron on tree defoliation, rated August 1983, and trees killed, rated September 9, 1984, resulting from aerial treatment with 40% pellets.

Tree species	Stand composition	Average tree height	Desiccation rating	Trees killed
	(%)	(M)	(%)	*(%)*
Pine (loblolly and shortleaf)	33	15	98	95
Sweetgum	37	16	60	75
Oak (water, Southern red, white, and post)	19	12	100	100
Yellow Poplar	4	8	0	65
Persimmon	1	6	10	30
Black Gum	3	8	80	95
Red Maple	1	11	50	85
Hawthorn	1	5	100	100
Red Cedar	1	8	0	0

Because of high humidity during the fall of 1983, the treated site would not carry a hot fire. However, approximtely 70% of the area was covered with ash at the time the seed were aerially applied by a fixed-wing airplane. The fescue established into a good stand during the spring of 1984 (Table 2). Due to cold weather much of the white clover stand was lost over the winter and the forage was predominantly tall fescue at the June, 1984 harvest. The site had 2300 kglha green forage available in June, 1984 and 1800 kglha green forage in October, 1984.

Table 2. Forage establishment following aerial seeding into leaf ash on October 29, 1983.

Rating date	Seedling Count clover	Seedling Count fescue	Ground cover clover	Ground cover fescue	Green forage production
	----No./M^2-------		-------%-------		-----kg/ha------
Dec. 19, 1983	112	162	5	8	----
June 18, 1984	20	96	10	45	2300
Oct. 31, 1984	-	-	0	72	1800

Pine seedling survival decreased from June, 1984 to February, 1985 indicating the presence of herbicide in the ecosystem over this period of time. Only 52% of the pine seedlings survived one year after planting and two years after herbicide application (Table 3).

Table 3. Pine seedling survival following 1984 planting date.

Rating date	Survival	Average seedling height	Vigor rating
-	%	cm	
June 18, 1984	87	14	8*
Aug. 13, 1984	64	16	7
Dec. 17, 1984	61	22	9
Feb. 4, 1985	52	23	8

*Rating scale from 1 → 10 where 1 equals no branching and/or greater than 70% needle discoloration and 10 equals healthy seedling.

Results of this research and research conducted on other sites indicate that tebuthiuron can be effectively used for killing woodland species in a system of conversion to grazing land using tall fescue as the forage species. The persistence of the herbicide in the ecosystem for up to 24 months provided good control of all brush on vine weed species. The site remained free of all broadleaf weed species throughout the 18 months of fescue establishment. However, this herbicide persistence resulted in approximately 50% loss in pine seedlings planted one year after herbicide application. Therefore, pine plantings will have to be delayed for up to two years after herbicide treatment on sites being converted to reforestation or another herbicide will have to be used.

There was no additional gully soil erosion during the conversion period and only minimal sheet erosion occurred during this period. Chemical site preparation will be about one-fourth the cost necessary for mechanical site preparation.

Erosion from Reduced-Till Cotton

C. K. Mutchler, L. L. McDowell, and J. R. Johnson

USDA-ARS and North Mississippi Branch Experiment Station

Erosion plots at the North Mississippi Branch Experiment Station have been used to evaluate the erosion control effectiveness of conservation tillage systems since 1956. Results from no-till and reduced-till for corn, soybeans, and soybeans-wheat double-crop were described in the 1984 Proceedings of the No-Tillage Conference (Mutchler and Johnson, 1984). In this paper, we will discuss the results of our evaluations using no-till, reduced-till, and conventional-till (control treatment) for cotton. A more complete discussion is given in Mutchler et al. (1985).

Procedures

The research reviewed here was done on erosion plots 13.3 by 72.6 feet located on 5-percent sloping land. The soils on the plots are predominantly Providence silt loams (Typic Fragiudalfs).

Conventional tillage was disk, chisel about 20 cm deep, disk and bed about 3 weeks before planting. The final tillage before planting was disk and spike-tooth harrow leaving the beds about 10 cm high. Weeds were controlled with preemerge herbicides and 3 cultivations. Fertilizer and liming rates were kept to levels recommended by soil testing.

No-till cotton was planted in a slot opened by a small chisel following a fluted coulter which cut through surface residues. Fertilizer was placed in the bottom of the slot and covered by soil under the cotton seed. The remainder of the slot was closed by a press wheel. Fertilizer and lime applications were the same as for the conventional till treatments. In addition to preemerge herbicides used for conventional till, a burn down herbicide was used for control of existing vegetation. Post-directed herbicides were used to control weeds during the crop growing season.

Reduced-till cotton was planted the same as no-till. The cotton was cultivated three times. Preemerge herbicides, fertilizer application, and liming rates were about the same as used for no-till. For all treatments, cotton stalks were shredded after harvest.

Results and Discussion

Data were collected from cotton tillage treatments studied during different periods of years since 1979 because the previous soybean tillage evaluation was not completed on all the erosion plots at the same time.

Rainfall during the experiment was 64, 55, 42, 62, and 58 inches for 1979 to 1983, respectively. Average annual rainfall for all treatments was higher than the long-term average of 52 inches.

The greatest amount of runoff was the conventional-till cotton after 11 years of conventional-till corn or soybeans. This treatment can be compared directly to the conventional-till cotton after 11 years of no-till corn or soybeans. The no-till history reduced runoff 13% from the continuous conventional-till cotton treatment which lost an average 26 in/yr rainfall as runoff. This large amount of runoff undoubtedly contributed to the greater soil loss from the continuous conventional-till treatment.

Annual soil losses adjusted to a common rainfall erosivity are given in Table 1. It is apparent that cotton production on our soils and slopes created a very erodible field condition. Soil loss from continuous cotton, conventionally-tilled, averaged over 30 t/ac*yr. In contrast, losses from conventional-till soybeans tested earlier were about 8 t/ac*yr and losses from corn were about 7 t/ac*yr, all under similar conditions (Mutchler and Greer, 1984; McGregor and Mutchler, 1983).

Table 1. Annual soil loss from treatments adjusted to normal rainfall year and measured cotton yield.

	Seed Cotton lb/acre	Soil Loss t/ac
No-till cotton		
After plot leveling (3-yr average)	1710	8.2
After no-till soybean-wheat (1-yr data)	1550	0.5
Reduced-till cotton		
After no-till fallow (3-yr average)	1910	4.7
After no-till soybean-wheat (2-yr average)	1910	4.8
Conventional-till cotton (3-yr average)		
After 11-yr no-till corn or soybeans	2040	17.5
After 11-yr conventional-till corn or soybeans	1690	32.9

The large effect of prior cropping history is seen in the results from the two no-till treatments. Soil loss from the 3-yr no-till should be lower than the data indicate because the surfaces of the plots were broken to level the plots before starting the cotton treatments. Losses from no-till cotton after soybean-wheat double-crop is lower than expected because of the extensive cover prior to initiating the cotton treatment.

Soil losses from the two reduced-till systems were about the same. In this case, residue cover from the preceding no-till fallow and no-till soybeans-wheat double-crop were not greatly different. Also, tillage during the growing season in the reduced-till system served to equalize the effect of preceding residue cover.

The two conventional-till treatments give the most interesting comparison. The effect of the 11 years' previous no-till management reduced soil loss by about 47%. The record is probably too short to determine how long the no-till history effect will last.

Major significance of the information about cover is the destructive effect of tillage on cover. The no-till treatment had residue cover as low as 15% only during the period when canopy was highest, and cover was generally greater than 50% for the part of the year when canopy was not present. Cultivation in the reduced-till treatments resulted in much the same annual pattern of cover percentage, but reduced cover from that found for no-till. Conventional-till totally destroyed cover by primary tillage and left the surface with no residue protection during the tillage and early growth cropstages.

Crop yields from the two conventional-till treatments strongly suggest an effect of previous erosion on soil productivity. Crop yields from the conventional-till after no-till were about 20% higher than from the plots with a continuous conventional-till history. It is difficult with the short 3-year record to determine if this loss of productivity from excessive erosion is permanent or whether the higher yield from previous no-till management will disappear with time.

Conclusions

Soil loss from only the no-till cotton after no-till soybeans-wheat double-crop was below tolerable soil loss limits established by the Soil Conservation Service. Residue cover from cotton is less than from soybeans and corn, and the peculiar tap root system of the cotton plant contributes little to holding soil in place.

The beneficial effect of conservation tillage is seen in the comparison of plots conventionally tilled but with either an 11-year no-till or a conventional-till history. The no-till history affected erosion because soil loss from conventional-till cotton was reduced by 47%, runoff reduced to 35% of the rainfall compared with 48% from long term conventional tillage, and seed cotton yield increased about 20%.

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Erosion-Productivity Relationships for Blackland Prairie Soils in Mississippi

J. G. Miller, P. K. McConnaughey, and J. E. Hairston

Mississippi Agricultural and Forestry Experiment Station

J. O. Sanford

USDA-ARS

Introduction: The Soil and Water Conservation Act of 1977 created an interest in research quantifying erosion-induced productivity losses for soils in the U.S. Many such eroded sites with low productivity occur in the Blackland Prairie of Mississippi and Alabama. Soils in this land resource area are, in general, alkaline Vertisols high in montmorillinitic clay overlying impermeable chalk (2,3). On this land resource area, an erosion-productivity study was initiated in 1982 (2), and expanded in 1984.

The primary objective of the expanded study was to determine effects of soil depth to chalk and water stress on growth and yield of nonirrigated soybeans.

Materials and Methods: Six experimental sites were located in farmer's fields where 'Centennial' soybeans were planted on either Binnsville or Dempolis soils. These sites were located in four counties of east Mississippi so that rainfall distribution within a growing season could be included as a variable. Weed control and fertility status at all sites was good, as cooperating farmers used "best management" practices for nonirrigated monocropped soybeans. Utilizing within field variability, 25 miniplots (0.00044 acre) were established with the depth of soil ranging from 5" to greater than 60". Depth of soil to firm chalk was measured with a penetrometer-type probe. Weekly rainfall was determined at each site, as was plant height and growth stage. Soils were tested for nutrient availability, and bean and biomass yields were taken at the end of the growing season.

Results and Discussion: For comparative purposes, fields A and B are the southernmost sites (Noxubee County), fields C and D are 25 miles further north (Clay County), and fields E and F are northernmost (Chickasaw County and Lee County, respectively). Soybean yields as a function of soil depth are seen in Figures 1-6. In four cases (Figures 1,2,5, and 6), depth to chalk accounted for more than 60% of the yield variability. In Figure 4, depth to chalk accounted for less than 28% of yield variability while in Figure 3, there was no significant relationship between yield and soil depth.

Weekly rainfall distribution for all six locations is seen in Figure 7. A comparison shows that fields A and B received the highest total rainfall. Note, however, that during pod fill (August 25 - September 22) fields A and B recorded rainfall during only one week. Fields C and D were planted late (21 days later than field A). Although they received considerably less total rainfall than fields A and B, the distribution of rain was reasonably uniform throughout the season.

Field E received the least total rainfall, and rainfall distribution was poor. From planting through early vegetative growth, significant rainfall was recorded only once (0.47 inches). Note that for this field, 96% of the variability in yield can be accounted for by soil depth. Similarly at site F, soil depth accounted for 80% of the variability in yield. Here, rainfall distribution was consistent throughout the season but the bulk of the total occurred after early vegetative growth.

In four fields (A,B,E,F) rainfall was insufficient during a particular growth period (e.g. early vegetative growth, flowering, or pod fill), and yields were lower than fields C and D. A comparison of rainfall distribution was made between these four fields. Fields E and F experienced drought during the early vegetative stage but received rainfall during pod fill. Their yields were the lowest recorded, and soil depth accounted for 96% and 80% of the variation in yield. Conversely, in fields A and B, rainfall was sufficient during the vegetative period, and drought occurred during pod fill. In these cases, yields were increased and soil depth accounted for 61% of yield variability. Thus, when rainfall is adequate during the vegetative stage, yield potential is maintained. Then, if drought occurs during pod fill, soil moisture storage (a function of soil depth) influences yield. In the case where drought occurred during the vegetative stage, yield potential was low, and this deficit could not be offset by adequate rainfall during pod fill.

Fields C and D recorded the highest yields because rainfall was sufficient during both early vegetative stage and pod fill. In these two cases, within-field yield variability is not related to soil depth.

It is concluded then, that when rainfall is adequate during critical plant development periods, soil depth is not a yield determining factor. When rainfall is inadequate during critical development periods, soil moisture storage becomes a yield determining factor and erosion-productivity relationships can be identified for these soils.

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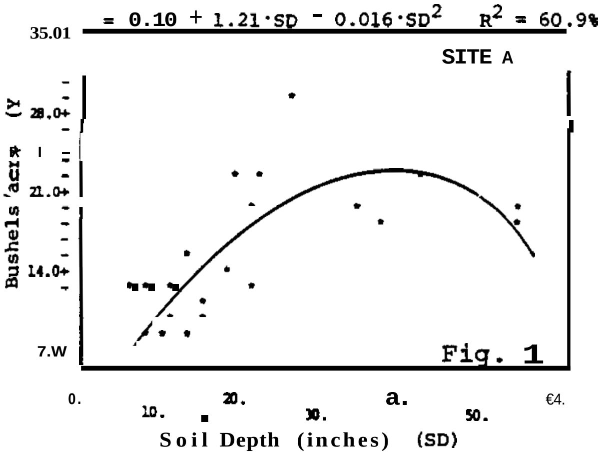

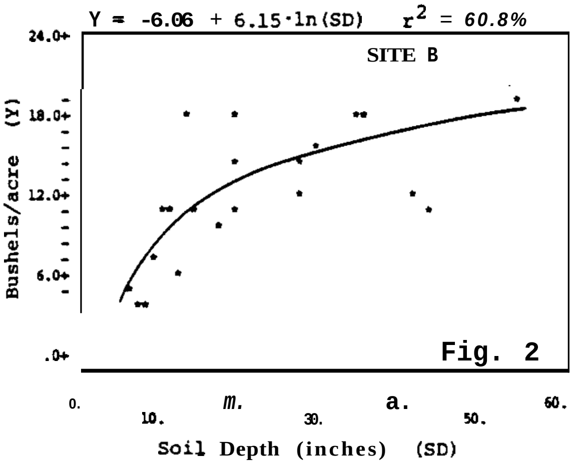

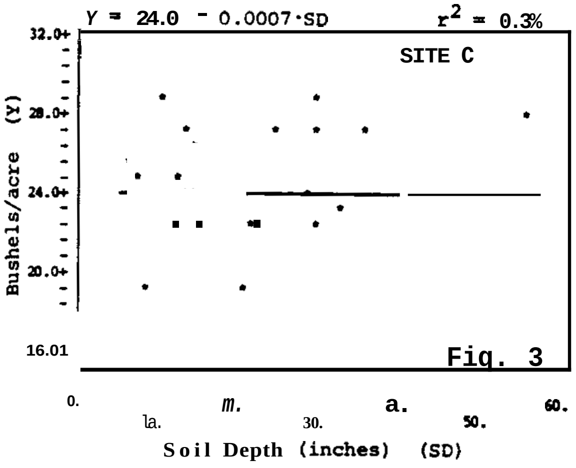

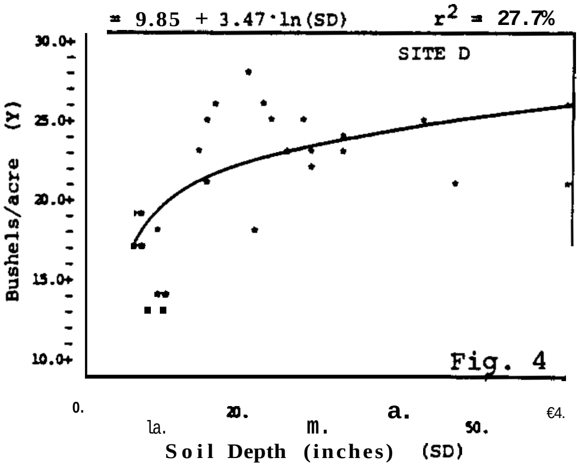

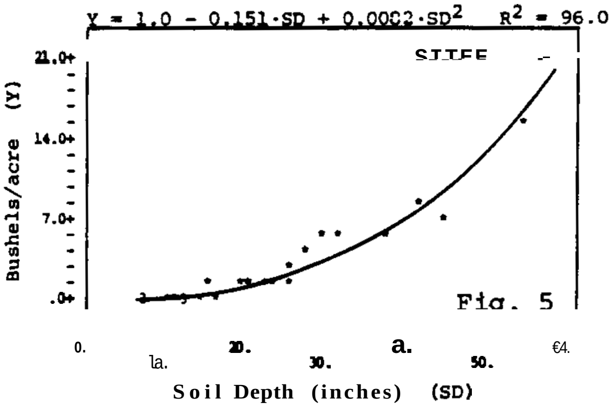

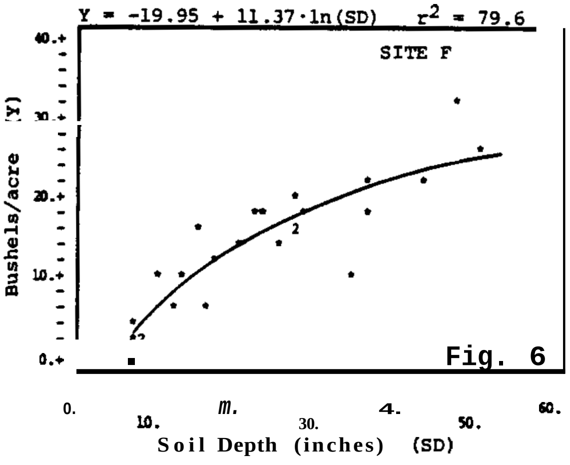

Figures 1-6: Soybean yield vs. soil depth for sites A-F in the Blackland Prairie of Mississippi, 1984 growing season.

