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1988 Southern Conservation Tillage Conference

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Proceedings

1988 Southern Conservation Tillage Conference

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Foreword

The first no-till conference was hosted by the Georgia Experiment Station at Griffin in 1978, with seven southeastern states as participants. The Georgia Station was the host again in 1985, when the Conference was expanded to include all 13 states in the Southern Region. In 1987, when Texas served as the host state, the steering committee voted to change the conference title to *Conservation Tillage Conference.* The primary objective thus becomes the promotion of conservation production systems, not just no-till, by providing a communication link between various agencies and personnel interested in resource conservation.

Farm managers currently face a tremendous challenge — conserving farm resources while increasing production and reducing soil degradation and water pollution. In order to survive, farmers must remain competitive and productive, but must be concerned with the use and management of soil and water resources as well as other resources such as energy, fertilizers and pesticides more than ever before. Agriculture is still the backbone of the American economy; but agriculture is no longer exempt from accountability of actions that may degrade the environment.

The 1988 conference theme, "Conservation Farming: Focus on a Better Future," was chosen because of its relevancy to other actions currently underway to promote improvements in teaching, research, and extension activities to keep the Mississippi farm community well informed and on the cutting edge of science and technology. Speakers recognized for their knowledge and experience, including farmers, were chosen to discuss issues and components of conservation farming systems that are pertinent to the conference title and theme. The proceedings contains invited and voluntary contributions that are relevant to the conference title and theme. We appreciate the opportunity to host this annual conference, especially during the year we celebrate the 100th anniversary of the establishment of the Mississippi Agricultural Experiment Station system.

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The Tillage Revolution and the Impact of Conservation Mandates in the Southern Region

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In the 1930's, Hugh Hammond Bennett and the dust bowl captured the nation's attention and dramatized soil erosion problems. Some 50 years later, Congress enacted the Food Security Act. This act is creating an entirely new approach to agricultural resource conservation. Title XI1 of the Food Security Act makes conservation practices on certain erosion-prone land an eligibility requirement for participation in many USDA programs. In the past, conservation practices were installed on a voluntary basis and administered separately from commodity programs. Since a high percentage of farmers participate in commodity programs, tying conservation to program participation provides a powerful economic incentive to comply. Program payments equaled 40 percent of net income for all of agriculture in 1987-88.

During the time since passage of the Act, highly erodible land has been defined as having an Erodibility Index (EI) > 8, and acceptable soil loss has been set at predetermined tolerance (T), which ranges from 1 to 5 tons per acre per year. There are some exceptions to this, with greater soil losses acceptable under certain conditions. Farmers have been notified of the Act and its details, including sodbuster and swampbuster provisions for erodible and wetlands, respectively. The Universal Soil Loss Equation (USLE) has been selected as the vehicle to estimate soil loss and to plan for reduction of soil loss to target levels. A monumental task remains; plans for nearly a million farmers with highly erodible fields must be completed by 1990 and these plans implemented before 1995.

A local farm planner with SCS outlined his approach to bringing highly erodible fields into compliance by using the following steps:

1. Eliminate fall tillage.
2. Plant on the contour (P=0.6).
3. Install grass strips on the contour (P=0.4 plus the contribution of the grass strip).
4. Terraces (cost=$250/A).
5. Suggest the last be enrolled in the Conservation Reserve Program.

This seems to be both a practical and workable approach. With an escape into the CRP if application of practices are insufficient to reduce erosion to acceptable levels, this planner was doing little to propose modifying tillage practices except to eliminate fall plowing. Most of the soils in his area are in the Black Belt and, seemingly, he did not think that no-tillage or any other from of tillage that maintains surface residue cover was highly desirable. Productivity often suffers with these limited tillage systems on the Black Belt soils. Further, unless the operator requested terraces, he would probably skip these and suggest the CRP After all, that highly erodible field may have already lost much of its topsoil and not be very productive.

A part of the title of this paper involves the tillage revolution. This might be defined as a radical change in practices made over a short period of time and an example might be moving from conventional tillage to no-tillage. At this point, we might ask several questions:

1. *Has a tillage revolution taken place?*
2. *What might we gain toward meeting the conservation mandates by such **a** revolution?*
3. *If the revolution has not occurred, what would be needed to create conditions to foster the process?*

In reflecting on the first question, 1 thought about my grandfather who was born 129 years ago and who farmed just a few miles south of Tupelo in the Black Belt. He grew cotton and some corn to feed the mules and to make bread. He never owned a tractor, although there were some in the neighborhood. In growing cotton, he used a turning plow to throw last year's row into the middles which formed a bed. A middle buster completed the bed formation. The bed was dragged and planted. When the crop emerged, hoes were used to thin the stand. As the crop grew, rows were cultivated frequently and weeds that were missed by cultivation were eliminated by hoeing. Corn was produced using similar techniques.

If someone from that era came back today, what changes would they see and would they recognize the operations used to grow crops? Today, fields are much larger than the 2 or 3-acre patches worked with mules. Disks and plows are used to prepare the soil for planting and sweeps to cultivate after crop emergence. These same kinds of tools were used 50 years ago. Soil is worked as intensely today and often tilled deeper than 50 years ago because power is available to do so. There has been a revolution in how the implements are pulled, but this should not be confused with degree or intensity of tillage. There has been another revolution. During this time, chemicals have completely eliminated hand hoeing of weeds.

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Someone from that era would not recognize a no-tillage planter. If they saw one operating in wheat stubble, they wouldn't know what was happening and wouldn't believe that a crop could be produced in that manner. This would constitute a revolution! In the mid-South today, no-tillage seems to refer to the specific system of planting soybeans following wheat harvest. Although there is research devoted to production of major crops by planting into crop residue or cover crops, little of this seems to be standard production practice. In contrast, in some parts of Ohio more than 50 percent of the corn acreage is no-till planted. That constitutes a revolution; the revolution has not yet arrived in the South.

What could tillage contribute towards meeting the conservation mandate?

In predicting erosion, the USLE addresses a number of factors. These include rainfall characteristics of the area, the slope length and steepness, the erodibility of the soil, the crop itself, and the practices used to grow the crop. Many of those factors are determined by the inherent characteristics of the site and cannot be changed. The practices (P) used to grow the crop, such as row direction (straight, or contour, up and down slope), can be modified as can some of the crop (C) factors (soil residue cover, tillage, crop grown). Modifying practices may provide a 2x reduction in erosion; adopting no-tillage with a high amount of residue cover can reduce erosion by as much as 4x, according to the handbook values for the USLE.

Unfortunately, the current version of the USLE may understate the value of no-tillage in reducing erosion by a factor of several fold. In experimentally derived C factors for corn, McGregor and others (1982, 1983) reported only 1/16 to 1/22 as much soil loss with no-tillage as with conventional tillage. Soil losses for soybeans grown with no-tillage were cut by 80 to 97 percent when compared to conventional tillage systems (McGregor, 1976, and Mutchler & Greer 1984). In work with no-tillage cotton, the best no-tillage treatment had soil loss of < 2 percent of the amount from conventional tillage (Mutchler et al., 1985). Van Doren el al. (1984) reported that amount of erosion decreased with time since the last tillage. They also reported C values for no-tillage much more favorable than those listed in the USLE handbook. Thus, untilled systems could decrease in their erodibility with passage of time.

Field technicians charged with developing erosion control plans for individual farmers have no authority to modify USLE values to reflect new information; this will have to come from a higher administrative level. I am told a new means of predicting erosion is being developed (WEPP), but no details are generally available. Values shown above, however, indicate that no-tillage with suitable mulch cover could reduce erosion to acceptable levels for most crop, soil, and slope combinations. The Conservation Reserve Program may be an excellent solution for today's use of the most erosive land, but programs change and the prices or profitability of various commodities change. Within the past decade, high commodity prices brought erosive land into production and this could happen again. Suitable tillage practices would permit cropping much of this land without unacceptable soil loss.

A revolution in tillage practices—the adoption of systems that leave the soil surface undisturbed and covered with mulch during the production of annual crops—could decrease soil loss to acceptable levels on much of our cropland. Sites and crops with a yearly soil loss potential of 20 tons per acre could have these losses reduced to less than 2 tons per acre. Further, this could be done on many sites without resorting to terraces or other structures that are expensive to install and difficult to maintain.

The tillage revolution could solve most erosion problems for this region, but are we ready for it? What would foster a tillage revolution?

To be adopted, any management practice must offer advantages without unacceptable disadvantages. No-tillage has a clear advantage over conventional systems in erosion control. We must also be sure that it is dependable and that we can maintain productivity with its use. At least a part of the dependability factor involves intimate knowledge of how to make the system work. The system must also be profitable. High on a grower's list of priorities is staying in business. Most growers have mortgage payments to make and other debts to service, as well as a family to feed and clothe. Adopting a practice that reduces yields and, in turn, profits may be unacceptable, no matter what other advantages the practice may have. In many parts of the Southern Region, profitability of no-tillage has not been demonstrated to the satisfaction of many producers.

In successful crop management systems, the factors that limit crop growth are identified and corrected as well as possible. These factors include soil suitability, water, nutrients, crop establishment, plant populations, proper timing of operations and the control of weeds and other pests (Triplett, 1986). Tillage is not a requirement, although it can affect several of the other factors, either positively or negatively. As tillage is changed, these growth requirements must be met or yields suffer. For successful no-tillage, new methods of planting, pest control, and fertilizer application, among other factors, must be devised and evaluated. This commonly requires the formulation of new management systems. Often the new management system requires several modifications before it is successful. Inadequate stands and poor weed control are common causes of failure. In fact, tillage systems should not be compared until stand and weed control requirements arc satisfied and all practices are equal in this regard!

Once the basic management requirements for growing crops are satisfied, other factors may become important in how crops respond to tillage. In the Midwest, soil characteristics are considered so important in crop response to tillage that soils are rated according to their suitability to tillage systems (Griffith et al., 1986). Basically, the better-drained soils are the best candidates for no-tillage. This is fortunate because well-drained soils often occur on slopes where soil erosion is more of a problem. In various studies, crop yield decreases have occurred with reduced tillage on poorly-drained soils with clay texture (Triplett, 1986). Fortunately, crop rotation helps mitigate yield decreases on these soils so that no-tillage may be acceptable under some circumstances. Further, more recently, some have begun to think that different soils may require varying amounts of tillage to create optimum conditions for crop growth. There is no reason this should not be so; only recently have we been able to remove weed control as a reason for tillage and to evaluate soil tillage solely for its effect on the crop.

Mulch cover emerges as another major factor determining response of crops to tillage on some cornbelt soils, but not on others. This mulch effect is largely related to rainfall infiltration on soils that have poor structural stability and seal during rainstorms. On better-drained Alfisols with this characteristic, 50 to 60 percent mulch cover at planting may be required for yield equivalency with tilled systems (Van Doren and Triplett, 1973). Crop yields increase for greater mulch cover and decrease for less, with corn yields changing by as much as 1/2 bushel per acre for each percent change in mulch. On these soils, the amount of mulch cover must be considered when deciding whether or not to till. On soils with high clay content and with shrink-swell potential, cracks form when the soil dries and the response to mulch cover is much less.

The soil texture and mulch relationships that seem important in the cornbelt may not be the same in other areas. In the low-rainfall areas of the Texas Panhandle, where land may be kept fallow for a year or so to conserve water for the next crop, no-tillage works only if there is a suitable mulch cover. Sorghum grown with no-tillage, for example, should follow a wheat crop that produced at least 25 bushels per acre and a corresponding amount of straw. Further, the soils used for crop production with no-tillage include clay and clay loam texture; soils that are not considered the best suited to no-tillage production in the cornbelt.

The soil-tillage-drainage-crop-climatic relationships indicated above, while obviously important, have not been well defined for many geographic areas. Further, they reflect our current level of understanding. Future developments may permit use of reduced or no-tillage on sites or soils now considered unsuitable for these practices.

The development and adoption of new practices follows a fairly well-defined chronology. First, research workers investigate a practice and try to develop a workable system. No matter that the idea sometimes comes from farmers. Complete success with these first efforts is usually accidental. If the practice shows promise, research continues to refine and develop the practice to increase its dependability. Often there is considerable publicity at this stage and a few farmers may try it. These are watched by other farmers for a radius of at least 50 miles and successes or failures are communicated rapidly in the community. If the practice proves useful, neighbors begin to adopt the new method. All of this takes time. All parts of the system must work together satisfactorily or yields suffer. Hybrid corn, a development few of us question, took 20 years from introduction to 95 percent adoption. Modern no-tillage research started in 1960.

When no-tillage is viewed in these terms, progress is reasonable in some areas and slow in others. Other than wheat-soybean doublecropping, there is little farmer adoption of no-tillage crop production in the lower South. Research with full-season soybeans, corn, and cotton has not resulted in development of dependable, high yielding no-tillage management systems, although this seems to be changing. Recently published research reports from the Piedmont region of Alabama (Edwards et al., 1988) and Georgia (Wilkinson et al., 1987) indicate equal or better corn and soybean yields with no-tillage than with conventional systems. In a very recent report, Unger (1988), in west Texas, evaluated sorghum varieties for forage production using no-tillage. This study did not contain a tilled treatment, which implies the researcher considered no-tillage as a standard management practice for that crop and area. No-tillage is well developed and has been adopted by a significant number of farmers in the upper southern states of Kentucky, Virginia, North Carolina, and to some extent, Tennessee.

Few current agricultural research topics polarize research workers more than crop production with no-tillage. Some workers are sold on the practice while others report decreased yields and poor dependability with no-tillage. Published reports sometimes do not provide enough information to reliably determine reasons for poor performance of the system. Those reporting either good or poor performance of no-tillage must be assumed to be careful and objective in their work. It follows, then, that there may be some factor or factors that vary between the good and the poor locations for no-tillage, and thus, account for these differences in results.

Weed control has been a major barrier to no-tillage in the lower South. In the Midwest, a single, low-cost herbicide, atrazine, would control practically every important weed in cornfields—until fall panicurn populations increased. There is no atrazine equivalent for any mid-South crop. Fortunately, recent herbicide developments are expanding the weed-control spectrum and making weed control less difficult for crops grown in untilled soil.

Soil compaction in untilled fields is a barrier to no-tillage crop productivity on certain lower Coastal Plains soils. This problem is being managed by using subsoil planters to penetrate the compacted layer. Compaction may very well be a barrier to no-tillage crop production on other soils, but these have not been clearly defined. Interestingly, at the 1987 meetings of the American 'Society of Agronomy, a session dealt with no-tillage and soil conditions. In several reports, as penetrometer resistance readings increased, yields increased. This is hardly the relationship one might expect where significant compaction problems exist. Perhaps there are more meaningful ways to measure compaction. Where compaction problems exist, controlled traffic might help to minimize these.

Mulch cover is needed in untilled fields to reduce soil erosion. The value of mulch cover in improving soil moisture storage and crop yield is clearly defined under west Texas conditions but not so well defined elsewhere in the South. Mulch is burned in some doublecrop systems to facilitate planting. This practice could influence soil moisture late in the season. Few studies from the region report mulch cover levels present in tillage studies or the influence of mulch on crop yield. Mulch may be relatively unimportant for water conservation on soils that shrink and crack open.

Soil differences may represent an important factor in crop response to tillage systems in the mid-South. Positive responses reported for no-tillage have often been located on better-drained soils. No-tillage crops have often yielded less than crops grown with conventional tillage systems on soils with poor drainage. However, ridges, raised beds, and crop rotation seemingly help overcome these soil limitations. Fine-textured soils also may contribute to poor crop response of no-tillage. There should be an adequate amount of experimentation already performed on different soils throughout the region to indicate how soils and soil characteristics might influence crop response to different tillage systems if the information was pooled and evaluated. Such an effort could provide information regarding soils and conditions where no-tillage crop production is most likely to be successful and other conditions where no-tillage should not be recommended to farmers until better systems are developed.

An important question that follows the one of soil suitability for no-tillage is: *if some soils are not suited to a no-tillage production system, how much tillage is necessary to maintain yields?* Tillage systems, from conventional to no-tillage, represent a continuum. Tillage intensity is decreased by eliminating operations. Often conventional tillage and no-tillage are the only treatments present in crop production-tillage studies, and these do not address the question of how many operations are needed for a particular soil or site. Other unanswered questions include: *What tools should be used to what depth, should the tillage be before planting, afier crop emergence, or during both times?*

In summary, the tillage revolution has not reached much of the Southern Region. We may not be ready for it from the standpoint of having well developed and dependable crop management systems that can be recommended to growers. Moving the tillage revolution ahead in this region could help greatly in meeting the conservation mandates in the 1985 Food Security Act. There is, however, more work to be done before the revolution can be successful.

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Tillage Selection: Soil Stewardship versus Financial Survival

David C. Ditsch, Richard L. Trimble, and Jill M. Wade[1]

Introduction

After December 31, 1989, the basis by which row crop producers select tillage systems could change for many planning to participate in government programs. According to the conservation compliance guidelines set out in the 1985 Food Security Act (FSA), land classified as highly erodible will be subjected to various tillage restrictions depending upon its intended use. On January 1, 1990, row crop producers are expected to have an approved conservation plan specifying the type of tillage and cropping systems they have elected to implement on the highly erodible land they use for the production of annual crops. In states like Kentucky, where approximately 46 percent of the cultivated land is classified as highly erodible, conservation compliance may mean a major change in specific tillage use.