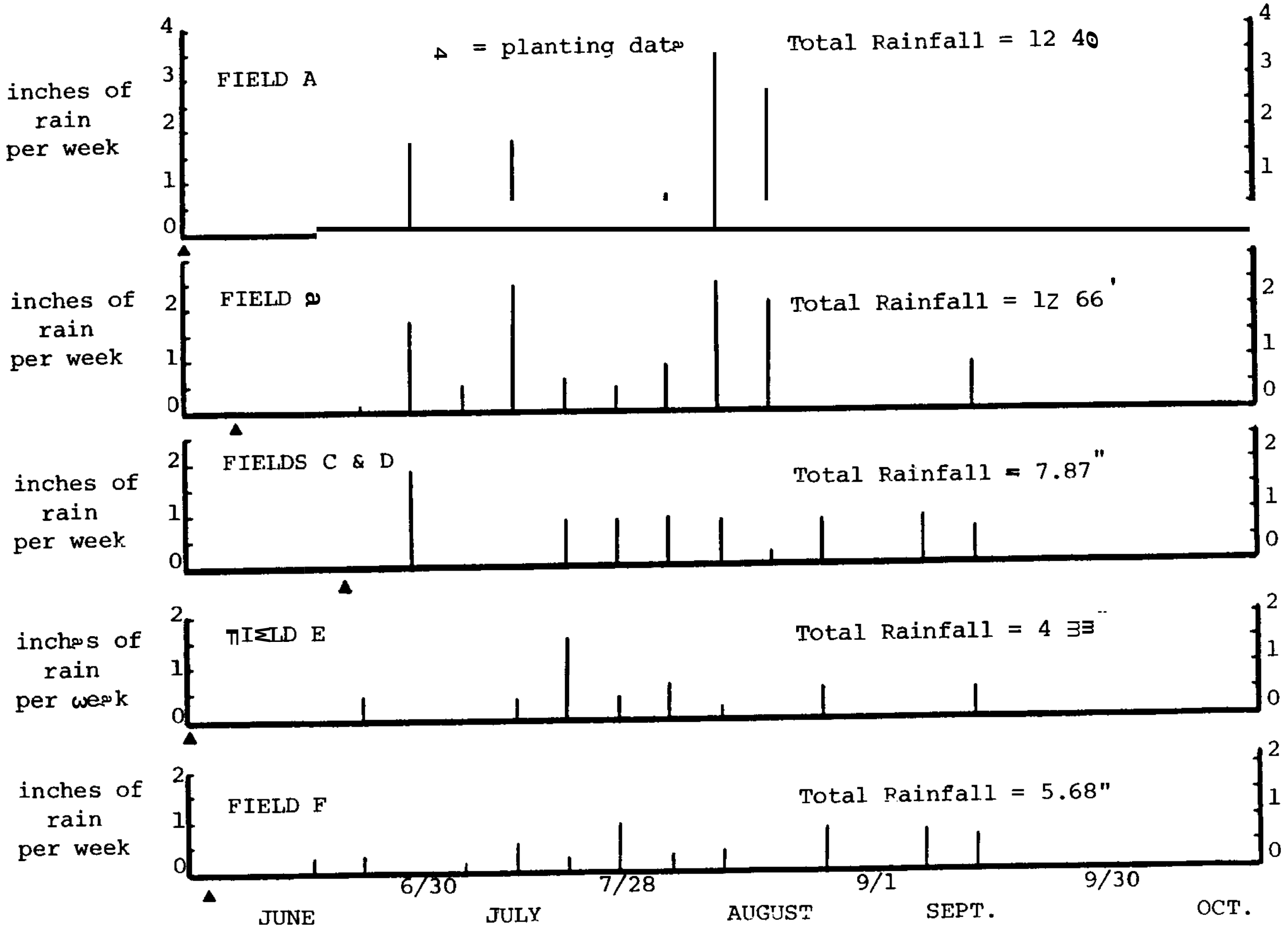

Figure 7: Weekly rainfall for Blackblet Prairie Sites A-F from 6-6-84 to 10-6-84.

Effect of Tillage on Soil Loss and Corn Grain Yields on Sloping Land

M. J. Bitzer, R. L. Blevins, M. Aswad, and P. Deaton

University of Kentucky

J. Childers, D. Henry, and H. Amos

Soil Conservation Service

Many areas of sloping land in the United States are experiencing serious erosion problems. Much of this erosion is due to excessive tillage. The eastern half of Kentucky and adjoining areas of Ohio, West Virginia, and Tennessee are gently rolling with 50 percent or more of the tillable soils located on 6 to 20 percent slopes. The corn acreage in these areas has been expanding rapidly, thus more corn is being grown on potentially erodable land. Some type of conservation tillage is required on this land to prevent severe soil erosion and maintain the potential productivity of these soils.

The objective of this study was to determine the effect of four tillage methods on soil loss and corn grain yields on sloping land.

This research was conducted on a farm in eastern Kentucky on a Lowell silt loam soil. The soil is deep, well-drained, with medium textured surface layers, underlaid by a slowly permeable, clayey subsoil. Four naturally separated watersheds adjacent to each other in the same field were chosen. Each watershed contains approximately 0.6 acre with a slope ranging from 8 to 15 percent from top to bottom. These areas had been in no-tillage corn for the two years prior to this study.

Each watershed was prepared for corn each year by one of the following four tillage treatments: (1) no-tillage into established rye, (2) chisel-plowed and disked, (3) disked only, and (4) moldboard plowed and disked (conventional). Corn stalks were chopped each fall following corn harvest and left on the soil surface to provide additional winter cover except for the no-tillage treatment. Rye was established in the fall by broadcasting and disking on the no-tillage plot. Corn was planted each year near May 10 at a seeding rate of 24,500 in 36 inch rows. All other cultural practices were the same on all plots. For collection of water runoff and soil loss an H-type flume with a Coshocton wheel was installed on each watershed. To prevent water from moving into or out of the watersheds a soil berm was constructed around the boundary of each watershed.

RESULTS

The results of the soil losses are presented in Table 1. The no-tillage and disk-only treatments resulted in significantly lower soil losses than the other two tillage methods. The low soil losses in 1983 and 1984 were due to the very dry summers with light showers accounting for most of the rainfall. In 1982, a couple of very intense rainfalls in late July accounted for the heavier soil losses from the chisel-disk and the conventional tillage areas. Overall, no-tillage reduced soil losses by 97 percent and disk only by 95 percent as compared to conventional tillage. Soil loss data from this study shared that the chisel-disk was not effective in reducing soil erosion losses on steeper slopes.

Table 1. Soil loss for four tillage systems.

	Tons per Acre			
Tillage	1982*	~~1983~~	1984	Ave.
No-Tillage	0.14	0.08	0.06	0.09 b
Disk-Only	0.20	0.15	0.11	0.15 b
Chisel-Disk	5.18	2.64	0.97	2.93 a
Conventional	6.10	2.63	1.25	3.33 a

*Includes losses from June through December. Construction of water and sampling equipment was not completed until late May.

The corn grain yields are presented in Table 2. The yields are closely correlated to rainfall and mulch cover. Rainfall was critical during the months of July, August, and September each year. Total rainfall during those periods was 11.35 inches in 1982, 2.4 inches in 1983 and 6.0 inches in 1984. The extra mulch from the rye cover conserved more moisture in both 1982 and 1984 to allow the corn grown under no-tillage to fill longer with no stress as compared to the other tillage methods. In 1984, a very dry June put considerable stress on all treatments early except the no-tillage treatment. In 1983, the rye was removed above the ground by cattle just prior to planting. With the extremely dry weather in 1983, none of the tillage treatments allowed high corn yields.

Table 2. Corn grain yields for four tillage systems.

	Bushels per Acre			
Tillage	1982	1983	1984	Ave.
No-Tillage	200 a	59 a	165 a	142 a
Chisel-Disk	164 b	69 a	105 c	113 b
Disk-Only	169 b	71 a	141 b	127 ab
Conventional	158 b	67 a	102 c	115 b

CONCLUSIONS

The no-tillage and disk-only treatments resulted in significantly lower soil losses than the chisel-disk and conventional tillage treatments. The lower corn yields from disk-only as compared to no-tillage was due in part to the extra moisture conservation provided by the rye mulch. There was no difference between chisel-disk and conventional as far as amount of soil loss or grain yields.

Conservation Tillage
and
Environmental Quality

The Role of the Georgia Soil and Water Conservation Committee in P. L. 92-500, Section 208, Nonpoint Source Agricultural Pollution Control

F. Graham Liles, Jr

Georgia State Soil and Water Conservation Committee

The State Committee role in nonpoint source pollution from agriculture began with the passage by Congress in 1972 of the Federal Water Pollution Control Act, or Public Law 92-500. It was the most far-reaching legislation ever enacted in protecting and maintaining the quality of the Nation's water.

The original goal of this act was to make waters of the United States fishable and swimmable by July 15, 1983 with no discharge of pollutants by 1985. The Environmental Protection Agency is the Federal agency responsible for carrying out this law.

The law was divided into several sections. One of the most important was Section 208 which called for area and statewide water quality management planning which would deal with point and nonpoint sources of pollution. In Georgia, the Governor designated the Environmental Protection Division as the state agency to develop the overall 208 plan for the state.

For the nonpoint portion of the 208 plan, EPD decided to use the task force approach. Seven task forces were selected with one being the Agriculture/Irrigation Nonpoint Source Technical Task Force.

This Task Force charged by the Executive Director of the State Soil and Water Conservation Committee inventoried all agricultural activities in the state and ranked individual counties for their pollution potential. The Task Force did not find any specific pollution problems related to agriculture but pointed out areas where problems would most likely occur.

To explain a bit, nonpoint source pollutants are those carried by runoff from many areas and which cannot be pinpointed. Some examples are: soil eroded from a plowed field, pesticides and fertilizer leached from cropland, and runoff from construction sites. Major sources contributing nonpoint pollutants are: construction, silviculture, mining, urban runoff, agriculture and salt water intrusion.

The State Water Quality Management Plan which was developed favors a nonregulatory approach for controlling agriculturally-related nonpoint source pollution. In accordance with this plan, the State Committee was designated as the administering agency, working through soil and water conservation districts, to carry out the agricultural portion of the state plan.

The State Committee then initiated a 208 program based on the voluntary approach to meeting national goals. In this role, the Committee has secured a staff person who is expert in nonpoint pollution control. His job is to develop and present to districts and the public various types of information displays explaining 208 requirements and the methods through which they can be met. He also helps develop and implement long range programs for districts and coordinates activities between the State Committee and other agencies.

The Committee also assisted the 40 soil and water conservation districts in developing 208 plans in agriculture. The ultimate goal of the Committee is that all the agricultural land in Georgia is managed under a current conservation plan.

In 1981, the Committee entered into a contract with the EPD that would provide funding for certain activities. The main thrust of this program was to fund informational and educational activities relating to nonpoint efforts.

I would like to say that this money has been used widely and wisely. We have now had leadership roles in planning, publicizing and conducting 50 demonstrations or demonstration projects which have been visited by an estimated 15,000 youth, adults, landowners, nonlandowners, farmers, etc.

Furthermore, we pledge to continue our efforts in nonpoint pollution control because, basically, the practices which control pollution almost always control erosion or sediment runoff. And that's what this agency is here for.

Conservation tillage, for instance, includes a number of methods such as no-till, minimum tillage, chisel planting and more. Aside from being great conservation practices, they are doing a great job of controlling nonpoint source pollution.

Today the requirements and goals of Section 208 are not getting too much publicity. We must not, however, assume that the requirements of the law are invalid or forgotten. Accordingly, the Committee will continue to educate and inform all who need to know the benefits and needs in nonpoint source pollution control. It is very important to keep demonstrating that farmers and landowners in Georgia can control nonpoint pollutants through a voluntary program. The alternative is a federally-mandated regulatory program emphasizing cross-compliance with other programs of federal assistance to agriculture. None of us wants more federal regulation in farming.

We applaud efforts such as this which, though not directed specifically to Section 208 goals, will contribute greatly to those goals through increased understanding and appreciation among the participants.

Effects of Tillage on Quality of Runoff Water

P. L. Baldwin, W. W. Frye, and R. L. Blevins

Department of Agronomy, University of Kentucky, Lexington, KY 40546

The issue of water quality is of great importance to agriculture today as agricultural land is implicated as a leading contributor of nonpoint source water pollution. In many cases, overland flow from irrigation and natural rainfall exiting cropland is rich in plant nutrients, especially nitrate and phosphate, and agricultural pesticides that are threatening the purity of our waters. The effect on man is both immediate through contaminated drinking water (Baker, 1985) and long term through degradation of aquatic bio-systems (Lee, 1973). These conditions have been reported in agricultural areas across the United States; Indiana (Romkens et al., 1973), Lake Erie (Baker, 1985), Texas (Trichell et al., 1968) are a few documented areas.

Success in reducing sediment loads in field runoff has been accomplished with conservation tillage. Harrold and Edwards (1972) reported about 0.16 Mg/ha sediment lost from no-tillage contour-row corn compared to about 51 Mg/ha with conventional tillage in Ohio. Cogo et al. (1984) found that chisel tillage with spring sweep increased rainfall infiltration and increased the length of time to runoff, resulting in decreased soil loss over no-tillage or fall moldboard plowing plus spring disk; the results were 12, 33, and 21 Mg/ha, respectively, for the three systems. In plots with continuous corn on 1.6 to 2.7% slopes, Van Doran et al. (1984) reported soil losses of 4.2 to 9.4 Mg/ha under plow-disk tillage and 0.5 to 0.8 Mg/ha under no-tillage.

These tillage systems are now being evaluated at the University of Kentucky for their effect on water quality. The data contained in this report are from the first year of a long-term field study at Lexington. The objective of the study is to compare water quality parameters of field-edge runoff under conventional tillage, chisel-plow tillage and no-tillage. In addition to total runoff volume, the water quality parameters being determined include amounts of sediments, nitrate (NO_3^-), soluble phosphorous

(P) and atrazine (2 chloro-4-ethylamino-6-isopropylamine-5-triazine) in the liquid phase of the runoff. This study does not consider actual delivery rates to a nearby stream.

MATERIALS AND METHODS

The study site is a Maury silt loam soil (fine-silty, mixed, mesic, Typic Paleudalf) with 9% slope. The site was in bluegrass sod for at least 20 years prior to establishing the experiment in 1984. Plots are 9 m wide by 30 m long. All plots were sprayed with paraquat to kill the sod. Tillage treatments were conventional tillage (CT) (moldboard plowed and disked once), chisel-plow tillage (CP) (straight shank plowed and disked once) and no-tillage (NT). There were three replications of each tillage treatment, and values reported are averages of the three replications. Following tillage and planting, fertilizers were broadcast on the soil surface at rates of 170, 60, and 135 kg/ha, N, P, and K, respectively, as ammonium nitrate (34% N), triple superphosphate (20% P), and muriate of potash (50% K). Atrazine was applied at a rate of 2.5 kg/ha active ingredient (a.i.).

Runoff samples were collected in storage tanks down-slope of the flumes positioned at the edge of each plot. Within 24 hours, usually less, after each rainfall event, a stirred, 200 ml runoff sample was collected for chemical analysis. The sediment was separated from these samples by refrigerated centrifugation for 15 minutes at 2,000 RPM, and the liquid phase was stored in a refrigerator at 3 C until analyzed. The sediment will be analyzed at a later date. A 1 liter sample was also collected from each storage tank for determination of sediment load. Nitrate was analyzed according to the procedure of Lowe and Hamilton (1967). Soluble phosphorous was determined by the stannous chloride procedure (Jackson, 1958) and atrazine was partitioned and analyzed with high performance liquid chromatography (HPLC) as described by Lawrence (1982). The samples discussed in this report are from rainfall events from June 11 to November 4, 1984.

RESULTS AND DISCUSSION

Although results are preliminary, statistical analyses incomplete, and interpretations and conclusions tentative, there are important trends suggested by the data. During the first four rains, either the NT or the CP produced the lowest runoff volumes. However, from mid-season, runoff amounts were about the same for all three tillage systems during most of the rains. This suggests greater infiltration with the conservation tillage methods during the first half of the season, but little difference after mid-season. Total runoff volume measured during the season was two times greater with CT than with CP or NT.

Except for one rainfall event, June 22, the CP treatment appeared to produce the greatest amount of sediment in the runoff and NT the least (Table 1). The total amount of sediment measured during the season was slightly more with CT, mainly because of the much higher amount on June 22.

From this, it appeared that the sod cover of the NT was more effective in protecting the soil from erosion. We have no explanation for the tendency for more sediments from CP than from CT.

Table 1. Total rainfall, runoff volume, and sediment load, 1984.

Date of event	Rainfall	Runoff volume			Sediment load		
		CT[†]	CP	NT	CT	CP	NT
	cm	---------liters/ha--------			--------kg/ha-------		
6-11[‡]	1.2	560	4,763	512	--[‡]	--	--
6-18	4.5	39,409	21,229	16,903	--	--	--
6-22	2.6	11,622	3	3,335	46	13	7
7-4	4.8	16,729	7,271	12,134	31	33	21
7-11	0.4	3	227	256	2	2	1
7-26	1.6	911	1,005	1,127	1	8	4
8-1	1.3	13,618	1,481	1,625	2	3	2
10-21	5.3	3,160	3,532	3,623	2	5	2
10-28	2.9	1,861	2,328	2,076	2	4	1
11-1	2.4	1,319	1,855	1,510	1	2	<1
11-4	1.5	741	740	774	<1	3	<1
Season total	28.5	89,933	44,434	43,875	87	74	38

[†] CT = Conventional tillage, CP = Chisel-plow tillage, NT = No-tillage.

[‡] Delay in installation of equipment delayed start of sampling.

The concentration of NO_3^- in the liquid phase of the runoff tended to be highest with NT and lowest with CP (Table 2). Total NO– per event (runoff volume times NO– concentration in runoff) was not greatly different among tillage treatmeits, except for three events (June 22, July 4, and August 1) when runoff was much greater from CT and one (June 11) when CP resulted in the greatest NO_3^-. Overall total NO– from CP plots tended to be somewhat less than from CT. Total NO_3^- removal during the season (average NO_3^- concentration in Table 2 times total runoff in Table 1) for CT, CP, and NT were 171, 53, and 145 g/ha N, respectively.

Water-soluble P concentration in the runoff liquid phase are shown in Table 3. One of the notable trends in the water-soluble P concentration was what appeared to be a substantial increase in concentration at the end of the season, specifically the October 28, November 1, and November 4 sampling dates. We have not determined the cause of this, but intend to study it more thoroughly in the future.

Total water-soluble P in runoff, i.e., total runoff values in Table 1 times average P concentration values in Table 3, were 90, 67, and 22 g/ha P, respectively, for CT, CP, and NT.

Table 2. Nitrate in runoff liquid phase as affected by tillage, 1984.

Date	Concentration of nitrate			Total nitrate†		
	CT‡	CP	NT	CT	CP	NT
	mg/liter N			g/ha N		
6-11	0.2	3.1	9.8	<1	15	5
6-22	2.2	0.8	2.7	26	<1	9
7-4	1.6	0.8	0.5	27	6	6
7-11	3.1	1.8	3.0	<1	<1	<1
7-26	2.1	0.4	2.9	2	<1	3
8-1	0.9	0.5	2.5	12	1	4
10-28	2.2	0.9	3.0	4	2	6
11-1	1.3	1.2	2.5	2	2	4
11-4	3.5	2.2	2.5	3	2	2
Avg	1.9	1.2	3.3			

† Runoff volume times NO_3^- concentration in runoff.

‡ CT = Conventional tillage; CP = Chisel-plow tillage; NT = No-tillage.

Table 3. Concentration of water-soluble P in runoff liquid phase as affected by tillage, 1984.