Prior to the enactment of the 1985 FSA. the acceptance of conservation tillage practices was strictly a voluntary decision. Despite educational efforts of the universities, Soil Conservation Service (SCS), and other related groups, the adoption and application of conservation tillage practices have been limited. In fact, the SCS estimates the current annual rate of sheet and rill erosion in Kentucky to be approximately 12 tons per acre per year on soils that have a tolerable soil loss of only 3 to 5 tons. This situation is somewhat of an enigma in a state where years of conservation tillage research have resulted in numerous recommendations to growers suggesting the many benefits of no-tillage crop production. It is difficult to understand why such no-tillage advantages as increased moisture availability, reduced soil loss, improved soil structure, reduction in machinery and labor expenses, and finally increased yields have not convinced more producers to adopt no-tillage production practices.

The Case Farm

To investigate the economics of various tillage systems in Kentucky, a "typical" west Kentucky cash grain farm was investigated. The assumed farm consisted of 400 tillable acres that were well suited to either conventional tillage, reduced tillage or no-till methods of crop production.

The case farm used a rotation of 200 acres of corn, 100 acres of full season soybeans (FSSB), 100 acres of wheat, and 100 acres of doublecrop soybeans (DCSB). It was assumed that the owner-operator of the farm supplied all labor required by the operation. All cultural practices used were those recommended by the University of Kentucky.

Defining Tillage Systems, Machinery Requirements, and Costs

This analysis examined three different tillage systems defined as follows by the SCS:

Conventional tillage involved planting the crop in a prepared seedbed where less than 30 percent ground cover from the previous crop's residue or cover crop is maintained. For this analysis the conventional till operation included chisel plowing (twisted shanks) + 2 diskings.

Reduced tillage planted the crop in lightly tilled soil where 30 to 90 percent ground cover from the previous crop's residue or cover is maintained. The more erosive the land, the more residue required. The reduced-till operation included chisel plowing (twisted shanks) + 1 disking.

No-tillage refers to planting the crop in undisturbed soil with a minimum of 90 percent ground cover from the previous crop's residue or cover crop.

Machinery cost information was obtained by a survey of six major west Kentucky equipment dealers during the summer of 1986. Based on this information, the total initial machinery investment for the conventional/reduced tillage systems was $173,880. The cost of the no-till system was $158,282.

Yields. Results of tillage research in Kentucky suggest that, on average, higher yields can be expected from reduced tillage and no-till systems than those produced by conventional methods. Yield levels were selected for each crop based on the yield capability of a well-drained Class IIe soil in west Kentucky.

The assumed yield levels used in this analysis were as follows: For the conventional tillage system: corn = 100 bu/acre, DCSB = 31 bu/acre, FSSB = 40 bu/acre, and wheat = 45 bu/acre. For the reduced tillage system: corn = 105 bu/acre, DCSB = 32 bu/acre, FSSB = 40 bu/acre, and wheat = 45 bu/acre. For the no-till system: corn = 110 bu/acre, DCSB = 34 bu/acre, FSSB = 40 bu/acre, and wheat = 45 bu/acre.

Input Costs and Grain Prices. The input costs used in this analysis are those that prevailed in west Kentucky during the summer of 1986. Assumed crop prices used in the analysis

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were: corn, $1.93/bu.; soybeans, $460/bu.; and wheat, $2.50./bu.

Economic Comparison of Tillage Systems

The Beginning Farmer

For the beginning producer, all machinery is newly purchased. The annual costs of machinery ownership were obtained by amortizing the total cost of the equipment complement over its average useful life. Equipment used in the conventional tillage system was assumed to last 10 years. Machinery used in the reduced till or no-till system was assumed to last for the same number of hours, and therefore more years than in the conventional tillage system.

Based on this analysis, the net return of $33.53 per acre from the no-till system was the greatest. The net return of $26.49 per acre provided by the reduced tillage system was second. The lowest return of $15.85 per acre came from the conventional system (Table 1).

The Established Farmer

For the farmer equipped to till and plant by conventional methods, a switch to no-till would require the purchase of a new no-till drill and a new planter or the modification of

Table 1. Crop production budgets using conventional, reduced, and no-tillage production systems.

	Conventional production				Reduced till production				No-till production			
BUDGET ITEM	**Corn**	**FSSB**	**DCSB**	**Wheat**	**Corn**	**FSSB**	**DCSB**	**Wheat**	**Corn**	**FSSB**	**DCSB**	**Wheal**
EXPECTEDRETURNS												
Acres	200	100	100	100	200	100	100	100	200	100	100	100
Price/Bu	$1.93	$4.60	$4.60	$2.50	$1.93	$4.60	$4.60	$2.50	$1.93	$4.60	$4.60	$2.50
Yield/Ac	100	40	31	45	105	40	32	45	110	40	34	45
TOTALRETURN												
PER ACRE	$193.00	$184.00	$142.60	$112.50	$202.65	$184.00	$147.20	$112.50	$212.30	$184.00	$156.40	$112.50
TOTAL FARM RETURNS		$82,510.00				$84,900.00				$87,750.00		
OPERATING COSTS												
Seed	$19.38	$8.24	$8.24	$11.25	$19.38	$8.65	$9.51	$12.37	$20.93	$9.06	$10.87	$13.50
Innoculant	.00	1.00	1.00	.00	.00	1.00	1.00	.00	.00	1.00	1.00	.00
Nitrogen	17.50	.00	.00	14.40	19.60	.00	.00	16.00	21.00	.00	.00	19.20
Phosphate	10.80	7.20	.00	14.40	10.80	7.20	.00	14.40	10.80	7.20	.00	14.40
Potash	5.40	5.40	5.40	.00	5.40	5.40	5.40	.00	5.40	5.40	5.40	.00
Lime	8.00	8.00	.00	8.00	8.00	8.00	.00	8.00	8.00	8.00	.00	8.00
Herbicides	16.16	25.03	25.03	1.65	16.93	25.03	25.03	1.65	22.38	31.26	31.26	7.87
Insecticides	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Fungicides	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Custom Hire	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Drying	15.00	.00	.00	.00	15.75	.00	.00	.00	16.50	.00	.00	.00
Interest	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
Labor	7.25	7.25	4.80	7.70	6.20	6.20	4.80	6.30	4.35	4.35	4.35	4.30
MACHINERY COSTS												
Fuel & Oil	$7.09	$7.09	$4.51	$7.59	$6.01	$6.01	$4.51	$6.09	$3.26	$3.26	$3.26	$3.21
Rep & Main	11.67	11.67	9.57	12.81	11.48	11.48	10.07	12.42	9.78	9.78	9.78	11.60
TOTAL OPERATING												
COSTS PER ACRE	$123.25	$85.88	$63.55	$82.80	$124.55	$83.97	$65.32	$82.23	$127.40	$84.31	$70.92	$87.08
TOTAL FARM OP COSTS:		$47,873.00				$48,062.00				$49,711.00		
RETURNS ABOVE												
OP. COSTS/ACRE	$69.75	$98.12	$79.05	$29.70	$78.10	$100.03	$81.88	$30.27	$84.90	$99.69	$85.48	$25.42
TOTAL FARM RETURNS												
ABOVE OP COSTS:		$34,637.00				$36,838.00				$38,039.00		
ANNUAL MACHINERY												
OWNERSHIP COST:		$28,298.17				$26,241.41				$24,625.33		
PER ACRE:		$70.75				$65.60				$61.56		
TOTAL FARM COSTS:		$76,171.17				$74,303.41				$74,336.33		
PER ACRE:		$190.43				$185.76				$185.84		
WHOLE FARM												
NET RETURNS:		$6,338.83				$10,596.59				$13,413.67		
PER ACRE:		$15.85				$26.49				$33.53		

an existing planter allowing for the proper placement of the seed in heavy residue conditions. To analyze this situation the annual costs of ownership were determined for a producer who switches tillage systems in year 6 after initial startup of his conventional tillage operation. Changing to reduced tillage required no new investment in equipment. It did extend the useful life of existing machinery and thereby reduced the annual ownership cost. Adoption of no-till required the purchase of new coulters ($1,733) for the planter and a no-till drill ($12,275) in year 6. It was assumed that the producer would keep the existing tractor for use in the no-till system.

Costs and returns resulting from this switch to reduced tillage or no-till are summarized in Table 2. As was the case with the beginning farmer, the no-till system proved to be the most profitable with a net return per acre of $28.43. Reduced tillage returns of $24.10 per acre were slightly less.

Despite the cost associated with purchasing new equipment for no-till production, conservation tillage methods proved to be most profitable for both the beginning and established farmer when higher yields were assumed. However, many producers may not be in a position similar to those assumed in our base farm situation.