Date	Concentration of P			Total P		
	CT	CP	NT	CT	CP	NT
	mg/liter			g/ha		
6-11	0.35	0.04	0.09	<1	<1	<1
6-22	0.56	0.50	0.24	7	<1	1
7-4	0.67	0.45	0.68	11	3	8
7-11	0.49	0.35	0.14	<1	<1	<1
7-26	1.03	1.71	0.12	1	2	<1
8-1	0.42	0.64	0.19	6	1	<1
10-28	0.89	1.10	1.13	2	3	2
11-1	2.27	2.13	1.09	3	4	2
11-4	2.12	6.61	0.80	2	5	1
Avg	1.00	1.50	0.50			

The atrazine concentration tended to be highest from the conservation tillage plots, especially CP, during the earlier part of the season (Table 4); however, by the July 4 sampling date, this difference had disappeared. This may be attributed to less contact of the atrazine with soil under conservation tillage because of the killed sod mulch.

A gradual decrease in atrazine concentration was apparent as the season progressed, although there remained measurable quantities even in the November 4 runoff. Expressed as a sum for all dates (average concentrations in Table 4 times total runoff volumes in Table 11, atrazine amounts in

Table 4. Concentration of atrazine in runoff liquid phase as affected by tillage, 1984.

Tillage	Atrazine, mg/liter						
	6-11	6-27	7-4	7-11†	7-26	11-4	Avg
CT	0.03	0.02	0.03	0.07	0.02	0.01	0.03
CP	0.11	0.25	0.01	0.01	0.02	0.01	0.07
NT	0.10	0.02	0.04	0.01	0.01	0.01	0.03

† Only 1 replicate plot analyzed

relation to tillage systems were 27, 31, and 13 g/ha atrazine (a.i.) for CT, CP, and NT, respectively. Thus, because of the greater runoff from CT, the amount of atrazine removal appeared to be about the same as from the CP. Atrazine removal was apparently lower with NT than CP due to its lower concentration in the runoff and lower than CT due to less runoff.

Generally, the runoff from CP plots had the highest pH, NT runoff was slightly lower, and CT was lowest (Table 5). There was no apparent explanation for the relationship between pH and tillage system. The pH is considered to be a very important property of runoff due to its possible influence on the rate of atrazine degradation (Best and Weber, 1974).

Table 5. pH of runoff as affected by tillage system, 1984.

Tillage	6-27	7-4	7-11	7-26	8-1	10-28	11-1	11-4	Avg
	pH								
CT	7.16	5.78	6.17	6.48	6.17	6.12	6.16	5.86	6.24
CP	7.19	6.57	6.42	6.69	6.40	6.18	6.74	6.30	6.56
NT	7.30	6.19	7.25	6.37	6.23	5.86	6.35	5.45	6.38

SUMMARY

Generally, the first year's data from this study showed little statistically significant difference in water quality parameters due to tillage. At least part of this can be attributed to the homogeneity of these plots in their first year of tillage following many years in bluegrass sod. The data does indicate certain trends. Runoff from NT tended to be highest in NO_3^- concentrations throughout much of the season, but the total amount of NO_3^- was greatest in runoff from CT. Total runoff volume and sediment load for the season were also greatest from CT. Runoff from CP was most often highest in concentrations of both water-soluble P and atrazine and often carried higher total amounts of atrazine. Because of the higher volume of runoff, the greatest total amount of water-soluble P was removed from the CT plots. The pH values generally were highest for CP and lowest for CT runoff.

Our NO- and P results were similar to those reported by Romkens et al. (1973) ahd angle et al. (1984), although significant differences between tillage treatments were few. With subsequent cropping years, these plots are expected to become much more characteristic of their respective tillage systems in regard to surface condition, soil structure, organic matter and surface pH, all of which have been indicated as influencing runoff volume and its composition and sediment delivery.

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Weed
Control and Management

Weed Management: Key to No-Tillage Crop Production

A. D. Worsham and W. M. Lewis

North Carolina State University, Raleigh, NC

INTRODUCTION

No-tillage production of crops has been a goal of agriculturists for decades, The primary factor limiting development was the inability to control weeds present at crop planting and those that developed later. Until the early 1950's, tillage was the only method available to prepare a seedbed, temporarily free it of weeds, and control weeds that developed after the crop had emerged.

Prospects for controlling weeds by alternate means, however, improved during the 1950's with the advent of a host of new herbicides, These discoveries probably led Harper (1957) to write, "... For efficient longlasting weed control, ploughing should be avoided, surface tillage reduced to a minimum and any weed seeds which are formed should be left on the surface to be killed by spraying when they do germinate." The discovery and subsequent developnent of a new class of non-selective herbicides in the U.K. and marketing of the contact herbicide, paraquat in the U,S, around 1960 provided the reality of no-tillage crop production. New crop production techniques soon were developed and adopted in many areas of the U.S. An estimated 87 to 90 million acres of U.S. cropland were in some form of reduced tillage in 1983 and another 10 to 12 million acres were planted no-tillage (Magleby, et al., 1984).

These herbicides plus other new selective ones made no-tillage crop production possible, but even with the many compounds available, weeds and weed control remain the dominant concern. Results of a survey of 25 leading corn-producing states in 1980, led agronomists in three states to list lack of herbicide effectiveness and an increase in perennial weeds as major reasons for concluding that no-tillage corn production likely would nutincrease in their states by 1990. No-tillage corn acreage was predicted to decrease in two of the 25 states surveyed, and greater weed problems and difficulty of cultivation were listed as reasons for their expected decline (Worsham, 1980).

Poor weed control was listed by respondents in 24 of the 25 states as a serious problem and was predicted to worsen if no-tillage corn acreage increased, Insect control was the next most-listed problem in 14 states, Respondents in all the 25 states listed perennial weed control as a problem currently encountered in no-tillage corn, Perennial weed control was given by respondents in 16 states as the most important problem. Insects and poorly-drained, cold soils were the next most-listed (12 states) factors limiting the expansion of no-tillage corn acreage (Worsham, 1980).

A widely-held view among scientists is that weeds are the most important single problem limiting acceptance of no-tillage cropping systems. Farm acceptance will be expanded as the herbicides now being developed to meet weed problems as they arise are incorporated into no-tillage weed-management systems. For example, control of some perennial weeds with the non-selective, systemic herbicide, glyphosate, and of perennial grass weeds in broadleaf crops with new, post-emergence "grass" herbicides is now possible. The remainder of this paper provides examples of developing weed-management systems to fit specific situations.

WEED MANAGEMENT PROGRAMS

The major techniques or tools employed in cropping systems, both conventional and no-tillage include: (1) crop rotation, (2) crop competition, (3) mechnical tillage, (4) biological and predator control and (5) herbicides (Lewis and Worsham, 1981; McWhorter and Chandler, 1982).

These tools are discussed as they are employed in both conventional and no-tillage systems.

No-tillage systems have the same requirements for economic and effective weed control as do conventional tillage systems. The major difference is that more burden is placed on chemical methods of weed control. In most reduced- and in all no-tillage systems, herbicides must be relied upon for preplant, preemergence and postemergence control of weeds. Tillage after planting is rarely an option.

Thus, the essential components of weed management in these cropping systems consist of (1) control of existing vegetation at planting, (2) residual weed control and (3) postemergence weed control.

Use can be made of crop rotations, crop competition and biological methods to integrate these Components into a total weed management program. There is a delicate balance to the effectiveness of these methods.

Crop Rotation

Specific weed species tend to increase under cultural practices unique to the production of different crops. This is becoming increasingly evident and is an important factor in herbicide-weed-crop associations. Crop rotations must not be overlooked as an important weed-management tool, along with the array of herbicides available, Weaknesses in herbicide programs for specific weeds are much easier to overcome in some crops than in others. For example, weeds such as lambsquarter are more easily and/or economically managed in corn than in soybeans, peanuts or cotton. Large-seeded, broadleaf weeds such as cocklebur, morningglory and sicklepod can be controlled at three different times during the life cycle of corn, whereas only postemergence applications can be used effectively in soybeans. Timing is critical and crop tolerance may be marginal (Lewis and Worsham, 1981). Deep-rooted, broadleaf perennials such as trumpetcreeper, bigroot morning-glory and horsenettle can be managed in corn but not soybeans.

Rotating crops helps prevent the build-up of problem weeds. Equally, if not more important, the herbicides also will be rotated in crop rotation. Perennial crops such as some hay crops, fruits, permanent pastures and rangelands are not rotated as frequently as annual crops, but some of these can be intermixed into long rotation sequences (Aldrich, 1984).

Rotations are similar in reduced- and no-tillage systems. Exceptions exist where a heavy residue mulch or a killed living mulch may interfere with planting or introduce other undesirable factors. For example, the widely held view of crop specialists has been that peanuts cannot be planted and grown successfully without tillage before planting to bury plant residues. Traditionally, burial of all plant residues has been recomnended as a means of reducing disease and insect problems. However, experimental work in at least four Southeastern states has been successful in planting peanuts into various kinds of mulches and residues (Worsham, 1985). In double- and triple-cropping, no-tillage is beneficial because crops in the sequence can be planted sooner with less loss of land use, soil moisture, time and labor.

Crop Competition

Just as weeds compete with crops for light, nutrients, water and space, crops also compete with weeds. A grower can increase crop competitiveness appreciably by planning well to encourage it. This is possibly the most overlooked weed management tool. Crop competitiveness is increased by using combination of production practices to maximize vigor of the plant. Shading of weeds by the crop is an important factor. High-quality seed of vigorous cultivars, proper fertilization and liming, effective disease and insect control, narrow row spacing and timely planting are all important in giving the crop an advantage over weeds. Cultivars may also vary in their competitiveness through rooting habits and morphological characteristics that provide dense shade. The sooner the crop canopy closes the better the weed control with or without herbicides (Lewis and Worsham, 1981; Klingman and Ashton, 1982; Aldrich, 1984).

Many weeds interfere with crop growth through allelopathic effects. Some crops are allelopathic against weeds, but cultivars vary in their allelopathic effects on some weeds (Putnam and DeFrank, 1983; Radosevich and Holt, 1984; Rice, 1984).

Use of production practices to promote fast emergence, rapid growth and vigorous crops to shade weeds is common to all cropping systems. No-tillage systems may be at a disadvantage in certain years because crops planted in killed cover crops, heavy infestations of weeds or in fields with large amounts of previous crop residue usually emerge and grow more slowly during the first few weeks after planting. This is due to slower warming of soil in spring where a mulch cover is present and in years when it is dry at planting time the soil is drier where a living mulch is present as compared to a tilled field. The crop seedlings may be shaded during emergence if the mulch is excessive. However, the cover suppresses seedling weed development as well, Other factors influencing germination and early growth rates may be a temporary nitrogen deficiency and phytotoxic by-products of plant residues and microorganism decomposers (Putnam and DeFrank, 1983).

Mechanical

The major difference in mechanical weed-manaqement methods between no-ti1lage and conventional tillage systems is during primary and secondary cultivations. In conventional systems, tillage operations not only remove weeds to provide a weed-free seedbed, but also control weeds after the crop emerges. Limited postemergence tillage is possible in some reduced-tillage systems, but it is not possible with no-tillage culture, Exceptions include tillage with sweep cultivators in double-crop soybeans following small grain harvest where little or no straw residue remains. Ground driven rotary cultivators can be used if moderate amounts of residue are present. Some equipment manufacturers however, now advertise cultivation equipment designed to operate in "no-tillage" systems. All of these factors put heavy pressure on the herbicide component of weed management for complete control, whether preplant, preemergence or postemergence.

Biological and Predators

There are several outstanding examples of controlling weeds with other organisms. These have, in the past, included release of phytophagus insects and, more recently, use of fungal plant pathogens in a "bioherbicide" or "mycoherbicide" approach. The former has worked best in large areas infested dominantly with one weed species, the latter on selected weed species in row crops and orchards (Klingman and Ashton, 1982), Crop rotation, crop competition and crop allelopathy also are forms of biological control, These methods should be equally effective in conventional or no-tillage cropping systems,

Chemical

Weed-management systems for reduced- and no-ti1lage place great reliance upon the chemical component., The herbicide (or combinations of herbicides) must kill existing vegetation at time of planting (whether a living cover crop or weeds) and retain enough residual preemergence activity to provide control as necessary and often herbicides must be available for post-emergence control.

Lower herbicide rates or band treatments may be used in some instances to give growers temporary retardation of growth of existing vegetation (weed or crop) to permit establishment of an interplanted crop. Examples include the planting of small-seeded legumes into grass pastures, grasses into legumes and corn into coastal bermudagrass, tall fescue or other forage grasses. The success of reduced tillage systems requires keen and complex managerial decisions on the part of the grower,

WEED ECOLOGY IN NO-TILLAGE

Problem weeds are simply defined as those not adequately controlled by currently available techniques or that require difficult and/or expensive methods. The list changes with time, geographical location and crop grown.

When both tillage and herbicides are used for weed control, the list of problem weeds is shortened. As either practice is reduced, the number of weeds causing problems often increases because of inadequate control (Witt, 1984). Most surely, weeds that are troublesome where both tillage and herbicides are used will become more so as tillage is lessened. With continued herbicide development, this list of problem weeds will diminish.

Eliminating tillage causes shifts in weed species present (Triplett and Lytle, 1972). Perennials, such as poison ivy, horsenettle, trumpet creeper and tree seedlings that are readily controlled by tillage, become established and persist in untilled fields. Weeds botanically related to the crop and others that escape control increase in number to become a dominant problem. A classic example of this developed in the United States when atrazine was introduced to control weeds in corn. At first, atrazine controlled most annual weeds found in corn fields. Fall panicum, never a problem weed before atrazine was widely used, tolerates atrazine and increased dramatically in continuous corn. Coupled with reduced cultivation, fall panicum pressure rendered atrazine inadequate as a sole herbicide in corn. A similar situation was brought about in the Southeast and Midsouth with nutsedge. As growers shifted to more herbicide use and less cultivation, nutsedge became a severe problem in crops. Within weed species, biotypes that tolerate herbicides have appeared. Biotypes of pigweed and lambsquarter resistant to atrazine have been identified and have become problem weeds in parts of the U.S. and Canada (Bandeen, et a1., 1982). Fortunately, these species are susceptible to several other herbicides and can be controlled.

A rather recent, encouraging development in weed ecology in no- or reduced-tillage systems is the discovery that many annual broadleaf weeds are suppressed if mulches, especially small grain cover crops, are left on the soil surface (Liebl and Worsham, 1983; Putnam and DeFrank, 1983; Shilling, et al., 1985). This beneficial effect, largely due to allelopathic interactions, can help suppress difficult-to-control annual broadleaf weeds in many broadleaf crops and possibly reduce the need for post-emergence herbicide applications.

INDIVIDUAL COMPONENTS OF THE SYSTEM

Existing Vegetation Control

Complete control of existing vegetation at planting is essential before crop emergence in no-tillage systems, except in cases where one crop is interplanted into another without tillage (Anonymous, 1983). This vegetation control is accomplished mainly with a quick-acting, contact herbicide, such as paraquat, or a slower-acting, translocated herbicide, such as glyphosate, In rare instances in the Southeast of sparse populations of very small annual weeds, residual herbicides with contact activity, such as cyanazine, atrazine + crop oil, linuron or metribuzin, might be used satisfactorily at planting without a contact herbicide.

Analysis of the weed spectrum and stage of growth before and at planting is essential for the grower to determine the herbicide and rate required to control the weeds most effectively and economically. Different situations frequently dictate different treatments. For example, no-tillage corn planting may be made into perennial grass or legumes sods, annual cover crops (grasses or legumes), annual broadleaf and grass weeds and a few perennial broadleaf and grass weeds. No-tillage soybeans have not been recommended up until now even when low infestations of perennial weeds are present. However, the availability of new postemergence herbicides now makes possible the control of perennial grass weeds in some broadleaf crops.

Residual Control

Herbicides used for residual control of annual weeds in reduced- and no-tillage cropping systems are essentially the same as those used in conventional tillage systems where similar weed species and populations are present. One exception is the use of a herbicide that must be soil incorporated (most dinitroanilines and thiocarbamates) and cannot be used with no-tillage or where large amounts of crop residues remain on the soil surface. However, research is underway to develop methods of applying these herbicides with no-tillage. Many preemergence herbicide labels and accompanying literature give directions for shallow soil incorporation when moderate amounts of surface mulch are present. This allows use of these herbicides while maintaining enough cover to control soil erosion.

Postemergence Control

Controlling weeds with postemergence herbicides in reduced- and no-tillage crops differs little from methods and chemicals used in conventional tillage systems. An array of herbicides that are applied postemergence to the crop and weeds is available for use in most agronomic crops. In no-tillage systems there generally is more reliance on postemergence herbicides. They are invaluable tools in controlling escaping weeds or those tolerant to preemergence applications. Postemergence herbicides also may be the primary means of controlling weeds that escape other treatments.

Available herbicides vary in selectivity for crop and weeds, application requirements, crop safety and effectiveness on small and large or annual and perennial weeds. Postmergence treatments in most crops consist of early-postmergence, over-top sprays--strictly directed sprays (directing the spray on small weeds under the crop and keeping spray off the crop foliage) and semi-directed sprays (directing the spray toward the base of the crop plant with some of the lower crop leaves being contacted).

The crop must tolerate rates of over-top sprays that control weeds present. Examples include atrazine and oil for small annual weeds in corn and sorghum; cyanazine for corn not beyond the 4-leaf stage; 2,4-D and dicamba for broadleaf annual and perennial weeds in corn and sorghum; sethoxydim and fluazifop for annual and perennial grass weeds in soybeans and cotton; bentazon and acifluorfen for small broadleaf weeds in soybeans and DSMA, MSMA or flumeturon for small broadleaf and grass weeds in cotton.

Selectivity for non tolerant crops is gained by directing the spray so that it touches only the base of the crop. This is accomplished by mounting spray nozzles on a rigid shank, a sliding or rolling support and/or having shields to cover the crop. To be used effectively, a height difference between crop and weed is necessary. Examples include DSMA, MSMA, fluometuron, diuron, cyanazine, linuron, dinoseb and oxyfluorfen in cotton; linuron, 2,4-DB, metribuzin, dinoseb and paraquat for grass and broadleaf weeds in soybeans and ametryn and linuron for corn. These and similar herbicides act mainly through contact activity and defoliate small weeds (and crop too if the foliage is sprayed). Directing sprays may be more difficult in no-tillage fields, if tall crop stubble (such as in double-crop soybeans, where the small grain was cut high) or if tall, dead weeds are present. Unless the crop is shielded with some type of fenders, splashing of the chemical onto the crop could occur. Examples of semi-directed sprays are 2,4-D and dicamba on larger corn. At this time, weeds need to be smaller than the corn for effective results. A listing of weed species controlled, timing, method of application and crop safety considerations are found on the label of each herbicide.

Postharvest Control

In many situations, especially where perennial weeds are present, an additional time of weed management treatment is after harvesting the crop. Here applications of translocated herbicides such as glyphosate, 2,4-D, or dicamba can be used for control of perennial grass and, for the latter two herbicides, perennial broadleaf weeds. This treatment is especially useful in crops that are harvested relatively early such as short-season corn for grain, corn for silage and tobacco.

HERBICIDE SYSTEMS

Successful no-tillage crop production requires adequate weed control. This consists of kill of existing weeds or cover crops at time of planting, residual control of broadleaf and grass weeds and/or postemergence chemical control and occassionally after-harvest treatment. The system actually now consists of a series of weed management decisions or options at each of the above mentioned crop stages. We will discuss situations and requirements at each of these stages in general terms, then give specific weed situations and weed management options.

Formulating the System - Weed Management Options

The aim of the no-tillage grower is to match herbicide capabilities with weed species present or expected and crop grown to meet the requirements set forth earlier as to weed management. With the number of herbicides and herbicide combinations now available to the no-till grower, weed management is largely a series of options or decisions at several stages in the life of the crop. The following section gives examples of weed management options in corn and soybeans in the Southeast.

No-Till Corn

A.

Situation at Planting	Management Option
1. Small annual grass and broadleaf weeds less than two weeks old	Paraquat, glyphosate, or cyanazine plus residuals
2. Horseweed	Glyphosate or 2,4-D
3. Small annual grass and broadleaf weeds plus a few large perennial broadleaf weeds	Glyphosate or cyanazine plus 2,4-D plus residuals
4. Small grain cover crop	Paraquat or glyphosate plus residuals
5. Alfalfa or legume cover crops	Paraquat plus dicamba or glyphosate plus dicamba 7 days before planting plus residuals or dicamba after corn emergence

B. Possible Combinations at Planting for "Knockdown" and Residual Control of Summer Annual Broadleaf and Grass Weeds

1. Paraquat plus alachlor plus atrazine
2. Paraquat plus metolachlor plus atrazine
3. Paraquat plus atrazine plus simazine
4. Glyphosate plus alachlor plus atrazine
5. Glyphosate plus metolachlor plus atrazine
6. Glyphosate plus atrazine plus simazine
7. Glyphosate plus alachlor plus simazine
8. Premix formulation of glyphosatelalachlor plus atrazine
9. Premix formulation of glyphosate/alachlor plus cyanazine
10. Premix formulation of glyphosate/alachlor plus atrazine plus cyanazine
11. Premix formulation of glyphosatelalachlor plus simazine
12. Cyanazine plus 2,4-D plus alachlor plus atrazine
13. Cyanazine plus atrazine plus alachlor or metolachlor

C. Early Postemergence Over Top (Corn Eight Inches Tall or Less)

For Broadleaf Weeds:

1. 2,4-D
2. Dicamba

D. Postdirected or "Lay-By"

1. Annual grasses	Ametryne or linuron plus surfactant
2. Annual broadleaf weeds	2,4-D, dicamba, ametryne plus surfactant or linuron plus surfactant
3. Annual grass and broadleaf weeds	Ametryne plus surfactant or linuron plus surfactant
4. Sicklepod	2,4-D plus surfactant, dicamba, ametryne plus surfactant or linuron plus surfactant

5. Perennial broadleaf weeds	2,4-D plus surfactant or dicamba

E. After Harvest

1. Johnsongrass	Glyphosate
2. Perennial broadleaf weeds	Glyphosate or 2,4-D plus dicamba

No-Till Soybeans

A. Weed Management Options at Planting for Control of Existing Weeds

1. Small annual grass or broadleaf weeds	Paraquat, glyphosate or glyphosate/alachlor premix
2. Horseweed plus perennial broadleaf weeds	2,4-D four to six weeks before planting, glyphosate/alachlor premix

B. At Planting for "Knockdown" Plus Residual Control (an option would be to use the "knockdown' herbicide and rely on postemergence herbicides for annual grass and broadleaf control and perennial grass control).

1. Paraquat plus linuron or metribuzin
2. Paraquat plus linuron or metribuzin plus alachlor
3. Paraquat plus linuron or metribuzin plus metolachlor
4. Paraquat plus oryzalin
5. Paraquat plus oryzalin plus linuron or metribuzin
6. Glyphosate plus alachlor plus linuron or metribuzin
7. Glyphosate/alachlor premix plus linuron
8. Glyphosate plus metolachlor plus linuron

C. Postemergence Over Top

1. For annual grasses and johnsongrass	Sethoxydim or fluazifop
2. For annual broadleaf weeds	Bentazon, acifluorfen, bentazon plus acifluorfen, 2,4-DB (late Post)
3. For annual grasses and broadleaf weeds	Bentazon plus sethoxydim, acifluorfen plus sethoxydim, bentazon plus aciflurofen plus sethoxydim, acifluofen plus fluazifop

D. Postemergence Directed (for annual broadleaf and grass weeds)

1. Linuron
2. Metribuzin
3. Linuron plus 2,4-DB (sicklepod)
4. Paraquat

E. Postemergence with Wick Applicator

For grasses and certain broadleaf weeds taller than the soybeans	Glyphosate

SUMMARY

The single factor that kept the idea of no-tillage crop production from becoming a reality much sooner - control of vegetation at planting and of weeds - is still the major factor reported as limiting expansion and adoption of no-till and causing grower problems. Much progress has been made, however, in the last decade in making new, chemical options available to the no-till grower. These herbicides plus use of the traditional weed control tools of crop rotation, crop competition, and biological control now make possible weed management in no-till crops under a wide variety of different situations. Probably the main limiting factor among growers is the managerial ability of making decisions on the many options now available to manage weeds in their no-till crops.

Weed management is now largely a series of options or decisions at several stages in the life of the crop. For example, at planting the grower must chose the most effective and economical of several alternatives for weed and/or cover crop kill. He can use a contact herbicide, a translocated herbicide, or a residual herbicide with contact activity - all depending on the situation. Also at planting, there are a great number of premergence herbicides and combinations of herbicides available to control annual broadleaf and grass weeds. Again the choice depends on weeds expected to be present. We know that leaving a mulch of cover crop residue, especially small grains, on the soil surface suppresses many broadleaf weeds and more than makes up for any preemergence herbicides retained in the mulch.

There are a number of herbicides for over-top treatment in soybeans that will control annual broadleaf weeds and perennial and annual grasses; and in corn and sorghum, annual and perennial broadleaf weeds. There are postdirected herbicides for use in corn, cotton, soybeans, and sorghum for control of annual broadleaf and grass weeds. Escaped perennial grasses and certain annual broadleaf weeds can be controlled after they get taller than a soybean crop by use of recirculating sprayers or wick applicators. An additional time for attacking many perennial broadleaf and grass weeds, especially if a no-till crop is to follow the next year, is after harvest of a shorter-season crop.

With the many management options now made possible by a wide variety of herbicides, weed management in no-till crops, even hard-to-control weeds, many perennials and weed population shifts, can be handled by making the proper management decisions.

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Insect
Control and Management

Management of Arthropod Pests in Conservation-Tillage Systems in the Southeastern U.S.

G. J. Musick

Department of Entomology, University of Arkansas, Fayetteville, AR

For centuries crops have been produced using a system that mechanically manipulates the soil a number of times for the purpose of improving soil structure, managing crop residues and/or controlling weeds. In the U.S. this has usually involved plowing and one or more diskings followed by one or more cultivations after crop emergence. This system is commonly referred to as conventional-tillage.

With the development of selective, efficacious herbicides and planting equipment that will function in minimally disturbed soil, various conservation-tillage systems have evolved. Conservation-tillage has been defined by the National Conservation Tillage Information Center in Ft. Wayne, IN, as any tillage and planting system that retains at least 30 percent residue cover on the soil surface after planting. Such systems include reduced-till, mulch-till, strip-till, ridge-till and no-till (slot) planting.

Although various pest problems have been encountered, producers continue to adopt various conservation-tillage systems because these systems significantly reduce soil and water erosion, conserve soil moisture and fossil fuel, reduce soil compaction, save time and labor, require lower investment in equipment and optimize the use of land resources. Over the past decade, the potential pest problems in the more diverse conservation-tillage environments has concerned entomologists. Current entomological research has shown that broad generalizations about pest problems associated with conservation-tillage systems are not appropriate. Each crop and pest situation must be evaluated and independent judgments made.

In my discussion pest problems associated with conservation-tillage systems throughout the U.S. will be presented, but emphasis will be placed on specific pest problems associated with conservation-tillage systems in the southeastern U.S. These pests will be categorized as seed/seedling and post seedling.

SEED/SEEDLING PESTS. Conservation-tillage practices generally minimize the losses from soil insects. Gregory and Musick (1976), however, reported that some pests have become more serious on crops because herbicides eliminated preferred host(s).

Soil insects are among the most difficult insects to control. Insecticides have limited efficacy as they are difficult to properly time or place at the site of the infestation. In addition, early identification of damaging populations of soil insects is difficult, and limited information on action thresholds is available.

Failure of seeds to germinate or emerge is not always a result of feeding by a specific pest(s). In cool, wet springs seeds may rot in the soil as a result of poor seed-soil contact and/or cooler soil temperatures associated with heavy mulch covers. Before definitive statements on stand reductions are possible, the seed must be examined for evidence of attack by a pest(s).

The following discussion addresses some of the seed/seedling pests of major concern in crops grown using conservation-tillage practices in the southeastern U.S. No attempt will be made to identify specific pesticides, as new and more effective chemicals are continually being developed. Current pesticide recommendations can be obtained from publications of your Cooperative Extension Service.

Southern Corn Billbug, *Sphenophorus callosus* (Oliver). As a major pest of corn. the southern corn billbug causes significantly greater losses in no-tillage than conventional-tillage systems (All et al. 1983). Adult southern corn billbugs feed in the pith/meristem of corn and produce symptoms varying from mild foliage perforations to severe stunting and death of seedlings (Metcalf 1917). Stage of plant growth when feeding occurs and the length of time billbugs have access to a feeding site are important in determining the degree of damage that will occur (Durant 1982). However, factors that promote vigorous seedling growth increase tolerance to billbug feeding. Fast-growing seedlings can "outgrow" moderate billbug damage. Larval survival is low on later plant-growth stages (Wright et al. 1983).

Southern corn billbug adults are active at the time of corn planting, and highest populations in conventional-tillage systems are associated with unplowed weedy areas near fields (Metcalf 1917). In continuous no-tillage systems, spring populations of billbugs in corn are associated with weeds and corn debris from the previous season. In double-cropping systems with corn following a small grain, the spring generation of billbugs occurs in the small grain and infests corn after it is planted (All et al. 1983; All, unpublished data).

Various management techniques suppress billbugs in conservation-tillage systems. Cornfields with a history of southern corn billbug problems should not be planted using no-tillage practices unless billbug populations have been reduced by other control measures, such as insecticides. The southern corn billbug does not attack legumes; thus crop rotations with these crops should be considered. The use of subsoiling in fields with hardpan layers aids plant recovery from billbug feeding, especially under drought conditions. When billbug infestations are high, insecticide applications used in conjunction with subsoiling in no-tillage systems act synergistically to improve corn growth and yield and reduce damage (All and Jellum 1977, All et al. **1983).**

Corn Root Aphid, Anuraphis maidiradicis (Forbes), and the Cornfield Ant, Lasius allenus (Forster). The corn root aphid and attendant ants are one of the most interesting pest complexes in nature. Gregory (1974) considered the corn root aphid to be the most important pest of no-tillage corn in Kentucky.

The honeydew secreted by the corn root aphid during feeding is collected by the ants. The aphid feeds on a variety of grasses, but it appears to prefer corn. The ants often move aphids considerable distances in the spring to establish them on corn. Young corn plants, may wither and die, especially under drought conditions. Gregory (1974) reported stand losses exceeding 50% in some fields, although conventional-tillage corn also has been severely infested. Most infestations in conservation-tillage were associated with corn planted in grass sods or with areas that have not been planted in field crops for several years. It is unclear if the no-tillage habitat per se favors outbreaks.

Growers in regions with historically serious corn root aphid problems should be cautious when using no-tillage systems for the first time, especially when fields have laid fallow for one or more years. In these situations, a thorough examination of the field for ant mounds is recommended. Because early-spring deep-tillage operations disrupt and destroy the ant nests in fields with high ant populations, conventional-tillage in ant- and aphid-infested regions should be considered for one or two years before initiating a no-tillage program, Selection of a nonhost crop, such as soybeans, also may be advisable for high-risk areas. Highly effective insecticides are available.

Sugarcane Beetle, Euetheola rugiceps (LeConte). Severe infestations in corn by The suqarcane beetle have been observed in conservation-tillaqe systems (J. N. All, unpublished data). Although the biology of the sugarcane beetle is not well known, infestations in conventional-tillage systems are usually associated with crops grown in freshly tilled sod fields or fields high in organic matter. Affected seedlings wither and die as **if** drought-stricken. Examination of dying plants reveals large gouge-like wounds in the pith tissue, usually at or slightly below the soil surface. Heavy beetle infestations have been observed in crops using both no-tillage or conventional-tillage systems. In general, heaviest damage is located adjacent to wooded areas and/or pastures. In double-crop systems utilizing conservation-tillage methods, small grains may serve as larval hosts from which adults emerge and attack corn.

At present, the hazard of the sugarcane beetle as a major pest in conservation-tillage systems is not clearly established. However, caution should be exercised when any crop is planted following a pasture or in other sods where high larval populations have been observed. Deep plowing is recommended for recurring sugarcane beetle infestations. Little information is available on the efficacy of insecticides against this pest.

Lesser Cornstalk Borer, Elasmopalpus lignosellus (Zeller). This insect is a significant pest of many major field crops in the southern United States. Losses to lesser cornstalk borer are high in conventional-tillage and certain conservation-tillage systems (i.e., especially those using various disking systems). No-tillage cropping systems are considered an effective management strategy for this pest (All and Gallaher 1976; All 1978, 1979a; All et al. 1982).

The lesser cornstalk borer has a semisubterranean biology. Larvae attack many crops including corn, sorghum, or soybeans. Devastating infestations have occurred in these field crops especially if droughty weather occurs for several weeks after planting. In similar environmental situations, damage is often greatly reduced if the second field crop is planted using the no-tillage system (All 1978). Lesser cornstalk borers are polyphagous, and larvae are often present in small grains or weeds when fields are plowed (All and Gallaher 1977; All et al. 1979). The disking operations either bury or chopup plant residues, leaving them exposed for rapid desiccation. These tillage operations have little, if any, impact on the resident lesser cornstalk borer populations; therefore, larvae are present in the field and attack the second crop as soon as it germinates.

The lesser cornstalk borer is a semisaprophagous insect that is capable of completing its development on plant residues in no-tillage systems (Cheshire and All 1979a, b). Although resident populations are present in no-tillage situations, they seem to be, in effect, deterred from feeding on the germinating field crop because of the abundant food source in the surrounding environment (All 1980b). Use of no-tillage practices, whenever feasible, in double-cropping systems using corn, sorghum or soybeans following harvest of small grains would avoid damaging populations of the lesser cornstalk borer. If conventional-tillage or more intensive conservation-tillage operations are followed, planting should be delayed for at least two weeks to allow resident populations of the lesser cornstalk borer to complete development and leave the area or to succumb to starvation. Because soybeans have consistently lower infestations of this pest (Rogers and All 1982), they should be given high priority in double-cropping systems when damage from lesser cornstalk borer is likely.

Insecticides may be used to control lesser cornstalk borer infestations (All et al. 1979; All 1979b; Gardner and All 1982). However, acceptable control is difficult to achieve, especially under dry soil conditions (Tippins 1982).

Other Seed/Seedling Pests. In areas other than the southeastern U.S. a variety of other pests occur in crops grown using conservation-tillage systems. The armyworm (Pseudalatia unipuncta (Haworth)) is a serious problem in conservation-tillage systems for corn production in the north-central U.S., especially when a rye cover crop precedes corn planting (Musick and Petty 1973, Wrenn 1975). Maggots (Musick and Beasley 1978), stalk borer (Musick and Beasley 1978, Stinner et al. 1984), corn rootworms (Kirk et al. 1968, Musick and Collins 1971, Chaing et al. 1971, Gregory and Musick 1976), slugs (Musick and Petty 1973) and rodents (Beasley and McKibben 1976) also have been problems in conservation-tillage systems of corn production. The black cutworm (Agrotis ipsilon (Hufnagel)) on corn (Musick and Beasley 1978) and cotton (Dumas 1983) and the variegated cutworm on cotton (Gaylor unpublished data) have posed sporadic problems. Wireworms (Gregory 1974, Edwards 1975, Musick and Beasley 1978) also have caused occasional sporadic problems on several crops in the north-central and northwestern **U.S.** White grubs (Musick and Petty 1973, Gregory 1974, Rivers et al. 1977) have damaged several crops in many regions of the U.S. Birds (J. N. All, unpublished data) have been pests on several crops using conservation-tillage systems of crop production.

POSTSEEDLING PESTS. Several pests attack crops following seedling establishment and infest the plant throughout the vegetative, fruiting and maturation stages. In general, the hazard from infestations by pests in this group is similar in all tillage systems. Information currently available indicates that the survey methods, action thresholds and control procedures developed for these pests in conventional-tillage systems are readily adaptable to conservation-tillage systems, but field studies are required to verify the extent of the problem for each pest/crop situation.

Corn Earworm, *Heliothis* zea (Boddie). The corn earworm is a major pest of corn and other field crops (soybeans, small grains, etc.) when conservation-tillage production systems are followed.

Increases in injury from the corn earworm in corn have not been observed in conservation-tillage systems, except when crops are planted later than normal (All and Gallaher 1976). Roach (1981a) reported that *Heliothis* spp. populations were similar in comparisons of conservation-tillage and conventional-tillage systems in cotton and tobacco. However, he found that greater numbers of moths emerged from the conservation-tillage plots (Roach 1981b). Serious damage from the corn earworm has occurred on corn and sorghum planted as the second crop in a double-cropping system (All 1980a).

Concern has been expressed that several insects, like the corn earworm, will be favored in conservation-tillaqe systems because pupation sites are not destroyed by tillage and because ground cover provides protection from natural enemies (Hoards 1970, Watson et al. 1974, Roach 1981b). This has not occurred probably because higher populations of natural enemies occur in conservation-tillage. The level of predation of pupating earworms appears to be higher in conservation-tillage. Also, *Heliothis* spp. pests feed on a wide variety of crop plants and have a strong migratory behavior. Dispersal patterns from conservation-tillage fields appear to be similar to that from conventional-tillage fields.

Crop selection is a wise pest-management consideration for corn earworm control in certain conservation-tillage systems such as double-cropping, where late planting dates often cannot be avoided. Soybean as the second crop would receive substantially less damage from late-season earworm populations than would corn or sorghum as the second crop (All and Rogers 1983). A wide variety of effective insecticides are available for control of earworm infestations (All 1979c). The use of insecticides particularly in corn is not always economical due to an unfavorable cost/benefit relationship as a result of low crop value and/or the necessity for multiple applications.