Economic Profit vs. Net Cash Flow

Based on the results of this tillage analysis, we would have to conclude that many farmers in Kentucky are not using the most profitable tillage system available. Perhaps they simply

Table 2. Crop production budgets after change to reduce/no-till production systems.

	Reduced tillage production				No-till production			
BUDGET ITEM	**Corn**	**FSSB**	**DCSB**	**Wheat**	**Corn**	**FSSB**	**DCSB**	**Wheat**
EXPECTED RETURNS								
Acres	200	100	100	100	200	100	100	100
Price/Bu	$1.93	$4.60	$4.60	$2.50	$1.93	$4.60	$4.60	$2.50
Yield/Ac	105	40	32	45	110	40	34	45
TOTALRETURN PER ACRE	$202.65	$184.00	$147.20	$112.50	$212.30	$184.00	$156.40	$112.50
TOTAL FARM RETURNS:		$84,900.00				$87,750.00		
OPERATING COSTS								
Seed	$19.38	$8.65	$9.51	$12.37	$20.93	$9.06	$10.87	$13.50
Innoculant	.00	1.00	1.00	.00	.00	1.00	1.00	.00
Nitrogen	19.60	.00	.00	16.00	21.00	.00	.00	19.20
Phosphate	10.80	7.20	.00	14.40	10.80	7.20	.00	14.40
Potash	5.40	5.40	5.40	.00	5.40	5.40	5.40	.00
Lime	8.00	8.00	.00	8.00	8.00	8.00	.00	8.00
Herbicides	16.93	25.03	25.03	1.65	22.38	31.26	31.26	7.87
Insecticides	.00	.00	.00	.00	.00	.00	.00	.00
Fungicides	.00	.00	.00	.00	.00	.00	.00	.00
Custom Hire	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Drying	15.75	.00	.00	.00	16.50	.00	.00	.00
Interest	.00	.00	.00	.00	.00	.00	.00	.00
Labor	6.20	6.20	4.80	6.30	4.35	4.35	4.35	4.30
MACHINERY COSTS								
Fuel & Oil	$6.01	$6.01	$4.51	$6.09	$4.08	$4.08	$4.08	$4.00
Rep & **Main**	11.48	11.48	10.07	12.42	10.51	10.51	10.51	12.30
TOTAL OPERATING COSTS PER ACRE	$124.55	$83.97	$65.32	$82.23	$128.95	$85.86	$72.47	$88.57
TOTAL FARM OP COSTS:		$48,062.00				$50,480.00		
RETURNS ABOVE OP COSTS/ACRE	$78.10	$100.03	$81.88	$30.27	$83.35	$98.14	$83.93	$23.93
TOTAL FARM RETURNS ABOVE OP COSTS:		$36,838.00				$37,270.00		
ANNUAL MACHINERY OWNERSHIP COST:		$27,196.81				$25,898.05		
PER ACRE:		$67.99				$64.75		
TOTAL FARM COSTS:		$75,258.8I				$76,378.05		
PER ACRE:		$188.15				$190.95		
WHOLE FARM NET RETURNS:		$9,641.19				$11,371.95		
PER ACRE:		$24.10				$28.43		

cannot afford it! While conservation tillage systems may be more profitable than conventional, it may not be financially feasible for a producer to adopt the new technology.

Economic profit or net return as it has been used in this study is the return to all unspecified factors of production. In our analyses, this has been referred to as the return to land and management since all operating costs and machinery ownership costs have been specified.

Net cash flow is the amount of actual cash (cash coming in less cash going out) that is generated by an enterprise or business. To arrive at net cash flow for our case farm, one simply deducts total cash spent for operating inputs from total returns from sale of all crops. The resulting net cash flow is the amount (per acre, enterprise, or total farm business) that remains to: (1) provide the farm owner-operator family living expenses, (2) repay outstanding debts, or (3) contribute to savings for the future.

The immediate concern in Kentucky is for the established producer using conventional-till methods to produce annual crops on highly erodible land. Assuming a grower is required to use no-tillage in order to remain in conservation compliance, can he afford to buy the equipment to make the conversion? Normally, the established producer would change to a no-till system only if the additional net cash flow generated by the new tillage system was sufficient to pay for the added machinery investment.

Table 3. Net cash flow advantage of conservation tillage systems over conventional tillage, established producer, constant **yields.**

Crop	Conv. tillage	Reduced tillage	Advantage to reduced tillage	No-till	Advantage to no-till
Corn	$69.75	$ 69.20	$ – .55	$65.55	$ – 4.20
FSSB	98.12	100.03	1.91	98.14	.02
DCSB	79.05	77.28	– 1.77	70.13	– 8.92
Wheat	29.70	30.27	.57	23.93	– 5.77
Total net cash flow advantage above conv. tillage system:			$ – 39.00		$ – 2,307.00
Net cash flow advantage of no-till system over reduced tillage system:				$ – 2,268.00	

Due to less than perfectly adapted soils, inexperience, and new management requirements, many producers switching to no-till for the first time may not be able to significantly improve yield over their conventional-till production. The net cash flow generated by each tillage system when equal crop yields across all systems are assumed is shown in Table 3. As indicated, when yields are equal for all tillage systems the net cash flow generated by either conservation tillage system is less than that provided by conventional tillage. If reduced tillage is used, it would generate **$39.00** less in total farm net cash flow than would conventional tillage. If no-till is used, the net cash flow for the farm would drop by $2,307.00.

Conclusions and Implications

The implications for the established conventional tillage producer are clear. Unless yields improve with conservation tillage, net cash flows will be reduced by a switch in tillage systems. This reduced net cash flow would make it impossible for the established producer to repay any loan associated with the purchase of no-till equipment.

Further, if all labor for the operation is supplied by the owner-operator, there is no cash outflow associated with the labor used by any tillage system. Thus, the labor saving aspects of either reduced tillage or no-till are not realized as increased cash flow. This situation would simply act to place the conservation tillage systems at a greater cash flow disadvantage than reflected in these results.

Certainly, there are numerous long-term advantages to be derived from conservation tillage systems for both society and the individual producer. However, this study provides one possible explanation of why no-till production has not escalated. More importantly, it suggests that already financially strapped crop producers required to switch to no-till for conservation compliance may be forced into further financial hardship.

Wildlife Benefits from Conservation Tillage

Ralph W. Dimmick and William G. Minser[1]

Abstract

Conservation tillage benefits wildlife by retaining vegetative residues on the surface. These residues provide food above the soil surface, cover for nesting, and protective cover during winter. Greater numbers of insects in no-till fields enhance food supplies for young birds during summer. Reduction in mechanical disturbances from summer tillage reduces nest destruction, loss of flightless young, and mortality of incubating hens. Off-site benefits accrue principally to aquatic ecosystems from reduced sediment losses and transportation of agricultural chemicals. Data-based wildlife research literature is too meager to permit wide-ranging evaluation of long-range benefits of conservation tillage.

The amount and quality of wildlife habitat on private lands has trended sharply downward over the last several decades (Carlson 1985, Vance 1976). Conventional agricultural practices traditionally have been regarded as competitive with or destructive to efforts to manage wildlife habitat. Land managers desiring to provide wildlife habitat on farm lands have often found it necessary to idle some cropland. They may expect reduced farm income and often a high unit price for wildlife produced on these diverted acres (Soutiere 1984). As a consequence, wildlife is usually given low priority on private lands, particularly those which are highly arable and fertile. Those species whose ecological requirements are best met by a combination of croplands and idle lands suffered the greatest habitat loss, and offered wildlife managers the least hope of reversing the trend on private farm lands.

Agricultural programs which subsidize farmers for retiring crop lands into permanent herbaceous or woody cover offer wildlife some relief from the downward spiral. Clearly, several provisions of the "Food Security Act of 1985" are having tremendous impact upon the farm environment in the United States; their benefits to many forms of wildlife are notable.

Similarly encouraging to wildlife managers is the development of agriculture technology which has a potential for benefiting wildlife habitat rather than destroying it. Succinctly stated by Soutiere (1984), *"Wildlife's only hope on prime farmland is to ride on the "coattails" of farm practices. programs, and polices that bring reduced costs or added income to the individual farmer, and the conservation of soil and water to the nation."* Conservation tillage in its many diverse forms is just such a practice. It is a new farming technology with potential for reversing the historical trend of modern agriculture to erode and degrade America's wildlife habitat base (Carlson 1985).

Wildlife Benefits

The potential benefits of conservation tillage to wildlife include on-site benefits, which are often immediately realized in the form of increased food and cover, and off-site benefits, particularly to aquatic ecosystems, which may be cumulative over somewhat longer time spans as a result of significantly reduced soil erosion. At present, the bulk of literature addressing wildlife benefits of conservation tillage is speculative and hypothetical. The few research reports primarily emphasize relationships between tillage methods and birds using farm lands for nesting and/or winter habitat.