Grasshoppers, Redlegged Grasshopper, Melanoplus femurrubrum (DeGeer); Differential Grasshopper, Melanoplus differentialis (Thomas); Migratory Grasshopper, Melanoplus sanguinipes (Fabricius), etc. Recent studies indicate that grasshoppers may be a significant problem in certain conservation-tillage systems (Sloderbeck and Edwards 1979, D. A. Crossley, Inst. of Ecology, University of Georgia, Athens, personal communication, Aug. 1983). Grasshoppers are the paradigm of grazing insects. Crop decimations by these pests are well known throughout the world. Grasshopper infestations in conservation-tillage systems have been reported for double-cropping systems where corn, sorghum or soybeans follow small grains in a rotation. Although no major outbreaks of grasshoppers in large-scale conservation-tillage operations have been reported, the potential should be recognized in order to avoid the devastations from grasshoppers.

In double-cropping systems, close examination of fields during the germination and seedling phase of the second crop following small grains should be made, especially in areas with periodic grasshopper outbreaks. Action thresholds vary with crops, grasshopper species and region. Information developed for conventional-tillage crops in a particular region should be applicable to conservation-tillage systems. Occasional intensive-tillage operations may be required in some regions to reduce the numbers of overwintering eggs. Grasshopper populations tend to build up in weedy habitats and migrate into crops; thus good early-season weed control in the areas adjacent to crop fields and in small grains may be beneficial. Resistant varieties of sorghum should be selected over nonresistant corn or soybeans if this rotation is compatible with the farm-production program. Grasshoppers can be controlled with a variety of insecticides.

Sorghum Midge, Contarinia sorghicola (Coquillett). The sorghum midge is a major pest of sorghum in many areas of the world. In direct comparisons midge damage in conservation-tillage systems is usually similar (J. N. All, unpublished data) to that observed in conventional-tillage systems. In conservation-tillage sorghum midge outbreaks have been observed in double-cropping situations where sorghum was planted late. Also, heavy infestations have occurred in no-tillage systems where johnsongrass, control is poor and moderate to high johnsongrass levels were present during the sorghum fruiting period. Johnsongrass is attacked by the sorghum midge and has been implicated as an early-season host of overwintering populations. In many areas, the flowering of johnsongrass coincides with peak midge emergence in the spring and is an important factor in promoting the development of damaging midge infestations in sorghum (Roth and Pitre 1975).

Control of johnsongrass and early planting of sorghum have proved to be effective in conventional-tillage systems and should be utilized in conservation-tillage sorghum where possible. Because early planting may not be feasible in certain conservation-tillage systems (i.e., double-cropping), the selection of short-season and uniform-flowering sorghum varieties should be helpful.

Sorghum midge adults are vulnerable to several insecticides. An insecticide program for midge control may be necessary in areas with a history of midge outbreaks. Spray applications of insecticides must be made during the period of sorghum flowering when adult midges are active (Huddleston et al. 1972).

Fall Armyworm, Spodoptera frugiperda (J. E. Smith). Damage from the fall armyworm is similar to that from the corn earworm in many respects. The fall armyworm has a strong migratory habit, and in many areas-of the United States damage increases greatly as the growing season progresses. Devastating infestations have occurred in both corn and sorghum. But, like the corn earworm, high population levels are influenced more by late planting than by the tillage system.

Moths lay batches of eggs on foliage, and during outbreaks larvae quickly devour seedlings, leaving only a stub. **If** infestations occur when corn is silking, up to six larvae can be found in an ear, often reducing the ear to pulp (Sparks 1979). In the South, the fall armyworm is considered a limiting factor to the efficient production of corn in double-cropping systems. Direct comparisons of no-tillage and conventional-tillage systems associated with double-cropping practices indicate that infestations were initiated sooner on young corn seedlings in the conventional-tillage system (All 1980b). Little damage was observed in no-tillage systems while the seedlings were growing within the small-grain stubble. However, as the seedlings grew and became exposed above the mulch, infestations occurred rapidly and damage to older corn seedlings was equal to that observed in the conventional-tillage system.

If feasible, late plantings should be avoided to reduce fall armyworm damage. In double-cropping conservation-tillage systems where fall armyworm hazards are high, crop selection is important. Soybeans and other legumes are less preferred by fall armyworm than grass crops. Of the grasses, sorghum is less vulnerable than corn. Because damaging infestations occur rapidly, early detection of fall armyworm populations is especially important. A reliable, yet inexpensive, method of determining the onset of fall armyworm infestations is placement of red surveyor's flags in susceptible crops. Moths readily oviposit on these flags, and infestations can be detected before serious feeding damage commences (Thomson and All 1982). Insecticides that are effective in conventional-tillage systems are equally efficacious in conservation-tillage systems (All 1980a).

Virus Diseases. The two major virus diseases, maize chlorotic dwarf and maize dwarf mosaic, can be serious problems in conservation-tillage systems (All 1983) of corn production. The epidemiology of these diseases involves the interaction of the vectors, the pathogens, and the overwintering weed host of the pathogens, johnsongrass. This represents a unique multifaceted challenge for pest management (All et al. 1981, All 1983).

Maize chlorotic dwarf and maize dwarf mosaic both profoundly affect corn growth. The most striking symptom of both diseases is stunting of plants, often resulting in severe yield reductions. Maize chlorotic dwarf virus is transmitted by leafhoppers, particularly the black-faced leafhopper, Graminella nigrifrons Forbes. Maize dwarf mosaic virus is vectored by several species of aphids. Both diseases overwinter in rhizomes of johnsongrass, which is the only perennial host of these viruses.

The presence or abundance of the vectors and presence of the overwintering host of the pathogens, johnsongrass, at various times in the season influence the rate at which disease is spread within fields. An additional and highly important aspect of the impact of these diseases is the time when the infection occurs in corn. In general the younger the plant at inoculation, the greater the severity of the disease(s) and the loss in yield.

A variety of management strategies for maize chlorotic dwarf and maize dwarf mosaic may be considered. The objective is to disrupt one or more links in the virus/vector/johnsongrass/corn interaction. Corn hybrids with moderate to high tolerance for the diseases are available. Some systemic insecticides, applied at planting, effectively control the leafhopper vectors of maize chlorotic dwarf and result in reduced disease loss (All et al. 1976, 1977; All and Alverson 1979). These systemic insecticides, although effective against aphids, are not effective in reducing transmission of maize dwarf mosaic (Kuhn et al. 1975). Early planting of corn results in reduced disease incidence because large vector populations are avoided. Also, irrigation and optimum fertilization practices are useful in aiding tolerance of corn to the diseases. The threshold for reducing johnsongrass populations to minimize the incidence of the virus diseases is lower than the threshold to eliminate **it** as a weed pest. Therefore, crop rotation with a noncereal crop, like soybeans, may be advisable in situations where a history of the virus disease and johnsongrass coexist. This tactic has special merit since over-the-top herbicides can be used throughout the season in soybean fields to eradicate johnsongrass, and disease-free corn production may be possible during subsequent years (All 1983).

The optimum management strategy for maize chlorotic dwarf and maize dwarf mosaic in conservation-tillage systems is a program utilizing all of the tactics outlined. However, cost/benefit relationships indicate that disease-resistant hybrids and early planting are the most efficient management strategies for these diseases. At-planting applications of systemic insecticides in combination with these tactics may be justified when disease levels are high or when the pesticide also is used for other pests that are present (All 1983).

Miscellaneous Postseedling Pests. Several other insect pests attack postseedling stages of crops and are potentially damaging in conservation-tillage plantings. Limited research data are available on the relative impact of some of these pests in conservation-tillage systems, but their biologies in conventional-tillage systems suggest that the impact of these pests may be important. The southwestern corn borer, Diatraea grandiosella (Dyar), and the southern cornstalk borer, Diatraea crambidoides (Grote), have been observed at low levels in continuous no-tillage cornfields (Gregory and Musick 1976; All and Gallaher 1976). Various defoliating pests such as the soybean looper, Pseudoplusia includens (Walker), the green cloverworm, Plathypena scabra (Fabricius), the velvetbean caterpillar, Anticarsia gemmatalis Huebner, and several species of armyworm occur on conservation-tillage crops at about the same intensity as in conventional-tillage. Mexican bean beetle, Epilachna varivestis Mulsant, populations were reduced in soybeans planted in no-tillage systems compared directly to conventional-tillage (Sloderbeck and Edwards 1979). The chinch bug, Blissus leucopterus leucopterus (Say), has been observed intermittently in double-cropping systems of no-tillage corn planted after harvest of small grains for silage or grain.

Bird problems occur in harvest-stage crops. Damage to corn is common, and bird losses in sorghum can be tremendous in conservation-tillage systems. However, observation indicates that bird problems in harvest-stage crops are similar in conventional-tillage and conservation-tillage systems (J. N. All, unpublished data).

BIOLOGICAL CONTROL. The environment near the soil surface in conservation-tillage systems provides a habitat that supports higher numbers and a greater diversity of arthropods than does conventional-tillage systems. Many of these arthropods, particularly spiders and Carabidae and Staphylinidae beetles, are predatory on many pest insects (House and All 1981; Blumberg and Crossley 1982; McPherson et al. 1982; House and Stinner 1983). When high populations of predators are present in conservation-tillage fields at the time crops are germinating and becoming established, reduction in damage by seed/seedling pests has been substantial. The actual role of predatory arthropods in controlling pests in conservation-tillage systems needs further study. The process involves a complex interaction between many abiotic and biotic factors in the unique environment of a particular conservation-tillage system. It is becoming increasingly evident that these predatory arthropods aid in preventing outbreaks of pests in crops produced using conservation-tillage systems.

Increased moisture, reduced temperature and reduced lighting occur within the mulch residues and on the soil surfaces under conservation-tillage systems. Such conditions are more favorable for the development of certain disease epizootics in pest populations (Burges and Hussey 1971). Several insect pathogens, especially fungi and entomophilic nematodes and perhaps viruses and bacteria, may be enhanced in conservation-tillage habitats. Higher populations of entomophilic rhabditoid nematodes were observed in no-tillage as compared to conventional-tillage sorghum (M. C. Saunders and J. N. All, unpublished data). Additional research is needed on the influence of conservation-tillage systems on insect pathogens.

CONCLUSIONS. Insect pest management in conservation-tillage systems is complex. Current knowledge indicates that some pests may behave differently in conservation-tillage systems than in conventional-tillage systems. However, management strategies still involve long-standing principles of applied entomology. The entomologist's challenge has been and still is to develop management programs based on the biological idiosyncrasies of the insect/crop/environment interaction. When anxiety and ignorance about the impact of conservation-tillage on pest problems are eliminated, management strategies can be developed. In conservation-tillage systems it is apparent that many of the pest-management strategies that have been developed for specific pests in conventional-tillage systems are readily adaptable to conservation-tillage systems. In certain situations, such as with cutworms, wireworms, aphid-ant complexes, slugs, rodents and birds, new pest-management strategies must be developed. Generally, agronomic practices that promote rapid growth and establishment of the crop for specific site conditions (i.e., soil type, fertility, hybrids) are important. The depredation of pests is minimized when optimal growing conditions occur.

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Cover-Crop Effects on Billbug Damage to Seedling Corn and Sorghum in Conservation Tillage Systems

Wayne A. Gardner and John N. All

Department of Entomology, University of Georgia College of Agriculture, Athens, GA 30602

Research quantifying the effects of tillage on the incidence of crop pests has demonstrated that insect pest problems are generally higher in conservation tillage than in conventional tillage. For example, green cloverworms *(Plathypena scabra)* and seedcorn maggots *(Hylemya platura)* have caused more damage to conservation tillage than conventional tillage soybeans in the Midwest (Sloderbeck and Yeargan 1983, Funderburk et al. 1983). In South Carolina, Roach (1981) observed 4.4X more corn earworm *(Hellothis zea)* and tobacco budworm *(H. virescens)* moths emerging from no-till plots than from conventional till plots. The tillage operation itself apparently injures and kills many insects while increasing the exposure of others to natural predation. Crop residues, decaying organic matter, and weeds also attract insects, thereby, increasing pest infestations.

However, utilization of conservation tillage technology, especially in multiple-cropping systems, can reduce labor expenses, eliminate moisture loss associated with tillage at planting time, reduce soil erosion, and maximize land use. Predictions indicate that more than 65% of the acreage planted in the seven major grain crops will be under conservation tillage in the United States by the year 2000. The use of cool-season legumes in multiple-cropping conservation tillage production to restore crop productivity on eroded soils is a high priority and is increasing in popularity.

The suitability of selected legumes in these production systems depends at least partially on the relative susceptibility of the cover crop to pest damage and the influence of the cover crop on the incidence of pests in the following crop. In gathering descriptive data on the role of this latter factor in corn and grain sorghum production, we observed considerable damage by billbugs (Coleoptera: Curculionidae) to seedling corn and sorghum following Crimson clover.

Two separate tests spanning three cropping seasons examined the amount of damage to the grain crop caused by the southern corn billbug *(Sphenophorus callosus)* in response to clover crop residue management practices and to the type of cover crop. Test 1 was conducted in 1979 and 1980 on the 8ledsoe Research Farm near Griffin, Georgia. Crimson clover served as the winter crop. After crop maturity, the clover was cut and removed from one-half of the plots, while the clover was killed and utilized as mulch in remaining plots. Grain sorghum was then planted by conservation tillage. Test 2 was conducted on the Southeast Georgia Station in Midville in 1983. Corn was planted into either Crimson clover, hairy vetch, or winter fallow after killing the previous cover.

In Test 1, billbug adults damaged approximately 16% of the sorghum seedlings in areas in which the clover residue remained as mulch. Only 2% of the stand was damaged in the areas from which the residue was removed. Billbug damage in this test was sublethal with a characteristic transverse pattern of holes in emerged leaves and some deformed plant parts on the damaged plants.

In Test 2, plant damage was often lethal with a greater percentage of the stand affected in corn following clover than in corn following vetch or winter fallow (Table 1).

Table 1. Effect of Winter Cover Crop on Billbug Damage to Conservation Tillage Corn. Midville. GA, 1983.

Winter Cover Crop	% Corn Plants Damaged	Cover Crop Residue (kg dry matter/ha).
Fallow	22.2	-
Clover	47.4	3846
Vetch	28.6	2346

Factors responsible for the increased damage by billbugs to seedling corn and sorghum in clover mulch have not been fully ascertained. Based upon biological information on billbugs, this response apparently is not due to a selective preference of clover **as** an overwintering or feeding site. Billbugs usually overwinter as adults at the edges of crop fields and seldom in crop stubble. In addition, their host range is extremely restricted (Wright et al. 1982). Although adults feed on a variety of host plants and females oviposit on at least six plant species, larvae are able to complete development on corn and yellow nutsedge only (Table 2). Feeding and oviposition do not occur on either soybeans or peanuts. Therefore, billbugs do not overwinter in the cover crop and, in general, do not feed **OR** legumes.

However, the increased billbug activity in the clover mulch could be correlated with crop residue on the soil surface when overwintered adults disperse into crop fields. (Dispersal is primarily accomplished by walking; adults seldom fly.) In Test 1, the damage was greater in mulched areas than in areas from which the residue had been removed. In Test 2, more residue was produced by the clover than the vetch (Table 2). Due to their sedentary nature, overwintered adult billbugs may be attracted to areas with crop residue and subsequently feed on susceptible host plants.

Table 2. Host Range of the Southern Corn Billbug

Plant	Adult Feeding	Oviposition	Larval Development
Field corn	+++	+++	+
Yellow nutsedge	+++	+++	+
Grain sorghum	++	+	-
Sudangrass	++	+	-
Sudax	++	+	-
Johnsongrass	++	+	-
Fall panicum	+	-	-
Giant foxtail	+	-	-
Kenaf	+	-	-
Giant cane	+	-	-
Pennsylv. smartweed	+	-	-
Peanut	-	-	-
Soybean	-	-	-

From Wright et al. (1982).

Due to its restricted host range and its sedentary nature, crop rotation between host and nonhost crops is recommended as a primary tactic in managing the billbug. Early planting and proper fertilization of susceptible crops are recommended to promote rapid seedling growth in order to reduce the period of overlap between plant stages that are susceptible to damage (i.e., seedlings) and the time of adult billbug activity. However, when the risk of billbug infestation is high (i.e., susceptible crop, late planting date, previous infestations in the same field, etc.), several insecticides labelled for use against the billbug are available for application at planting time.

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Disease
Control and Management

Effect of Tillage on Take-All of Wheat

Craig S. Rothrock

Department of Plant Pathology. University of Georgia, Georgia Experiment Station. Experiment, GA 30212

Take-all of wheat, caused by Gaeumannomyces graminis var. tritici, has become a common disease in recent years in wheat fields throughout Georgia and other states in the Southeast. This fungus is a soil-borne pathogen which infects roots throughout the growing season, resulting in poor growth and premature ripening and thus a reduction in wheat yields. Survival and dissemination of the pathogen is primarily by infested wheat residue from the previous season.

Cultivation technique might be expected to affect root diseases because of the changes in the soil environment and the changes in the distribution of crop residue. The effect of tillage on take-all has been variable. In England, Brooks and Dawson (1968) found take-all severity was less when wheat was drilled directly into wheat stubble than when wheat was planted after cultivation. Novotny and Herman (1981) also reported that tillage increased take-all. Yarham and Norton (1981) observed no differences in disease incidence with different cultivation techniques. In the Pacific Northwest, Moore and Cook (1984) reported that wheat planted following no tillage had more take-all than wheat planted following tillage. Because of the increase in take-all in the Southeast and the discrepancy in the effects of tillage on disease severity, an experiment was established to examine the effect of tillage on disease incidence and severity of take-all.

MATERIALS AND METHODS

Research plots were established in the fall of 1982 at the Bledsoe research farm in Pike County, Georgia, on land doublecropped with wheat and soybean since the fall of 1977. Take-all was observed in the experimental area in the spring of 1982.

The experiment was arranged in a randomized complete block split-split plot design. Tillage treatments were the main plots and were replicated six times. Cropping system and fumigation formed the subplots and sub-subplots, respectively. The two tillage treatments were no tillage and conventional tillage. Conventional tillage consisted of moldboard plowing and disking twice prior to planting wheat and disking or rotavating prior to planting soybean. The two cropping systems were wheat/fallow and wheat/soybean. Subplots were not split into fumigated and nonfumigated plots until the second wheat crop and will not be discussed in this paper. Sub-subplots were 6.1 x 4.6 m. The wheat cultivars McNair 1813 and Stacy were planted on November 9, 1982, and November 23, 1983, respectively.

Take-all was assessed between growth stages 11.1 and 11.2 using Feeke's scale. Ten tillers per plot were randomly selected and washed. Root systems were examined for symptoms of the disease by viewing roots under water against a white background using a stereomicroscope (x10) and the percentage of infected plants recorded. Plants were also rated for the percentage of roots infected; 0 = roots healthy, 1 = lesions on < 25% of the roots, 2 = lesions on 25% to < 50% of the roots, 3 = lesions on 50% to < 75% of the roots, and 4 = lesions on 75% - 100% of the roots. The area of the plots having whiteheads as a result of take-all was calculated by assessing disease at the intersection of one foot grids over the entire plot.