On-site Habitat Modification

The biological profile of a crop field is dramatically altered by many, if not all, forms of conservation tillage. This is particularly true for no-till vs. conventional tillage for row crops such as corn and soybean.

No-till crop fields may retain 90 percent or more of crop residues and other herbaceous vegetation over the entire annual cycle, whereas conventionally tilled fields turned in the fall remain barren of vegetative cover and wildlife food resources up to 6 months of each year. Castrale (1985) reported that no-till corn or soybean fields retained a minimum of 60 percent residue, but conventional fields retained less than 15 percent. Conservation tillage, then, provides direct onsite benefits to many species of wildlife in the form of nesting cover, brood-rearing habitat, available winter food resources, and winter cover at least sufficient to improve access to the residual food supply. The expansion of acreage suitable for nesting and winter cover into croplands may also dilute predator pressure on wildlife using permanent cover units such as woodlots, fencerows, and waterways.

Nesting Habitat and Nest Success

The benefits of conservation tillage to nesting birds varies by geographic region, species of bird, and characteristics of prevailing agriculture and land use. Minser and Dimmick (1988) located 31 northern bobwhite *(Colinus virginianus)* nests on agricultural and idle land in western Tennessee (Table I). Of 12 nests in crop fields, 11 (92%) were in no-till fields and 1 in a conventional wheat field. Bobwhites nested in no-till fields, fallow fields, and idle field edges, but not tilled crop fields, in proportion to their availability. Among no-till

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crop fields, they preferred soybeans planted in the previous year's stubble and residue. Basore (1984) observed 12 species of birds nesting in no-till corn and soybeans in Iowa compared with 3 in conventionally tilled crops; overall nest density was 7.5 times greater in no-till. Major species using no-till fields included ringnecked pheasants *(Phasianus colchicus),* mourning doves *(Zenaida macroura),* and several non-game birds. Nesting density of mourning doves in no-till approached or exceeded that in strip cover, but pheasant nest densities were much lower in no-till than in adjacent strip cover, and very low when compared with other cover types.

Warburton and Klimstra (1984) reported significantly more birds in a southern Illinois no-till cornfield than in a conventionally tilled field during April - September, though specific use of the fields for nesting was not mentioned. Bobwhites were common in the no-till field, and uncommon in the conventional field. Castrale (1985) reported 32 percent more species of birds using no-till fields in southern Indiana. Among those considered as probable nesters was the northern bobwhite.

Few studies have related success rates of nests in no-till vs. conventional fields. Minser and Dimmick (1988) noted that nest success of bobwhites in no-till crops and associated idle lands (16%, n = 19) was not markedly different from that in conventional crop and cover associations (18%, n = II), where most nests were situated on idle lands. Their sample size was small, but the success rate was similar to that reported by Dimmick (1974) for 1,571 nests (11%) on an adjacent bobwhite management unit with excellent nest habitat. Basore (1984) reported that pheasant nests in no-till crop fields and adjacent strip cover failed predominantly because of predation; crop fields incurred greater rates of nest loss in 2 of 3 years. Wooly et al. (1985), extrapolating from Basore's data, concluded that pheasant production on no-till fields in Iowa was so low that *"... it is not likely to solve Iowa's pheasant **problems."*** Rodgers (1983), however, noted that in Kansas surface tillage for spring weed control in the wheat-fallow system destroys all nests and flightless young in the wheat stubble, whereas undercutters used without mulch treaders saved 53 percent of the ground nests and many flightless young. Pheasant, bobwhite, mourning dove, and songbird nests were evaluated.

Table 1. Number of bobwhite quail nests found per cover type and amount of each cover type searched, no-till bobwhite quail study, Ames Plantation, TN, 1984-1986 (Minser and Dimmick 1988).

Type of Cover Searched	Nests Found n	Nests Found %	Hectares Searched n	Hectares Searched %
No-till area, crop fields	11	35.5	21.8	28.0
No-till area, fallow fields, and idle edge	9	29.0	15.3	20.0
Conventional areas, crop fields	1	3.2	16.2	21.0
Conventional areas, fallow fields, and idle edge	10	32.3	24.1	31.0
TOTALS	**31**	100.0	78.0	100.0

The scarcity of quantitative data does not encourage wide ranging conclusions regarding the value of no-till for the production of upland birds. Bobwhites make good use of no-till for nesting (Minser and Dimmick 1988) and probably for summer feeding areas (Basore 1984, Castrale 1985, Warburton and Klimstra 1984). Predation rates may be as high or higher in no-till fields as in adjacent strip cover (Basore 1984), but losses to farm machinery are reduced or avoided when surface tillage during the nesting season is reduced or eliminated (Higgins 1975, Rodgers 1983). Though some herbicides used in no-till, particularly paraquat, may negatively influence some aspects of reproduction (Bauer 1985), it seems unlikely that no-till crop fields will serve as reproductive "traps" comparable to that which pheasant nests and broods often experience in mowed hayfields (Gates and Hale 1975).

Winter Habitat

High quality winter habitats for upland birds, particularly gallinaceous game birds in farmland, are frequently more complex than breeding habitats. The degree of interspersion, the diversity of cover types, and the quality of those cover types typically determine the winter carrying capacity for bobwhites, ringnecked pheasants, and similar species. Protective cover, travel lanes, and feeding areas often are provided by strikingly different vegetative communities.

Whereas the quality and quantity of nesting and chick-rearing cover may influence the annual surplus available to hunters, in temperate and cold climates it is the winter food and cover resource which determines the size and condition of the breeding population. It may be in this context that conservation tillage likely yields its greatest contributiod to farmland habitat. It does so through the preservation of available surplus grain, and retention of crop residues and surface litter. Warner et al. (1985) noted that the abundance of waste corn and soybeans in intermediate tilled fields in Illinois was 74 to 90 percent less than in untilled fields. The major decline in waste grain and plant residues during winter was related to an increase in post-harvest tilling practices. In Indiana, 31 species of birds were observed in crop fields during winters of 1983 and 1984 (Castrale 1985). The mean number of species and frequency of occurrence using no-till corn stubble was nearly double those using no-till soybeans and tilled fields. The critical factor was the greater height and ground cover of corn residue which offered protection against wind and concealment from predators. In Tennessee, for example, we observed two coveys of bobwhites in no-till corn stubble 70 and 100 yards from woody cover on a bright December mid-day. Untilled corn stubble and johnsongrass provided food and security unavailable in disked or plowed fields. More significant, however, was our discovery (Minser and Dimmick 1988) that conventionally tilled fields associated with good surrounding habitat yielded bobwhite densities equivalent to no-till fields when fall plowing was not practiced (Table 2). Lowest densities occurred on conventionally managed farmland where crop lands were turned in autumn. Intermediate densities were the rule on moderately good habitat with fields managed by no-till.

We interpreted our results to mean that where protective cover is well dispersed, preservation of winter food supplies by eliminating fall plowing is sufficient to maintain a high density of bobwhites. Where cover is less adequate, no-till fields add to the quantity of this resource, and along with preservation of winter food, permit higher densities than conventional tillage (Minser and Dimmick 1988).

Off-Site Benefits

The most readily recognized off-site benefits to wildlife are those resulting from dramatically reduced soil erosion and its consequences to aquatic ecosystems. For example, the sediment yield from a single, intense rainstorm on single crop no-till soybeans in west Tennessee's highly erodible soil was 309 pounds per acre, vs. 22,785 pounds per acre from single crop conventionally tilled soybeans (Shelton et al. 1982). The reduction in sediment yield was attributed to the presence of plant residue on the crop field. In Clark County, Kentucky, a 31-mm November rainfall yielded 6 tons per hectare soil loss from a conventionally tilled cornfield, but no loss from a no-till field (Moldenhauer et al. 1983).

Table 2. Bobwhite quail population densities* on no-till and conventionally planted areas on Ames Plantation, TN, December 1983-85 (Minser and Dimmick 1988).

Area		Bobwhite quail/100 ha			
		1983**	1984	1985	1986
No Till A	No-till field trial area	290	351	274	198
Control A	Conventionally planted field trial area	215	247	308	235
No Till B	No-till (nesting study area)	115	101	137	130
Control B	Conventionally planted	24	93	81	91
Control C	Conventionally planted, fall plow	41	40	103	61

* Bobwhite quail numbers determined by flush census, adjusted by doubling birds flushed to account for birds not observed (Dimmick et al. 1982).

** The 1983 census was conducted before no-till or other agricultural practices relative to this study had been implemented.