Organic residue was sampled in wheat/fallow plots prior to planting for the 1984-1985 wheat crop. Four subsamples were taken per plot from an area 15 cm in diameter by 15 cm deep. These samples were wet sieved through sieves with openings of 5.6, 2, and 0.7 mm. The residue was then dried and weighed. Surface residue was collected from 0.2 m^2 and weighed.

RESULTS

Take-all was found in both 1983 and 1984. Incidence in 1983 was 28% and increased to 76% in 1984. Disease severity increased similarly from 0.5 in 1983 to 1.8 in 1984. Take-all was not significantly affected by the tillage treatment in 1983 as measured by either disease severity or incidence (Table 1). In 1984, take-all was significantly greater in the conventional tillage treatment. This increase in take-all was found for both the percentage of plants infected and the severity of infection. The increase in take-all with conventional tillage was found under both doublecropping and wheat monoculture, with no differences in take-all being observed between the two cropping systems. The percentage of the plot area with whiteheads as a result of take-all was greater with conventional tillage but was not significantly greater than the no-tillage treatment in either year.

No differences were found between the amount of plant residue sieved from soil under wheat monoculture between the two tillage systems (Table 2). The amount of residue left on the soil surface with no tillage was significantly greater.

DISCUSSION

The effect of tillage on take-all was found to be similar to the effect reported by Brooks and Dawson (1968), with tillage not affecting or increasing take-all. Since G. raminis var. tritici has no spores that are important in the dissemination of the pathogen, infested wheat residue is thought to be the primary source of inoculum. Thus spread of the pathogen is limited to mycelial growth from infested residue and infected roots or physical movement of the residue. In this study, tillage was found to be important in the dissemination of the pathogen and thus disease development, as found by the increase in disease incidence and severity in 1984.

Moore and Cook (1984) found the opposite effect with tillage in the Pacific Northwest. They concluded that the increase in take-all under no tillage was a result of a greater amount of wheat residue at planting and thus a larger amount of inoculum of the pathogen. In this experiment no difference in the amount of residue, and thus inoculum, was found between the two tillage systems. Thus, the only effect of tillage on take-all would be distribution of inoculum in the plots and thus an increase in disease where tillage moved infested residue.

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Table 1. Effects of tillage and cropping system on take-all of wheat

	Incidence(%)[a]		Disease severity[b]		Whiteheads(%)[c]	
Treatment	1983	1984	1983	1984	1983	1984
Tillage						
no	26.7	67.8	0.38	1.35	5.2	16.7
conventional	29.4	84.6	0.55	2.23	11.6	21.1
LSD(P=0.05)	ns	13.7	ns	0.66	ns	ns
Cropping System						
wheat/soybean	-	73.2	-	1.83	-	20.1
wheat/fallow	-	79.2	-	1.75	-	17.7
LSD(P=0.05)		ns		ns		ns

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[a] Incidence assessed as percentage of plants infected in a random sample of 10 plants per plot.

[b] Disease severity index 0-4 where 0=no roots infected and 4=75-100% of roots infected.

[c] Percentage of plot area with whiteheads.

Table 2. Effect of tillage on the amount of organic residue

	Tillage	
Residue	no	conventional
Buried(g/kg)[a]		
large	0.3	0.5
medium	0.4	0.4
small	1.3	0.8[b]
combined	1.9	1.6
Surface(g/m^2)	529.5	1.9[b]

[a] Sieve size (opening); large = 5.6 mm, medium = 2 mm, small = 0.7 mm.

[b] The differences between treatment means for residue samples are significant (P=0.05).

Economics
of
Conservation Tillage

Economics of Conservation Tillage in the Southeast

Lee A. Christensen

Economic Research Service — USDA and Department of Agricultural Economics, University of Georgia

There has been a dramatic shift in tillage technology used in American agriculture over the past 10-15 years. Conventional practices involving the multiple tillage of the soil by plow, disk, harrow, or cultivator have been eliminated or greatly reduced. In its place is a set of practices generally labeled conservation tillage. Several factors are behind this shift, but it is evident that individual farmers have led rather than followed this trend. One major factor contributing to the shift has been the production cost savings associated with conservation tillage.

This paper analyzes the trends in conservation tillage acreage in the southeastern United States and looks at some of the economic factors influencing this trend. It focuses on the factors influencing both total revenues and total costs the two components of the income equation. The paper closes with a look to the future of conservation tillage.

Conservation Tillage--What Is It?

The meaning of the term "conservation tillage" is continually evolving, depending on both regional usage and by whether the extent of soil stiring or amount of remaining residue cover is the distinguishing factor. When the amount of surface area worked is the dominant criteria, no-till has been defined as having up to 25 percent of the surface worked, while conventional tillage has 100 percent of the surface worked (No-Till Farmer). Current emphasis is on the amount of residue cover left on the soil surface after planting. Accordingly, conservation tillage is commonly used to describe situations where at least 30 percent of the residue cover is left on the soil surface after planting.

A broader definition of conservation tillage is "any tillage system that reduces loss of soil or water relative to conventional tillage; often a form of noninversion tillage that retains protective amounts of residue mulch on the surface"[1] Conventional tillage is "the combined

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1/ Accordingly, the no-till and minimum till definitions used in tables 1 and 2 are each considered conservation tillage techniques. The distinction is maintained because that is how the data have been reported.

primary and secondary tillage operations performed in preparing a seedbed for a given crop grown in a given geographical area" (Mannering, p. 141).

Regardless of the definition adopted, it is important to remember that conservation tillage represents a system of farming rather than a specific technique. Accordingly, practices, and equipment need to be selected based on soil and climatological conditions so as to adequately control soil erosion, conserve moisture and accommodate the crops grown. And most important from the farmer's perspective, tillage systems need to be selected which will contribute to sustained farm profitability.

Conservation Tillage Trends in the Southeastern United States

A review of conservation tillage acreage trends in the southeastern United States show how rapidly some of the tillage changes are occurring. Estimates of cropland acreage in no-till, minimum-till, and conventional-till in the southeastern United States are presented in table 1. The area has been subdivided into three farm production regions: Southeast, Appalachia, and Delta. Between 1973 and 1984, acreage in minimum tillage increased about 275 percent in the three combined regions, with the largest relative increase in the Southeast region. Acreage in no-till increased 290 percent in the three regions, with the greatest increase again in the Southeast region. Comparable increases for the United States were 220 percent and 300 percent. Relative to the United States, no-till is on a greater share of cropland acreage for the three regions, but minimum till is on less. The Southeast and Appalachia regions have larger shares of their cropland in no-till and minimum till than the Delta region (table 2).

While data on the use of no-till and conservation tillage systems shows increases in most states in the southeastern United States, the rate of adoption in the Southeast is considerably less than in the Corn Belt States. A USDA nationwide survey found that about 21 percent of the farmers who planted land to crops used conservation tillage. Thirty-eight percent of the Corn Belt farmers used conservation tillage, but in the Southeast and Delta, only 3-4 percent used it, and 12 percent used it in the Applachian region (Magleby). A major reason for this regional difference is that conservation tillage is used primarily to grow corn, soybeans, and small grains, the predominant crops in the Corn Belt.

A USDA survey of 11.000 farmers nationwide provides several insights into adoption of conservation tillage. Farmers have adopted conservation practices for both cost and time savings and soil and water conservation purposes, although without the cost and time savings many would not have initially tried the practice. Most farmers who adopted conservation tillage in 1983 did so without government cost sharing assistance (Magleby).

Table 1--Trends in acreage in no-till, minimum, and conventional tillage systems in the southeastern United States, with national comparisons

State and tillage system[1]	1973	1977	1981	1982	1983	1984
			1,000 acres			
No-till:						
Alabama	17.6	147.8	335.0	430.4	336.7	289.0
Florida	.6	7.0	11.7	25.5	34.9	29.8
Georgia	39.5	113.0	436.4	465.4	445.4	308.8
South Carolina	12.0	21.7	135.4	161.2	153.2	124.3
Southeast region	69.7	289.5	918.5	1,082.5	970.2	751.9
Kentucky	837.6	988.7	1,170.0	1,475.5	1,024.4	1,104.1
North Carolina	160.5	362.0	370.0	467.0	512.0	650.0
Tennessee	44.7	195.7	419.0	449.2	520.0	563.2
Virginia	258.2	343.2	591.0	594.5	527.2	642.6
Appalachia region	1,301.0	1,889.6	2,550.0	2,986.2	2,583.6	2,959.9
Arkansas	.4	0.8	23.2	64.0	66.3	81.2
Louisiana	5.8	3.0	30.0	17.6	29.1	73.0
Mississippi	8.6	95.3	126.5	164.0	142.5	172.2
Delta region	14.8	99.1	179.7	245.6	237.9	326.4
Three region total	1,385.5	2,278.2	3,648.2	4,314.3	3,791.7	4,038.2
U.S. total	4,875.8	7,271.7	9,185.2	11,571.9	11,745.5	14,758.6
Minimum:						
Alabama	16.5	194.6	814.0	1,174.8	545.1	607.0
Florida	34.0	20.0	91.0	217.6	225.7	597.5
Georgia	50.6	1,745.0	3,810.0	3,510.0	1,962.9	2,102.3
South Carolina	783.5	1,455.0	991.0	890.0	171.5	82.1
Southeast region	884.6	3,414.6	5,706.0	5,792.4	2,905.2	3,388.9
Kentucky	1,552.2	1,943.2	1,021.0	1,387.5	1,194.5	1,574.4
North Carolina	578.4	625.9	1,481.0	2,638.0	2,850.0	1,297.6
Tennessee	--	533.0	716.0	741.0	1,057.5	1,020.4
Virginia	370.0	383.8	520.0	642.5	462.8	558.8
Applachia region	2,500.6	3,485.9	3,744.0	5,409.0	5,564.8	4,451.2
Arkansas	.6	234.0	330.0	1,019.8	1,023.0	776.5
Louisiana	65.0	536.0	670.0	690.0	647.1	441.4
Mississippi	40.2	393.0	1,612.5	4,512.0	1,698.0	528.4
Delta region	105.8	1,163.0	2,612.5	6,221.8	3,368.1	1,746.3
Three region total	3,491.0	8,063.5	12,062.5	17,423.2	11,838.1	9,586.4
U.S. total	39,062.8	62,732.2	89,768.0	100,309.9	79,583.2	85,495.2

Continued

Table 1--Trends in acreage in no-till, minimum, and conventional tillage systems in the southeastern United States with national comparisons – Continued

State and tillage system[1]	1973	1977	1981	1982	1983	1984
			1,000 acres			
Conventional:						
Alabama	2,705.0	3,652.6	3,080.0	2,778.2	2,385.8	3,068.2
Florida	1,078.8	1,186.5	933.5	813.2	1,077.7	3,755.6
Georgia	3,571.5	3,601.0	839.0	1,430.0	3,716.7	3,533.0
South Carolina	1,568.5	1,271.0	1,815.0	2,142.4	2,088.8	2,857.1
Southeast region	8,923.8	9,711.1	6,667.5	7,163.a	9,269.0	13,213.9
Kentucky	539.5	884.8	2,437.0	1,485.0	1,348.3	2,546.0
North Carolina	3,079.3	3,277.2	3,162.0	2,860.0	2,560.0	3,233.7
Tennessee	3,222.5	1,979.0	2,944.0	2,840.0	2,699.8	3,638.4
Virginia	1,518.7	1,077.1	1,001.3	895.0	1,424.6	1,355.3
Appalachia region	8,360.0	7,218.1	9,544.3	8,080.0	8,032.7	10,773.4
Arkansas	6,413.0	7,241.1	7,802.0	3,793.8	3,796.0	7,736.2
Louisiana	3,044.2	3,109.0	3,893.0	4,005.0	4,237.0	4,493.9
Mississippi	4,196.0	5,259.9	2,220.0	1,430.0	4,252.5	5,334.0
Delta region	13,653.2	15,610.0	13.915.0	9,228.8	12,285.5	17,564.1
Three region total	30,937.0	32,539.2	30,126.8	24,472.6	29,587.2	41,551.4
U.S. total	203,991.2	228,631.0	218,326.8	204,175.3	205,049.5	231,302.2

-- = No data

[1] Definitions used are: No-till – where only the intermediate seed zone is prepared. Up to 25 percent of the surface area could be worked. Could be no-till, till-plant, chisel-plant, rotary strip tillage, etc. Includes many forms of conservation tillage and mulch tillage. Minimum tillage – limited tillage, but where the total field surface is still worked by tillage equipment. Conventional tillage – where 100 percent of the topsoil is mixed or inverted, by plowing, power tiller, or multiple diskings.

Source: *No-Till Farmer*. March 1974, 1978, 1982, 1983, 1984, and 1985.

Table 2--Relative distribution of acreage in no-till, minimum-till, and conventional-till, in the southeastern United States, 1973, 1977, 1981, 1982, 1983, and 1984[1/]

	1973	1977	1981	1982	1983	1984
	Percent of total cropland					
Southeast region						
No-till	0.7	2.2	6.9	7.7	7.4	4.3
Minimum-till	9.0	25.4	42.9	41.3	22.1	19.5
Conventional-till	90.3	72.4	50.2	51.0	70.5	76.2
	100.0	100.0	100.0	100.0	100.0	100.0
Appalachia region						
No-till	10.7	15.0	16.1	18.1	16.0	16.3
Minimum-till	20.6	27.7	23.6	32.8	34.4	24.5
Conventional-till	68.7	57.3	60.3	49.1	49.6	59.2
	100.0	100.0	100.0	100.0	100.0	100.0
Delta region						
No-till	.1	.6	1.1	1.6	1.5	1.7
Minimum-till	.8	6.9	15.6	39.6	21.2	8.9
Conventional-till	99.1	92.5	83.3	58.8	77.3	89.4
	100.0	100.0	100.0	100.0	100.0	100.0
Three region total						
No-till	3.9	5.3	8.0	9.3	8.4	7.3
Minimum-till	9.7	18.8	26.3	37.7	26.2	17.4
Conventional-till	86.4	75.9	65.7	53.0	65.4	75.3
	100.0	100.0	100.0	100.0	100.0	100.0
U.S. Total						
No-till	2.0	2.4	2.9	3.7	3.9	4.4
Minimum-till	15.8	21.0	28.3	31.7	26.9	25.8
Conventional-till	82.2	76.6	68.8	64.6	69.2	69.8
	100.0	100.0	100.0	100.0	100.0	100.0

[1/] Source: Data in table 1.

Economics of Conservation Tillage Systems in the Southeast

Profitability is an important factor influencing the adoption of conservation tillage technology. Information is available from research studies and field observation to aid farmers in evaluating changes in yields and changes in various inputs associated with conservation tillage. Several assessments of the impacts on yields and resource use have been completed, and indicate the great variability which exists (Crosson, Christensen).

It is necessary to take both a short- and long-run perspective when assessing the profitability of a conservation tillage system. It is also important to think in terms of impact on net revenues rather than total or gross revenues. Even if yield reductions are associated with a conservation tillage system, profits may remain about the same because of reduced input costs. Thus no system should automatically be ruled inferior just because of lower yields. Yields impact the gross revenue side of the profit equation, but the determinants of net operating profitability are both gross revenues and total variable input costs.

Let's consider for a moment what research results indicate about conservation tillage and yield impacts and major input requirements. Input costs are separated into energy use requirements, labor use requirements, fertilizer and pesticide use and equipment investment costs.

Impacts on Yields of Conservation Tillage Systems. Yield differences associated with tillage methods depend upon the crop and specific location. In general, conservation tillage systems perform better with respect to yields in areas with long growing seasons, which describes most of the Southeast. Nine years of data from a Tennessee experiment shows an average yield of 36 bushels of soybeans per conventionally till acre compared to 32 bushels of a no-till (Hayes, p. 8). Yield studies reported at this conference and in proceedings of previous no-till conference provide information showing how tillage and other factors influence yields in the Southeast (Touchton and Stevenson).

Soil suitability is a critical factor in the success or failure of conservation tillage systems, primarily through the interaction of tillage systems and soils on crop yields. It has been noted that conservation tillage techniques are not adaptable to all soils and that they provide a positive response on some soils but not on others (Cosper). Factors most likely to have adverse yield effects with conservation tillage have been associated with inherent physical limitations of particular soils. These include drainage problems, soil wetness levels, structural stability, water percolation, impervious or restrictive layers in the profile, and surface soil texture.

Labor and Management Requirements. Labor savings associated with conservation tillage are normally due to reductions in preharvest labor requirements. Conservation tillage usually requires less labor, primarily because of fewer operations and trips across the field with equipment complements. There may be an offset to this labor savings of higher labor requirements associated with chemical application, but most experiences seem to indicate that any increases are negligible.

It is well recognized that good management is the key to successful farming. This is particularly true in the use of conservation tillage. Conservation tillage systems are more complex to manage than conventional systems. Good managers will generally be able to successfully handle the additional variables associated with conservation tillage. Managers just getting by with conventional systems may get into real problems using conservation tillage systems.

Equipment Investment Costs. Many factors influence the machinery and equipment investment costs for alternative tillage systems. Variables such as location, farm size, and crop rotations make a comparative analysis of investment costs difficult. Much of the literature shows that conservation tillage requires less investment in equipment than conventional conservation tillage. However, many farm operations require both conventional and conservation equipment, making it difficult to make an either/or comparison. Conventional wisdom states that conventional tillage systems require larger or bigger tractors and more tillage equipment for all the operations than does conservation tillage. With conservation tillage alternatives, the moldboard plow, multiple diskings and multiple chisel plowings are replaced with field cultivators, sweeps, single diskings. and chisel plowings. The machine operations used for this alternative are designed to leave some of the crop residue on the soil surface. No-till options generally exclude any tillage equipment, but conventional grain drills and planters are replaced by specially designed no-tillage equipment which prepares narrow slotted seedbed areas during the planting process. Chemical weed control generally replaces cultivation in conservation and no-till alternatives.

Fuel and Lubrication Requirements. One of the most commonly cited economic savings associated with conservation tillane is reduced fuel consumption. Cost savings from lower energy use with conservation tillage can be significant. Fuel use depends on specific field operations as well as soil draft. Fuel consumption varies greatly between operations depending upon soil types, soil moisture, amount and kind of residue from the previous crop, condition of the implement and tractor and the way the tractor is operated. Under most circumstances, conservation tillage uses less fuel than conventional tillage since there are fewer passes over the field and/or less fuel consumptive machine operations. While it is hard to generalize across all situations, literature reviews have found that reduced tillage systems require on the average 3 to 5 less gallons of fuel per acre than conventional tillage systems (Crosson), and a 70 to 90 percent reduction in diesel fuel per acre between no-till and conventional tillage (Christensen).