Retention of soil on site and reduction of runoff should also reduce contamination of off-site ecosystems with agricultural chemicals transported with the sediment. Though chemical transportation, and consequent contamination of the downstream ecosystem, do not necessarily parallel sedimentation losses, one must almost assume that reductions of sediment transport are desirable (Baker and Laflen 1983).

Quantifying the benefits to wildlife of reducing non-point source pollution is difficult. Databased literature on this topic is scanty or non-existent, but much needed. At present, our aquatic ecosystems are among those most endangered; their preservation and upgrading are high priority national conservation goals.

Conclusions

Conservation tillage offers potential benefits to many species of wildlife, though translating these benefits into increased species population density or community diversity has only rarely been accomplished. The engineering, chemical, and application technologies of conservation tillage are dynamic; we can expect a significant lag between the development of a new technology and our grasp of its impact upon the wildlife community of affected farmlands.

Present technology benefits wildlife directly through preservation of crop and other vegetative residues, and by reduction of disturbance to the field surface. Residue provides (1) food in the form of waste grain on the soil surface, (2) diverse structure for protective cover, and (3) residual vegetation used for constructing nests. No-till corn provides vegetative structure not unlike that provided by untilled idle lands, creating habitat suitable for birds accustomed to weedy and brushy habitats. The added structure permits edge-loving species, such as the northern bobwhite, to penetrate farther into crop field interiors, using food resources less available to them in conventionally tilled fields, particularly where fall plowing or disking are common practices.

Conservation tillage practices which reduce surface disturbance during the nesting and brood-rearing period unquestionably save many nests, chicks, and nesting hens. The proportionate contribution of young to the population resulting from nests constructed in no-till fields, however, is virtually unknown.

The quantity of wildlife research involving conservation tillage is meagre, and the quality of that research is deficient. There is presently no justification for wide-ranging prognostication of the long-range benefits to wildlife to come from the developing technology of conservation tillage.

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No-Till Demonstrations in North Alabama

D. A. Mays, B. N. Bradford, and W. G. Bennett[1]

Although no-till and reduced tillage planting techniques were commonly used in some areas of the Southeast at least 20 years ago, these practices were never widely adopted in north Alabama. This region has traditionally relied on cotton production as one of its major farm enterprises. Intensive seedbed preparation and clean cultivation have always been considered necessary for efficient cotton production, and this attitude has apparently influenced other crop production practices in the cotton growing regions. This may explain the infrequent use of no-till planting, even with crops for which the practice is well adapted.

The Tennessee Valley Authority (TVA) has a long history of demonstrating improved agricultural practices to farmers in the Tennessee Valley and elsewhere in the United States. In late 1982, agronomists from TVA met with agricultural extension agents from several northwest Alabama counties and developed plans to conduct a series of 7½ to 10-acre no-till planting demonstrations with crops commonly grown in the area. From the TVA viewpoint, the objectives of the program were: (1) to gain experience in no- till crop production in north Alabama; (2) to demonstrate the practice to farmers; and (3) to help county agents with their educational programs on no-till crop production.

To minimize the risk to participating farmers, TVA and the county agents agreed to assume most of the costs of the demonstrations. The herbicides, tractor, no-till planter, and operator were supplied by TVA. The county agents selected participating farmers, approved the demonstration sites, took soil samples, supplied the fertilizer, and coordinated the planting schedules. Participating farmers were responsible for supplying the land and getting the seed. Some seed was bought, but some was donated by seed companies. At the end of the growing season, the TVA agronomists measured crop yields.

The proportion of crops planted varied from year to year depending on farmer interest. The 1983 demonstrations included only corn and soybeans. Because there was increasing interest in grain sorghum production in the Tennessee Valley, the no-till demonstrations for 1984 and 1985 included several grain sorghum plantings.

Several kinds of soil covers were used on the demonstration fields. Corn was successfully planted in tall fescue sod, crimson clover, and in corn or soybean stubble. Full season soybeans and grain sorghum were usually planted in corn or soybean stubble, while doublecropped plantings were made in wheat stubble directly after combining. Very successful sorghum plantings also were established in killed crimson clover.

Fertilizer, if needed, was applied broadcast preplant. Herbicides were applied at planting in 20 gallons of water per acre through a boom mounted directly behind the planter units. A four-row John Deere Max-Emerge® planter was used. Herbicide mixtures used for each crop are shown in Table 1.

In a few instances where johnsongrass or marestail were present, Roundup® was used instead of paraquat, and some of the soybean fields were given a followup treatment of Basagran® to control cockleburs.

Although rainfall wasn't recorded at the site of each demonstration, rainfall data from Muscle Shoals (Table 2) show that only 1985 had reasonably good rainfall distribution during the critical part of the growing season. Moisture was limiting from mid-July through mid-September in 1983; several times from late May through September in 1984; and in April and parts of May, June, July, and August in 1986. The drought effects are reflected in relatively low crop yields for all years except 1985. The lowest yields in the dry years were produced at locations where there was very little or no midsummer rainfall, while the best yields were obtained where heavy summer showers occurred at the right time.

Summaries of yield data from all the corn, soybean, and grain sorghum demonstrations are shown in Table 3. In one 1983 demonstration, corn planted in crimson clover yielded 66 bu/acre without extra nitrogen. A planting in tall fescue sod yielded ?2 bu/acre where all the sod was killed, but failed to yield anything in a part of the field where the sod was killed in 18-inch strips over the row. The third corn demonstration in 1983 was planted in early April when it was too wet for conventional tillage and yielded 91 bu/acre, but a nearby conventionally tilled field couldn't be planted until about 2 weeks

Table 1. Herbicides used for no-till plantings.

Crop	Herbicide mixture[1]	Rate, pint/A
Corn	**atrazine 4L**	**2**
	Lasso 4EC®	**4**
	paraquat	**1.5**
Soybeans	**Lasso 4EC®**	**4**
	Lorox L®	**2**
	paraquat	**1.5**
Grain sorghum	**atrazine**	**3**
	Dual 8E®	**1.5**
	paraquat	**1.5**

[1]A non-ionic surfactant was used with all herbicide mixtures.

[1]Agronomists, Agricultural Research Branch of the National Fertilizer Development Center, TVA; and Regional Director of National Programs Branch, TVA.

Table 2. Growing season rainfall at Muscle Shoals, AL.

		Rainfall, inches			
		1983	1984	1985	1986
March	1-15	3.3	1.9	0.0	2.3
	16-31	1.4	3.7	2.3	1.4
April	1-15	10.3	1.6	1.9	0.0
	16-30	2.2	2.6	2.6	0.4
May	1-15	1.7	5.9	3.5	1.1
	16-31	9.8	1.3	1.4	4.4
June	1-15	2.7	0.0	0.3	6.6
	16-30	4.7	1.6	2.6	0.8
July	1-15	2.3	0.8	2.2	2.4
	16-31	0.9	2.3	3.0	0.0
Aug.	1-15	0.8	1.2	2.6	0.7
	16-31	0.3	0.7	7.7	3.3
Sept.	1-15	0.6	0.1	0.2	3.7
	16-30	2.1	0.0	1.7	2.0
TOTAL		43.1	21.9	32.0	29.1

later and yielded very poorly because of midsummer moisture stress.

Soybean yields were extremely variable in 1983 because most late summer rain came as local showers. One field, which yielded only 5 bu/acre, received no rain between planting and harvesting. On three farms where side-by-side comparisons were possible, two no-till plantings were higher yielding by an average of 8 bu/acre, while no-till and conventional yields were similar at the third location. Corn and soybean yields were low in 1984 because of poor moisture conditions after mid-May, while grain sorghum yields were only a little helow average. Where comparisons were possible, conventionally planted soybeans were better than no-till soybeans once and poorer than no-till soybeans in another demonstration. In one tillage comparison, no-till sorghum yielded 9 bu/acre more than conventionally tilled sorghum.

Table 3. Summary of no-till demonstrations with corn, grain sorghum, and soybeans.

Crop	Number of demonstrations	Yield, bu/acre Average	Range
	1983		
Corn	3	76	66-91
Soybeans	7	25	5-38
	1984		
Corn	4	63	44-76
Soybeans	7	17	7-26
Grain sorghum	4	77	72-82
	1985		
Corn	6	118	47-186
Soybeans	4	29	18-46
Grain sorghum	10	86	59-130
	1986		
Corn	2	61	60-62

Soil moisture conditions in the region were generally good throughout the 1985 growing season, and no-till demonstrations produced good to excellent yields except in a few locations where weed control was poor. One corn planting yielded poorly because of competition from uncontrolled fall panicum and localized moisture stress, while another corn demonstration was damaged by heavy johnsongrass competition. One soybean planting suffered severe competition from uncontrolled marestail.

In 1986, two corn demonstrations were conducted in a county which had not yet participated in the no-till demonstration program. Although good stands of weed-free corn were established, midsummer moisture stress reduced yields to only about 60 bu/acre.

The experiences gained in this series of demonstrations emphasize the need to select against weed problems when choosing fields for no-till planting. Although this may be difficult for county agents and research workers to do on private farms because of a lack of knowledge about individual fields, most farmers should know what weed problems exist on their own fields.

High yields of corn are difficult or impossible by no-tilling on johnsongrass or bermudagrass-infested fields because of a lack of selective herbicides; grain sorghum can't be produced at all. However, soybeans can be successfully produced in such a situation because several chemical grass-control options are available. Conversely, a heavy infestation of cocklebURS or other broadleaf weeds can more easily be controlled in no-till fields if corn or sorghum, rather than soybeans, are grown.

The type of weeds present should also influence the type of burn-down herbicide which is used. Tough perennial weeds such as marestail must be treated with Roundup® rather than paraquat, which is adequate for easily killed annual weeds.

No-till planting is effective in controlling soil erosion under a wide range of conditions. It often allows earlier planting in wet springs, and it can be a cost-saving method of crop establishment. However, no-till is not a substitute for good management practices, and it will not be an effective crop production tool with poor management.

Tillage Practices on Kentucky Cropland: The 1985 Food Security Act's Effect

David Ditsch and Lloyd Murdock[1]

Kentucky has a great deal of soil erosion each year. The average rate of rill and sheet erosion on Kentucky's cultivated cropland is about 12 tons per acre per year, according to estimates by the Soil Conservation Service. This level continues despite extensive educational efforts and despite the cost-share program of the Agricultural Stabilization and Conservation Service (ASCS). This rate of soil loss is alarming because most of Kentucky's soil types have a tolerable soil loss rate ("T" Value) of only 3-5 tons per acre per year.

Food Security Act's Provisions

In 1985, Congress passed the Food Security Act (FSA) to accelerate use of soil conservation practices on highly erodible land and to protect wetlands. Although each landowner voluntarily decides whether to comply with FSA provisions, only those who do comply are eligible for USDA Farm Program benefits.

Three 1985 FSA programs are likely to significantly affect conservation farming practices in Kentucky: the Conservation Reserve (CRP), Sodbuster, and Conservation Compliance.

Conservation Reserve

If landowners remove highly erodible cropland from production for 10 years, they will receive annual payments. Based on the SCS definition of highly erodible lands, approximately 46 percent of Kentucky's cultivated cropland is highly erodible. Therefore, programs affecting this land have great potential for changing tillage practices in Kentucky.

Sodbuster

If land users plan to produce a commodity crop on highly erodible land which was not cropped during 1981-85, they must use cropping techniques outlined in an approved conservation plan.

Conservation Compliance

This portion of the FSA covers all remaining highly erodible cropland. Landowners producing crops on highly erodible land must develop a conservation plan. The plan must be approved by January 1, 1990 and fully applied by January 1, 1995 for the landowner to stay eligible for government support programs.

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The conservation plan should allow for crop production while controlling soil erosion within acceptable limits according to SCS specifications. Conservation practices such as crop rotations, residue management, cover cropping and reduced tillage are among the most practical and economical methods of controlling soil erosion in most areas of Kentucky. However, as the slope length and percent increase, cropping systems involving no-tillage, strip cropping, sod-based rotations and possibly structural measures may be necessary to adequately control soil loss.

Considering the differences in soil types, topography, and rainfall that occur across the state, how well have producers matched their tillage practices to the erosive characteristics of the land they use? According to the Conservation Tillage Information Center, in 1986, Kentucky reported only 40 percent of the cropland to be conventionally tilled, while 37 percent was reduced-tilled, and 23 percent no-tilled (National Survey of Conservation Tillage Practices. Kentucky County Summary. Ft. Wayne, IN). These tillage statistics certainly suggest that Kentucky producers are attempting to make conservation tillage a vital part of their cropping operations.

If the tillage system on much of Kentucky's highly erodible land needs to be changed in order to comply with the 1985 FSA provisions, then a large job lies ahead. An estimate of the tillage change required by the FSA should help professional conservationists and educators to know the size of the task and identify counties requiring the greatest change.

Food Security Act Effects

What will be the effect of the 1985 Food Security Act on farming practices in Kentucky? An answer is not easy to give because the bill is complex and because limited information is available on some aspects of soils and land use in Kentucky. However, we attempted to determine the potential impact of the FSA on tillage practices for each county in Kentucky using two different methods.

(A) Method for Cultivated Cropland

Information provided in the 1982 National Resource Inventory (U.S. Soil Conservation Service. Kentucky's Land Resource: Conditions and Trends. September 1985) was used to determine the number of continuously cultivated cropland acres in each land class across the state. Estimating tillage needs for "cultivated cropland" did not include the sod land in a sod-based rotation or exclude land currently enrolled in the CRP.

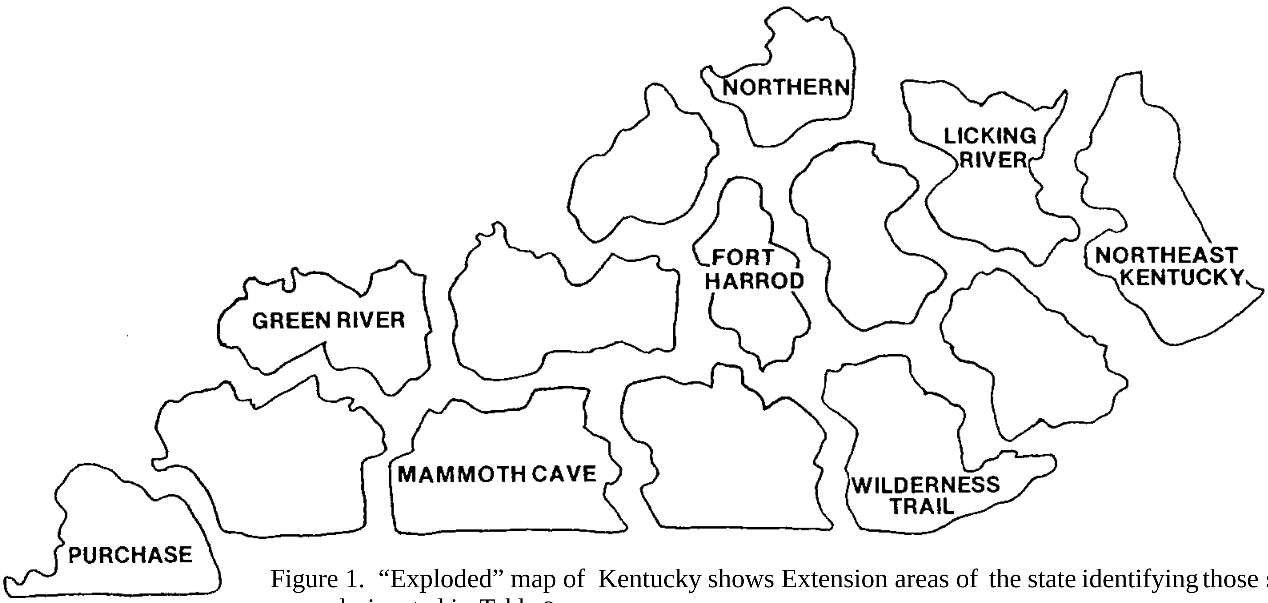

Figure 1. "Exploded" map of Kentucky shows Extension areas of the state identifying those selected areas designated in Table 2.

The type of tillage system required by land class for Conservation Compliance was derived from the SCS Technical Guide, Section 3, *Guidelines for Planning Alternative Conservation Compliance Systems. (U.S. Soil Conservation Ser*vice. June, 1987). Conventional tillage was considered acceptable on all cultivated Class I, IIw, IIs, IIIw, IVw, and IVs land. Reduced tillage would be required on all Class IIe land and 22 percent of the Class IIIe land (estimated acreage in doublecropping after wheat). No-tillage would be necessary on 100 percent of the Class IIIe and IVe land. The "cultivated" cropland acres for each tillage system were totaled and divided by the total cultivated cropland acres to give the required distribution of tillage system for Conservation Compliance.

(B) Method using Sod-based Rotation and the CRP

An attempt was made to adjust the estimates made by Method A for land enrolled in CRP and land managed in a sod-based rotation. To begin, all "cropland" acres in land Classes IIIe, VIe, VIIe, and 25 percent of IIe land were considered eligible for the CRP. The distribution of currently enrolled CRP acres by land class was assumed to be proportional to the distribution of eligible CRP acres. This results in most of the CRP acres being assigned to the IIIe and IVe land classes. The enrolled CRP acres were then subtracted from the appropriate cropland land class resulting in "CRP Adjusted Cropland Acres."