Pesticide Costs. Conservation tillage systems generally substitute pesticides for machinery operations to control weed, insect, and disease infestations. An important economic consideration for a farmer is the extent to which additional costs for pest control are offset by savings in equipment investments, energy, or labor. While it is generally assumed that more herbicides will be required with a conservation tillage situation, it is not inevitable that there will be an increased use of pesticides with conservation tillage. Application methods can be develop to reduce the quantities used on specific crops, and circumstances. Many of the problems can be reduced with better equipment, guidelines, scouting and monitoring, rotations, and development of more selective chemicals (Crosson). As mechanical cultivation is reduced, additional use of herbicides, insecticides, and fungicides may be needed to control pests. Estimates of chemical requirements with various tillage systems varies greatly between soils, crops, and total management systems. One survey found increases in pesticide use ranging from 14 to 43 percent for conservation tillage compared to conventional tillage (Christensen).

Looking to the Future

What is the future for conservation tillage? Pierre Crosson has suggested that as much as 50-60 percent of U.S cropland may be in conservation tillage by 2010. Others have projected levels as high as 90 percent. The enthusiasm over conservation tillage will continue only where it is found to be technically, economically, and environmentally acceptable. One way to assess the future for conservation tillage is to examine the factors behind the current trends.

Conservation tillage can result in significant reductions in soil erosion while improving the soil medium for agricultural plant growth. Concurrently, it offers an opportunity for farmers to cut production costs. While farmers may want to reduce soil erosion, they are most likely to adopt conservation practices when they contribute to income and other goals (Magleby). Economic evaluations by farmers typically take both a short and long run view. Many conservation programs in the past have focused on long term investments such as terraces and grass waterways. While these programs are good technical practices, their high costs and long payback period often reduce their economic attractiveness. Given the economic pressures that farmers face, short run economic forces generally have the greatest influence on their decisions. It is in this context that conservation tillage is particularly attractive, since it can produce tangible results in the first year of use. In fact, this short run payoff probably explains much of its attractiveness and rapid adoption, and is likely to continue.

The rate of continued adoption of conservation tillage will depend on the amount of acreage with soils suitable for conservation tillage and the changes in factors influencing its profitability. Soil suitability is a major factor in the success or failure of conservation tillage systems primarily through the interaction of tillage systems and soils on crop yields. Conservation tillage is suitable for many soils, but not all.

Conservation tillage has several attractive features. It reduces soil erosion by maintaining cover and reducing soil loss. It typically reduces the amount of fuel and labor required per acre, and in some instances it requires less investment in agricultural equipment. Yield impacts depend on crop and location factors. In general, conservation tillage will work best in areas with longer growing seasons. In dry years it can cause significant moisture savings.

Some of the areas of concern inlcude the ineffectiveness of chemicals to control weeds and insects and increased chemical costs. Typically, it is presumed that the increased costs of chemicals are offset by savings in labor and fuel. It remains to be seen if conservation tillage creates a new dependency on chemicals for agricultural production. A large increase in the price of chemicals relative to labor or fuel could slow the adoption process, and possibly cause a shift to more conventional systems. Conservation tillage requires more management than conventional tillage, particularly for weed, insect, and disease control. One farmer has noted that conservation tillage is a piece of information or tool to aid the farm business, if used properly (Wetherbee). Good managers have the capacity to adjust their operations to the precise requirements of conservation tillage and to use a total systems approach. Average to poor managers may have difficulty in handling the management requirements, and may not adopt or continue conservation tillage practices.

Summary and Conclusions

Public and individual concerns about the impacts of soil erosion on both soil productivity and the environment, combined with economic forces, have stimulated the development and adoption of conservation tillage technologies in the southeastern United States. Its adoption is increasing throughout the region and it is anticipated that this increase will continue. Acreage in conservation tillage in the southeastern region, increased about 180 percent between 1973 and 1984, somewhat faster than the comparable increase of about 130 percent for the entire United States.

The use of conservation tillage is influenced by physical, technical, and economic factors. Conservation tillage is suitable for many soils. but on some it has adverse yield impacts. The interaction of climatic and soil characteristics precludes conservation tillage on some soils. Yields may be impacted slightly if at all, and savings in energy, labor, and machinery costs often exceed increased chemical costs associated with conservation tillage.

Farmers considering conservation tillage will be closely looking at the returns associated with conservation tillage compared to conventional systems as well as the risks which might be associated with the system. They increasingly recognize that conservation tillage is a systems approach to farming which generally requires more management than conventional tillage, particularly with respect to weed, disease, and insect control.

Pressures to reduce production costs and increase net returns will continue to make conservation tillage attractive for farmers in the Southeast. It will not work on all soils or for all managers, but it is an approach to farming which can improve individual farm income and at the same time contribute to the goals of soil conservation and the improvement of water quality of the region's lakes and streams. Many of the reasons behind its adoption are expected to continue, but as with all technology, it should be treated as a means to an end, not an end in itself.

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Economic Feasibility of Adopting Conservation Tillage in North Mississippi

Lynn L. Reinschmiedt, Stan R. Spurlock, and Yasmin R. Mustafa

Mississippi Agricultural and Forestry Experiment Station

A key determinant of the private benefits of reducing soil loss by implementing soil conservation practices is the effect of current soil loss on future productivity within an individual farmer's planning horizon. The implementation of soil conservation practices is often a long-term phenomenon requiring sizable investments which do not yield short-term private benefits. Consequently short-run economic situations may dictate that farmers forego potentially feasible investments in soil conservation practices. The purpose of this study was to evaluate the economic feasibility of adopting soil conservation measures taking into consideration the productivity losses associated with erosion over time.

METHODS AND PROCEDURES

Panola county in North-central Mississippi is representative of soil types and erosion problems in north Mississippi. Soil Conservation Service personnel identified Loring and Granada soils as major erosive problem soils currently under intensive row crop production. Cultural practices and tillage systems utilized by farmers and those recommended for the area were identified for soybeans, the major row crop in the area. Based on this information, costs and returns budgets were developed for conventional, no-till, and min-till soybeans. Costs of production, excluding management and land charges, were estimated to be \$147.39, \$156.41, and \$153.16 for conventional, no-till, and min-till soybean production systems using 8-row equipment [Mustafa].

Estimates of various topsoil depth – soybean yield combinations provided by SCS personnel enabled the estimation of topsoil depth-yield curves for Loring and Granada soils [Cook]. the dependent variable, soybean yields (Y), was estimated as a function of inches of topsoil depth (X) for each soil type as follows:

$$\text{Loring:} \quad Y = 7.23 + 1.14X$$
$$\text{Grenada:} \quad Y = 12.42 + .94X$$

Soil losses attributable to conventional, no-till, and min-till soybean production systems for Loring and Grenada soils were estimated with the Universal Soil Loss Equation [USDA, SCS]. These data and additional information on discount rates, soybean prices, yield penalties, and length of planning horizon were used as inputs in a model that estimated and compared the present value of income streams associated with conventional, min-till, and no-till soybean production systems.

The model operates in the following manner for a hypothetical situation. Suppose a farmer has a realistic planning horizon of 20 years and wishes to determine which of two cultural practices, one being more erosive than the other, is desirable over time period specified. The model is designed to answer whether the producer should switch from the more erosive practice to the conservation system in the current time period. As a decision criterion the model calculates the net present value of the income stream for the conventional practice assuming that it is maintained to the end of the planning horizon. Secondly, assuming that the conservation practice is adopted in the current time period and maintained throughout the planning horizon, its net present value of the income stream is calculated. It would be feasible to adopt the conservation practice in the current period if its net present value exceeds that of the more erosive practice. If not, the more erosive practice is determined to be the economically feasible alternative and is maintained in the current year. The process is repeated for each successive year in the designated planning horizon to determine if changes in cultural practices should be made in any year during the planning horizon.

Assumptions and results in the model were varied to account for a lack of knowledge concerning certain variables and to provide a range of scenarios approximating real world situations. Two basic soybean cultural practices were compared: conventional and no-till. Planning horizons of 5, 20, 50, and 100 years were evaluated at discount rates of 5 and 10 percent. To account for uncertainty, yield penalties of 0 and 02 percent were attributed to the no-till system.

Conventionally tilled soybeans as opposed to no-till was the economically preferred choice for all situations evaluated on both Loring and Grenada soils when a 20 percent yield penalty was associated with no-till practices. The no-till system with a 0 percent yield penalty was feasible only for selected situations when a 50 or 100 year planning horizon was considered. These results indicate that the long-term benefits of no-till soybeans are insufficient to encourage farmers to switch from conventional tillage methods under normal circumstances.

SUBSIDIZED PRODUCTION PRACTICES

The preceding conclusion was based upon private costs and benefits attributable to erosion control measures. The effects of erosion, however, impact upon society as a whole and provide the basis for public assistance to encourage farmer adoption of conservation measures [Prato]. Given that society desires erosion reduction, financial inducements may be required to encourage farmer adoption.

The subsidy or cost-share level that would make the conservation tillage system as economically attractive as conventional tillage was estimated for Grenada and Loring soils of varying initial topsoil depths, planning horizons, yield penalties and discount rates. Since results for the two are comparable, discussion will be limited to Grenada soils, Table 1. Figures in Table 1 indicate that a producer with an initial soil depth of 18 inches and a five year planning horizon would require a subsidy of $8.06 per acre for each year in the planning horizon to switch from conventional tillage to no-till in the current year if he expected no-till yields to be compable with conventional. Assuming a 20 percent no-till yield reduction an annual subsidy of $48.97 per acre would be required over the length of the planning horizon. Higher discount rates increase the subsidy required. As shown in Table 1, the required subsidies decrease as the length of planning horizon increases.

The data presented in Table 1 also indicate that if policy makers are looking for the most cost efficient means of reducing erosion to specified levels, something less restrictive than no-till may be desirable. For example, if over-all erosion limits could be met with min-till, the subsidy costs per ton of erosion reduced for the situation previously described could be reduced from 67 cents to 54 cents per ton.

IMPLICATIONS AND CONCLUSIONS

The results presented indicate that given current relative costs of production estimates for conservation and conventional tillage soybeans in north Mississippi and estimated long-term erosion productivity relationships, conservation tillage is not a feasible alternative to the more erosive conventional tillage practices. Estimated subsidy or cost share payments needed to encourage adoption of conservation practices can be substantial depending upon relative yield and cost of production differentials. Given zero yield penalties, the subsidies required are probably not out of line with current cost-share programs in existence. However, it is probably not reasonable to expect public support of subsidy programs of the magnitude implied by this research to encourage adoption of conservation tillage practices. Hence, further research designed to improve yields or reduce costs of conservation tillage systems is essential for farm adoption in north Mississippi.

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Table 1. Annual subsidy requirements needed to switch from conventional tillage to minimum and no-till for selected discount rates, yield penalties, and planning horizons, Grenada Soils, Panola County, Mississippi[1]

Soil Depth	Planning Horizon	5% Discount Rate				10% Discount Rate			
		No-till Yield Penalty		Min-till Yield Penalty		No-till Yield Penalty		Min-till Yield Penalty	
		0%	20%	0%	20%	0%	20%	0%	20%
(inches)	(years)	Dollars/Acre							
18	5	8.06	48.97	5.02	45.89	8.10	49.01	5.05	45.94
		(.67)[2]	(4.08)	(.54)	(4.90)	(.68)	(4.08)	(.54)	(4.89)
	20	5.00	45.79	2.62	43.24	5.71	46.53	3.18	43.85
		(.42)	(3.82)	(.28)	(4.61)	(.48)	(3.88)	(.34)	(4.66)
	50	1.27	41.89	0	39.99	4.15	44.90	1.96	42.50
		(.11)	(3.49)	0	(4.27)	(.35)	(3.74)	(.21)	(4.52)
	100	0	39.76	0	39.22	3.93	44.67	1.79	42.31
		0	(3.31)	0	(4.19)	(.33)	(3.72)	(.19)	(4.50)
12	5	7.58	40.62	4.64	37.62	7.65	40.69	4.7	37.68
		(.43)	(2.28)	(.50)	(2.69)	(.43)	(2.29)	(.34)	(2.69)
	20	3.02	35.86	1.08	33.66	4.08	36.97	1.9	34.58
		(.17)	(2.01)	(.12)	(2.40)	(.22)	(2.08)	(.14)	(2.47)
	50	0	30.06	0	28.82	1.75	34.54	.06	32.55
		0	(1.69)	0	(2.08)	(.10)	(1.94)	0	(2.33)
	100	0	26.88	0	26.17	1.43	34.21	0	32.28
		0	(1.51)	0	(1.87)	(.08)	(.92)	0	(2.31)

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[1] Values were found by calculating the cost differential between conventional and conservation practices which make the present value differences of current year equal to zero.

[2] Values in parentheses represent the cost per ton of reducing erosion with this system.

Conservation Tillage: National, International, and Future Prospects

No-Till in the Lowland Humid Tropics

R. Lal

International Institute of Tropical Agriculture, Ibadan, Nigeria

ABSTRACT

The adaptation of no-till farming in the humid tropics is expected to be useful for soils that are susceptible to accelerated erosion, drought prone due to low plant available water reserves and shallow effective rooting depth, subject to supra-optimal soil temperatures during crop establishment periods, and for those that are of low inherent fertility. The system is adaptable for small- or large-sized farms and has the additional benefits of saving labor and energy, and facilitating multiple cropping. This report reviewssoil and environmental factors that favor the adaptation of no-till system for food crop production.

INTRODUCTION

The total area covered by the lowland humid tropics is about 2600 million ha. Major soils of this ecology are Alfisols, Ultisols and Oxisols. Together these soil orders occupy a vast area of the subhumid and humid tropics. In West Africa, for example, the majority of low activity clay soils are Oxic Alfisols and Ultisols especially in regidns where rainfall exceeds about 1200 mm per annum. The percent surface area in the tropics covered hy Alfisols, Ultisols and Oxisols is 16.2, 11.2 and 22.5 corresponding to 800, 550 and 1100 million hectares, respectively. These soils predominantly contain low activity clays i.e. the clay fraction comprises mostly kaolinite and halloysite with hydrous oxides of iron and aluminum. While in Oxic Alfisols and Ultisols a part of the clay fraction is readily dispersible that in Oxisols is relatively resistant to dispersion.

Constraints to intensive landuse in Alfisols are predominantly physical and comprise low available water holding capacity, and susceptibility to erosion and soil compaction. The drought stress frequently experienced by crops grown on Alfisols is due to low available water reserves and high surface soil temperatures. Accelerated soil erosion is caused partly by the development of crust or an impermeable surface seal. Easily dispersible Oxic Alfisols are particularly vulnerable to crusting and hard setting following extremes of temperature and moisture conditions. Surface custing is further aggravated by the low level of soil organic matter content. In addition to soil physical factors, nitrogen deficiency is also a major problem in Alfisols. In comparison the acidic Ultisols and Oxisols have additional constraints of nutritional disorders due to low pH, deficiencies of major nutrients, and A1 and Mn toxicity. When nutrient imbalance is corrected, however, soil physical constraints limit crop production.

There are two major consequences of severe physical and/or nutritional constraints i.e rapid deterioration in soil properties following new arable land development, and decline in crop yields. These consequences are particularly severe following mechanical land clearing and mechanized farming based on motorized plowing and harrowing and combine harvesting that involve considerable vehicular traffic.

SOIL SURFACE MANAGEMENT

Appropriate soil surface management practices are those that curtail the deterioration in soil properties. Providing a protective vegetation cover on the soil surface and minimizing exposure of soil are obviously desirable. No-till is a system of soil management that, while eliminating all preplanting seedbed preparation, achieves these conditions of minimizing soil exposure and providing crop residue mulch. The more the surface area covered by the crop residue mulch the better the protection it gives to easily dispersible soil beneath. The benefits of mulch farming techniques in relation to plow-based system for these easily dispersed and hard-setting soils are well established. These include improved soil and water conservation, reduced soil compaction, and savings in labor and fuel costs.

Crop response to no-till farming is soil and crop specific. Soil properties that favor the adaptation of no-till farming include the followings:

(i) Coarse-textured surface horizons and in soils with high initial porosity,

(ii) High biological activity of soil fauna e.g. earthworms,

(iii) Friable consistency over a wide range of soil-water contents.

In addition, no-till is naturally suited for those problem soils that are highly susceptible to erosion. With an adequate quantity of crop residue mulch, no-till is an effective measure in reducing soil erosion. The most important consideration is the development of agronomic packages that ensure adequate quantity of crop residue mulch. Some viable systems to procure residue mulch for no-till farming are:

(i) Crop residue mulch:

The use of previous crop residue as mulch is a viable alternative for those rotations and cropping systems where at least one crop produces enough biomass. The use of a grain cereal e.g. maize in rotation with cowpea or'soybean is a workable system for soils where maize can be grown.

(ii) Cover crops and integration with livestock:

A quick growing crop, preferably a legume, is grown to restore soil and to produce mulch in situ. Grain crops are seeded through the chemically or mechanically suppressed mulch without plowing. The practice of growing a food crop through the unsuppressed cover, called live mulch, is feasible only if the latter does not compete for moisture and nutrients and does not smother the grain crop. The desirable characteristics of an appropriate cover crop are (i) ease of establishment, (ii) vigorous growth and rapid establishment of surface cover, (iii) deep rooted, (iv) determinate growth that naturally dies during the dry season, (v) no interference with the crop grown in the following season, and (vi) some economic returns. Ley farming, whereever feasible, is the obvious answer.

(iii) Mixed cropping and integration with woody perennials:

Growing perennial shrubs in associations with food crops and growing more than one crop in the same field simultaneously are also effective conservation measures and preduce the required mulch material. Cropping systems with multicanopy structure and those that provide continuous vegetative cover throughout the year protect the soil against raindrop impact. The cropping systems involving alley cropping, strip cropping, and alternate strips of woody perennilas and annuals, and of mixed cropping are important components of no-till farming.

CROP RESPONSE TO NO-TILL FARMING

Different crops respond differently to the no-till system depending on differences in initial soil conditions, quantity and quality of crop residue mulch, effective rooting depth, and prevalent micro- and meso-climate. On high-fertility Alfisols crop yield with the no-till system is often equivalent or better than in the plow-based system if there is adequate amount of residue mulch, weeds are effectively controlled, and seedling establishment is satisfactory. Grain yields are often high in favor of no-till for soils of low available water holding capacity. Fertilizer response of maize and other cereals is often different than that of the plowed system because of the microbial immobilization, and due to differential losses by leaching and in water runoff. Grain legumes e.g. cowpea and soybean grown on ridges and plowed seedbed suffer more from drought stress and high soil temperature than those grown in an untilled seedbed. Soybean emergence is particularly sensitive to fluctuations in soil temperature and moisture regimes. In contrast to grain crops, root tubers require large "root room" for adequate development. Similar to soybean, however, yam seedlings are very sensitive to high soil temperatures. Crop residue mulch is, therefore, equally beneficial for root crops as well.

Because Ultisols have lower chemical fertility than Alfisols and are acidic, the choice of crops to be grown is an important aspect that affects yield response to no-till farming. For example, regardless of the tillage methods maize does not grow well on unlimed Ultisol. The no-till system on acidic Ultisols and Oxisols is, therefore, better suited to those crops that are relatively tolerant to low soil pH e.g. upland rice, cowpea and tropical root crops. Similar to Alfisols, however, crop response to no-till on Ultisols is also influenced by mulching. Mulching alters physical, nutritional and biological environments and enhances crop growth and yields.

Oxisols are similar to Ultisols in chemical and physical soil properties. Oxisols of the Amazon Basin and those in central Brazil are susceptible to accelerated soil erosion, and have low plant available water reserves. Experiments conducted in Brazilian Oxisols have shown that no-till system results in significant improvements in soil structural properties and in crop yields. High yields of soybeans have been reported with no-till system on Brazilian Oxisols.

SOIL CHARACTERISTICS UNSUITABLE FOR NO-TILL SYSTEM

A no-till system is usually unsatisfactory if its requirements are not met. Soil surface conditions which cause negative response to no-till farming are:

(i) Soil compaction:

Seedling establishment and crop growth with the no-till system are often unsatisfactory in soil with compacted surface layer. Soil structure must be restored prior to adapting the no-till system.

(ii) Eroded and degraded lands:

Severely eroded and degraded soils due to prior mismanagement do not respond to no-till unless the. physical, nutritional, and soil biological properties are restored.

(iii) Micro-relief:

An uneven ground surface is an obstacle in uniform crop establishment with motorized farm operations. Lack of seed-soil contact caused by smearing of a clayey soil also results in poor crop stand.

(iv) Residue mulch:

Both too much and too little crop residue mulch are problems in no-till system. Seed-soil contact is often poor and inadequate in soils with too much residue especially if the residue is moist. Pest and rodent problems are also more severe on an untilled and mulched soil than in plowed and clean seedbed.

(v) Perennial and rhizomatous weeds:

Some rhizomatous (e.g. Imperata and Talinum) and other perennial weeds are difficult to control with contact herbicides. Inadequate weed control can severely reduce crop yields with the no-till system.

Successful adaptation of the no-till system under the conditions listed above require alleviation of these constraints. Practicing no-till farming is based on the use of herbicides. The herbicides are often not available, and the dynamics of herbicides and their by-products in tropical soils have not been extensively studied. Surface application of fertilizers, soil amendments, herbicides, and pesticides has implications for environmental pollution. Regrettably there is little information about the fate and pathways of these chemicals. Use of Furadan insecticides in no-till plots nay result in elimination of soil macro-fauna e.g. earthworms. A biologically inactive soil is easily degraded in harsh environments of the tropics.

NO-TILL FARMING ON GRAVELLY SOILS

A common feature of many soils in the tropics, especially those derived from Basement Complex rocks, is the existence of subsurface gravel layer. These layers can inhibit root growth of annuals depending on the size and concentraction of gravels and on the texture and packing of the intergravel material. For utilization of water and nutrients present in the layers beneath, it is imperative to increase the proportion of root-sized pores in the gravel layer. An increase in macroporosity of the compacted gravelly horizon may be brought about through mechanical or biological means. Experiments conducted at IITA have shown some beneficial effects of sub-soiling by chisel or paraplow without soil inversion. Because loosening by paraplow is beneficial temporarily, this high energy treatment is frequently required to promote deep root penetration. Vertical mulching has also been tried to preserve the macroporosity created by mechanical loosening. The second alternative is to utilise the greater root penetration ability of tap-rooted perennials. Macroporosity of compacted subsoil layers can be increased by growing deep-rooted shrubs and woody perennials. The following shallow-rooted maize or soybean can use the bio-channels thus created to avail soil water and nutrient reserves in the layers beneath provided that soil is not disturbed. The continuity and stability of biochannels is ascertained through a no-till system. Biological methods of facilitating root extension such as appropriate cropping sequences, crop combinations and no-till farming are promising alternatives for management of soils with stone-lines.

NO-TILL FARMING ON ACID SOILS

In addition to unfavorable soil physical conditions root growth and proliferation in acidic subsoils is restricted due to A1 and/or Mn toxicity and deficiency of some essential nutrients. Addition of lime to replace A1 and Mn by Ca and Mg is one approach to overcome the problem if lime is locally available at economic rates. Surface application of lime as is done with a no-till system is less efficient than when incorporated by plowing. The need for incorporation of lime must be weighed against the erosion and compaction hazard on plowed land.

Experiments conducted in tropical America on management of acid soils have demonstrated the benefits of using large amounts of organic matter and crop residue. Procuring mulch in situ by growing an appropriate cover crop is a practical method of obtaining the desired quantity of residue mulch. Growing crops through the mulch by no-till system is an obvious choice especially if it can be combined with the species and varieties of crops which are tolerant to low pH.

UTILIZATION OF WETLANDS WITH A NO-TILL SYSTEM

Constraints to intensive utilization of wetlands for food crop production include trafficability and water control. Experiments conducted at IITA and elsewhere have shown the benefits of no-till farming for growing rice on wetlands during the rainy season and upland crops e.g. cowpea during the dry season.

CONCLUSIONS

Fragile ecosystems and easily degraded soils of the humid tropics can be used for intensive food crop production with mulch farming and no-till systems. No-till farming, however, is a system of soil and crop management that must fit into the overall framework of the soil's constraints and its potential and the socioeconomic conditions. Agronomic and cultural practices to seed through crop residue mulch without plowing are different than those needed in plow-based systems. The success of no-till system, therefore, depends on the availability of these agronomic packages for major soils, ecologies and crops to be grown. Since productivity of soils of the tropics declines rapidly with erosion and other ecological constraints, it is important to develop packages of agronomic practices that will facilitate adaptation of no-till farming techniques. Some of the researchable items that will facilitate rapid adaptation of no-till farming are:

(i) Integrated weed control methods need to be developed for plowless agriculture in the tropics. It is important to develop alternate weed control strategies especially for the regions where herbicides are not available.

(ii) Cropping systems should be designed to meet crop residue requirement for no-till system. There should be enough residue available to meet needs for alternate uses and for mulch. Cover crops and woody perennials are important components of appropriate cropping systems for no-till farming. Integration of livestock with crops and the use of animal traction are research priorities for addressing the problems of small-holders of the tropics.

(iii) Restoration of eroded and degraded lands is necessary prior to implementation of a no-till system.

(iv) Environmental protection in relation to the use of herbicides and other chemicals should be given a high priority. There is little research information regarding the fate of these chemicals in tropical environments. Research should be conducted to assess the movement of these chemicals in surface runoff, with eroded soil, and in percolation water.

These research needs emphasize the importance of a team approach involving a coordinated effort by soil and plant scientists, biologists, engineers and social scientists.

The Future of No-Tillage

G. W. Thomas

University of Kentucky

It is sometimes assumed that the development of wonder chemicals will solve the problems that arise in no-tillage such as persistent or resistant weeds or the changes in weed ecology that come with the practice. It is difficult to be a prophet when one can hardly keep up with what is going on at the present time, but leaving the future of no-tillage to the mercy of expensive chemicals of the present or future does not seem reasonable to me. It does not seem reasonable for two reasons: First, the price of crops most adaptable to no-tillage is almost certain to remain low for the near future, barring a world-wide disaster. Even if we should control production in the United States, nobody else will, and we have real competition in many parts of the world. Second, the use of chemicals to control weeds has limits. These limits are exceeded when it is much cheaper to mechanically till than to spray herbicide, or when changing to another crop can give better weed control than that obtained with the present crop.

Therefore, my view of the future does not envision the salvation of no-tillage as resting on a research base of wonder chemicals. Instead, some old-fashioned principles will probably be more important. These principles are heavy ground mulch to suppress weeds (and for other benefits), crop competition with weeds and the use of rotations.

To study the future, let us go back and study the past. The first no-tillage I ever saw was in 1960 in southwest Virginia. It was corn, planted in a bluegrass sod, killed with the use of black plastic. The corn was planted using a soil sampling tube to cut little disks of sod out of the soil. And, It worked. With the dead sod, there was a good ground cover to suppress weeds and the corn itself was a good competitor against the weeds that did come.

As time went on, there were less and less pastures to plant corn into and a substitute was devised. This practice was to plant rye or wheat as a winter cover crop and kill it with paraquat in the spring. Corn was then planted in the residue. If there was often encroachment by trees or bushes, the bushhog was employed, and often became the best friend no-tillage would have. Later developments the corn-wheat-soybean rotation which has been successful, partly because it provides good natural ground cover (cornstalks and wheat stubble), and because it includes a crop where grasses can be fought, if not controlled (soybeans). Still later came the use of legume cover crops during the winter to suppress weeds and to provide at least some of the nitrogen needed by corn. In all these systems, control of weeds by competition is an important part. The competition is offered by the shade of a tall plant such as corn, or by a thick-growing ground cover such as rye, wheat or vetch. In addition, the rotation of a broadleaf plant with members of the grass family allows some alternatives for chemical weed control. The rotation itself almost always gives a yield improvement to both crops. The reason for the effect is not truly understood, but as shown in table 1, it does exist. Table 1 shows average yields of corn with three covers under no-tillage. Where hairy vetch was used, yields were higher and the response to nitrogen was better as well.

So, it appears that in the past there has been success with good ground cover, crop shading and rotations. Earlier, it was suggested that most progress in the future would depend on these same principles. There is another factor involved also, which is why farmers accept no-tillage in the first place.

I have no formal study at hand, but in talking to hundreds of farmers, I would say that making money and/or saving money, time or work is, without doubt, the first consideration. Because time and work can be equated in some way with money, one would have to conclude that making or saving money is the primary consideration. A second reason, reducing erosion, is very secondary and is mentioned mostly because the Soil Conservation Service has done such a good job of brainwashing farmers for the past 50 years. A third reason, the effect of no-tillage on soil water, fertilizer efficiency, etc., exists mostly in the minds of technical workers. Most farmers never even consider these points and, in fact, do not know much about them even though working on them keeps us busy and paid.

Then, why do farmers abandon no-tillage? I suspect it is for the same primary reason; because it is not economically good for them. Hence, it seems to me, that we must concentrate, in the future, on no-tillage as seen from the farmer's point of view. If the other advantages of less erosion and incremental savings in soil water and fertility are obtained, so much the better. But, I rather doubt that no-tillage will survive on them alone.

Table 2 shows the returns to labor, management and land with a wheat-dry pea rotation with conventional and with no-tillage. Differences like these might conceivably lead to a certain stubbornness among farmers being courted with the no-tillage gospel. Looking at no-tillage strictly from the farmers' standpoint, what can we see?

First, we should see that if no-tillage costs more (or makes less) than conventional tillage, we can kiss it goodbye. I have just finished two-and-a-half years of work in the Dominican Republic where I worked on no-tillage, among other things. Table 3 shows some results with red beans in 1983. The results looked almost promising and farmers were interested. Decent weed control in beans required three herbicides, Roundup, Lorox and Prowl and they were slightly more costly than oxen and hoe-hands in the year 1983. By 1984, the Dominican peso had collapsed against the dollar and the price of herbicides changed rapidly, whereas the price of beans and the cost of labor moved up only slightly (they really moved down in dollar terms).

Thinking that the only way to keep a research program in no-tillage alive was to try something simple and cheap, I used paraquat on pigeon peas. Pigeon pea is a crop that grows tall and offers good competition to weeds once it develops. The results (table 4) were very favorable when the price of Paraquat was low (1983). Because of the large yield increase, even when herbicide prices climbed, the chemical weed control was more profitable than that with machete.

There will be those who say that this is a small sample from an economically-stressed, postage stamp of a country and that it hardly applies in the United States. That is possible but doubtful. The attitude of Dominican farmers is no different from that of American farmers. Both groups want to make money or at least to survive. Both are generally in trouble with the banks. Both hate unnecessary work and try to produce crops as cheaply as they can. Both are afflicted with the disease known as "love of the land" and both think that next year, somehow, will be better than this year. Their motivations are about the same and their response to economic factors does not seem to be different than that of their North American neighbors.

If we can accept that a major reason for the growth of no-tillage has been economic and that there are basic physical requirements for no-tillage, then what does the future hold?

1. Climatic Restrictions: No-tillage will never dominate where water is so scarce that a natural cover (mulch) cannot be established pretty much for free. The crop produced for the cover will have to pay for itself and this will be difficult if the cost of water is charged mostly or completely to the crop used as cover. A perfect example would be wheat produced under irrigation so that a crop of corn or sorghum can be produced using the stubble as mulch. Unless the wheat yields are very high or unless the price of wheat rises magically, which it will not, the practice is not feasible.

Another climatic restriction is cold spring weather. The bad effect under no-tillage is related directly to the mulch which inhibits soil warming through color, insulation and higher soil water content. The very advantage of the mulch in summer is its principal disadvantage in the springtime. At what latitude will no-tillage stop and some form of limited tillage begin? No one really knows but there will be a consistent restraint on no-tillage where soil temperatures are low at planting time.

2. Weed Control Restrictions: As in the case of any other problem in farming, there are ways to control the problem of weeds. In this case, one is confronted with the need to control weeds and the means to control them chemically. The constraint is the cost of controlling them. There is a certain romance in dreaming of the wonder chemicals that will come to our aid and destroy our enemies, the weeds. It is just dreaming unless these chemicals cost about the same as say, 2,4-D, and they won't. They will cost a lot more.

How can the future be seen, then? We probably will rely more on crop competition, good ground cover and cheap, or relatively cheap chemicals for weed control. Added to this, rotation of crops will play a big part and the rotations will be much more varied than those that we have now. They will be designed to make money but they will have a secondary purpose of controlling problem weeds.

Take, for example, our old friend, Johnsongrass. It is always happy when corn is around because they both have about the same growth habit and because chemical weed control at an affordable price does not exist in a really infested field. One approach is to switch to soybeans and wipe the Johnsongrass with Roundup. Alternately, one could spray with one of the newer herbicides to kill the Johnsongrass. The truth is, however, that when corn comes again, there will appear much more Johnsongrass than anyone thought possible.

A different and perhaps cheaper approach is to plant the field to a hay crop for two years. Cutting the field regularly will cause the Johnsongrass great pain and sap it of much of its vitality. Cash money will have been saved, but will money have been made? That will depend on the yield and use of the hay crop. But at least it is an alternative and it provides a good mulch for no-tillage corn.

In the future, I believe we will see a lot more of this approach to weed problems. It is especially feasible when there is less incentive to plant every acre to basic grain crops, and other production alternatives become more attractive.

In the future, I believe that the use of post-planting sprayings will be even more important than it is at present. The products used will certainly include such time-tested products as 2,4-D and Paraquat, because they are cheap. For example, in place of trying to concoct a recipe at planting to control all possible weed disasters, it may make more sense to use post-planting sprays, directed or non-directed to control some weed problems. Using this system, the farmer has the possibility of saving a lot of money. The system takes observation, planning and timeliness but offers real advantages. For one thing, the farmer does his own planning instead of leaving it to the chemical companies or the experiment stations. For another thing, we might learn a lot from his successes and failures.

As with any other farm problem, our concern should be to resolve it as simply and cheaply as possible. Somehow, four herbicide-tank mixes do not seem simple to me and they certainly do not come cheap. Is it not likely that post-planting sprays are a viable alternative, especially if they can be used with relatively cheap chemicals?

3. Taking Advantage of Some Consequences of No-Tillage: No-tillage sometimes leads to the reappearance of woods. I remember well bushhogging a marginal field which had been in no-tillage corn and noting that the field had a nearly perfect stand of young ash. I have wished several times that I had just left it so that my grandchildren could have sold the trees in the year 20 something. It is probably an extreme notion, but for some fields or corners of fields it may make better sense than fighting nature. And, suppose it had been walnut.

Another idea, less romantic, is to take advantage of the increased organic matter and organic nitrogen content of the soil under no-tillage by plowing it and planting it to a high-value crop. This approach takes advantage of some free nitrogen, good soil structure and at the same time, allows one to give the weeds a good mechanical workout if they happen to be a problem. There generally will be very little erosion because the physical characteristics of the soil will be excellent. It is much like using an old pasture soil and with similar advantages.

4. Not Being No-Tillage Fanatics: In the manner of most religious fanatics, we have sometimes been too severe with our critics when they question the use of more and more chemical control schemes simply so we can stick with our puristic notions of no-tillage. They may have a good point. There are other ways of controlling weeds besides the use of chemicals and they have a very long history of working. It may be time to consider a mixture of chemical, mechanical and competitive weed control in no-tillage. Perhaps that is what the future holds. If it does, it should not be a bad future, keeping in mind that using chemicals alone just to keep the faith pure is pretty foolish.

I hope the future will include more about how to mechanically control weeds without turning the soil. All these methods are basically variations on the theme of stubble mulching. One of the cleverest I have seen is an Argentine corn planter with duckfoot points which cuts the weeds just below the mulch cover. It seems to work well where there are no rocks or stumps. I also hope we can learn more about using competition to limit weed growth, whether it be by changing planting patterns or by turning to more impermeable ground mulches. There is a lot to be learned about this subject.

Summary

The principles which were important in the development of no-tillage in the first place are still important. They include crop competition, a good ground cover and rotations. The basic desire of the farmer to make money is also important. Because of these principles and the necessity for farmer survival, I have suggested that the future will have to look to the past. The no-tillage movement will have to pay more attention to these fundamentals and perhaps less attention to the siren songs of the new and expensive chemicals. Some have their place, but I doubt that they offer salvation to no-tillage. In the end, the basic principles are far more important.

References

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Table 1. Yields of corn under no-tillage with various cover crops (Ebelhar et al. 1982).

Cover	N Fertilizer, kg/ha 0	50	100
	-------grain yield, kg/ha-------		
Hairy Vetch	6410	6840	9040
Rye	4030	5720	7580
Corn Stalks	3790	5230	6820

Table 2. Returns to labor and management and land for a winter wheat-dry peas rotation of 445 ha, Palouse, Idaho-Washington (Hinman et al. 1983).

Conditions	Conventional Tillage Returns Labor&Mgt			No-Tillage Returns Labor&Mgt		
	Labor&Mgt	Land	Total	Labor&Mgt	Land	Total
Same Yield	$11,952	$37,301	$49,253	$2,074	$32,258	$34,332
Expected Yield Reduction	(same)	(same)	(same)	$20,185	$22,561	$ 3,454

Table 3. Yields, values, and production costs of conventional and no-tillage red beans in the Dominican Republic with 1983 and 1984 prices (average of three experiments).

	Conventional Tillage		No-Tillage	
	1983	1984	1983	1984
Yield, kg/ha	347	---	354	
Value RD$	473.20	788.00	482.70	804.50
costs				
Seed RD$	95.40	159.00	95.40	159.00
Land Prep & Weed Control RD$	151.00	199.00	165.60	522.60
Fertilizer RD$	33.30	89.70	33.30	89.70
Gross Net	193.60	340.30	186.40	33.20

Table 4. Yields, value, and production costs of pigeon peas in the Dominican Republic with 1983 and 1984 prices. Weeds controlled with paraquat or by machete (average of seven experiments).

	"Chapeo" with Machete		Paraquat	
	1983	1984	1983	1984
Yield,	1257	--	1899	--
Value RD$	553	636	835	961
Weed Control RD$	32	48	56	131
Picking RD$	56	84	84	126
Gross Net RD$	465	504	695	704