Consideration was then given to the cropland acres that are managed in a sod-based rotation. For this estimate an assumption was made that all cropland in a sod-based rotation followed a 2-year row crop/2-year grass rotation. According to SCS planning guidelines, cropland in a sod-based rotation can be cultivated more intensively. This allows more tillage on the rotated portion of the IIe and IIIe land classes. Applying these guidelines to cropland adjusted for CRP and sod-based rotations, conventional tillage was estimated to be acceptable on 100 percent of the cultivated land in Class I, IIw, IIs, IIIw, IVw, IVs, and 15 percent of the IIe adjusted cropland. Reduced tillage would be required on 70 percent of the Class IIe and 38 percent of the IIIe land. No-tillage would be necessary on 50 percent of the IIIe land and 65 percent of the IVe land. Table 1 depicts the required tillage distribution of land in Classes IIe, IIIe, and IVe.

Estimated Tillage Change

To determine possible changes in tillage brought about by the FSA, we compared our estimated tillage requirements to current tillage use (as reported by the 1986 Conservation Tillage Information Center Tillage Survey (Table 2). Actual

Table 1. Distribution of tillage required by 1985 FSA on land classes IIe, IIIe, and IVe.

Land class	Tillage system	Adjusted cropland % of acres	Land use
IIe	None	15	Rotated in Grass
	Conventional	15	Rotated in Crop
	Reduced	70	Continuous Crop
IIIe	None	25	Rotated in Grass
	Reduced	25	Rotated in Crop
	No-till	50	Continuous Crop
	Reduced	12.5	Seedbed Prep. for Wheat
IVe	None	35	Rotated in Grass
	No-till	35	Rotated in Crop
	No-till	30	Continuous Crop

use of no-tillage above what was required was credited to reduced tillage. Table 2 shows the average tillage change calculated for selected geographical extension areas across the state and also shows counties with extremes in each area. Figure 1 shows the location of the areas within the state.

The unadjusted estimate (A) appears to more accurately predict the tillage changes necessary for compliance in the western part of the state. (Several county and area personnel were contacted to obtain "ground truth" on these estimates. The percentage of cultivated cropland acres that will require a tillage change is smallest in western Kentucky and much higher in the central and eastern part. However, since the actual number of cultivated acres in central and eastern Kentucky is small, the magnitude of change may not be as great as the percentage indicates.

In most western counties the actual need for change may be underestimated. The Adjusted Estimate (B) appears to better reflect the situation in central and eastern Kentucky. For

Table 2. Estimated impact of the 1985 Food Security Act on tillage use for cultivated cropland in selected areas and counties in Kentucky.

	Required tillage Irrespective of rotations and CRP[1]			Required tillage adjusted for rotations and CRP[2]			1986 Tillage use[3]			Possible changes[4]	
	Conv. tillage	Reduced tillage	No tillage	Cnnv. tillage	Reduced tillage	No tillage	Conv. tillage	Reduced tillage	No tillage	Method A	Method B
	%			%			%			%	
State	34.82	40.67	24.51	42.32	38.99	17.70	40.10	37.30	22.60	5.00	0.00
PURCHASE AREA											
Area*	54.18	25.91	19.90	65.37	23.56	11.05	27.09	44.74	28.16	1.13	0.00
Ballard	61.22	22.91	15.88	70.21	20.74	9.05	10.10	64.65	25.25	0.00	0.00
Marshall	46.81	26.25	26.94	61.48	23.28	15.24	14.24	63.73	22.03	5.00	0.00
GREEN RIVER AREA											
Area	69.55	19.03	11.40	74.09	17.46	8.45	57.86	31.83	10.22	4.42	2.00
McLean	83.36	10.60	6.04	86.02	9.67	4.31	61.63	32.14	6.22	0.00	0.00
Ohio	56.87	22.28	20.84	63.80	21.52	14.67	71.66	16.90	11.44	15.00	8.00
MAMMOTH CAVE AREA											
Area	19.98	51.16	28.85	29.64	50.89	19.46	42.06	38.82	19.11	24.70	16.50
Logan	24.21	63.38	12.41	36.72	55.96	7.31	26.54	42.68	30.78	2.00	0.00
Metcalfe	14.73	56.90	28.37	24.54	54.63	20.83	66.95	24.10	8.95	52.00	42.00
NORTHERN KENTUCKY AREA											
Area	18.77	43.12	38.10	25.69	43.83	30.47	71.36	11.60	16.92	54.00	45.75
Carroll	60.81	35.90	3.29	67.17	30.64	2.19	69.24	25.93	4.83	8.00	2.00
Grant	4.36	28.85	66.79	9.34	24.87	65.79	71.13	5.00	23.07	68.00	62.00
FORT HARROD AREA											
Area	14.64	49.53	35.81	22.64	49.73	27.61	47.63	17.82	34.54	36.00	27.12
Franklin	51.10	42.70	6.19	58.93	35.06	6.00	41.05	12.37	46.58	10.00	0.00
Jessamine	2.97	71.26	25.77	14.08	67.12	18.08	80.25	9.88	9.88	77.00	65.00
LICKING RIVER AREA											
Area	31.62	33.76	34.61	37.31	32.81	29.86	56.71	24.07	19.20	37.20	31.20
Bath	59.66	19.13	21.21	62.97	19.14	17.89	57.46	22.39	20.15	1.00	0.00
Lewis	36.74	63.26	0.00	47.90	52.10	0.00	85.71	10.24	4.05	49.00	38.00
NORTHEAST KENTUCKY AREA											
Area	74.74	15.03	10.22	77.38	13.77	8.84	75.25	21.98	2.76	15.50	12.88
Boyd	100.00	0.00	0.00	100.00	0.00	0.00	90.00	0.00	10.00	0.00	0.00
Martin	56.10	0.00	43.90	56.10	0.00	43.90	7.14	91.14	1.71	42.00	42.00
WILDERNESS TRAIL AREA											
Area	59.49	24.28	16.22	63.68	23.85	12.46	63.20	24.95	11.83	17.25	14.00
Bell	100.00	0.00	0.00	100.00	0.00	0.00	46.67	40.00	13.33	0.00	0.00
Laurel	25.12	30.71	44.17	29.80	35.74	34.46	78.87	6.35	14.78	54.00	49.00

[1] Method 1: Distribution of basic tillage systems by percent cultivated cropland as proposed by SCS "Guidelines for Planning Alternative Conservation Compliance Systems.'' Cultivated cropland acres derived form SCS 1982 NRI. Does not include acres in some type of sod-based rotation and does not eliminate those acres currently enrolled in the CRP.

[2] Method 2: Distribution of basic tillage systems by percent cultivated cropland as proposed by SCS guidelines. Cultivated cropland acres are adjusted for acres in a sod-based rotation and acres enrolled in CRP.

[3] Distribution of basic tillage systems by percent cultivated cropland as reported by the Conservation Tillage Information Center. Refer to the 1986 National Survey of Conservation Tillage Practices - Kentucky County Summary.

[4] Percentage of change in tillage use that will be necessary to satisfy the Conservation Provisions of the 1985 FSA. Method 1: Possible % change when comparing the 1986 Tillage Survey to the Required Tillage irrespective of Rotations and CRP. Method 2: Possible % change when comparing 1986 Tillage Survey to Required Tillage Adjusted for Rotation and CRP.

*Extension Area values represent averages for all counties within the area. Counties identified in each area represent the extremes within that area.

counties with long-term sod-based rotations, the percent change needed may be over-estimated.

Why Variations Exist

Several conditions may cause a county's actual need for tillage change to vary from the two estimates.

(1) Most fields contain several different soil types. According to the Conservation Compliance guidelines, the most highly erodible one-third of the field dictates the tillage system for the entire field. Consequently, some land not classed as highly erodible will receive the same conservation treatment as the highly erodible part of the field. This situation will likely be more common in western Kentucky.

(2) A substantial portion of the no-till acres currently reported by some counties is (as a result of no-till double-crop soybeans) being planted on soils which may not be classified as highly erodible. This situation is probably more common in western Kentucky.

(3) Some counties have a high percentage of cropland in a sod-based rotation. Where this is the case, cultivated cropland will be permitted to use less conservation tillage than would typically be required for continuous cultivated cropland. This situation is probably more common in central and eastern Kentucky.

(4) The definition of reduced tillage may change. Reduced tillage, as defined by the CTIC, may not always provide adequate soil loss protection as required by the Conservation Compliance Guidelines.

(5) The most highly erodible land, often a producer's less profitable land, is generally the acreage enrolled in USDA programs which idle the land. Increased participation in these programs will tend to decrease the need for no-till and reduced tillage.

Conclusion

Based on our calculations, the amount of tillage change required statewide by the 1985 FSA appears surprisingly small. However, after examining individual counties' current tillage status, we see that many counties are exceeding the conservation compliance guidelines by practicing conservation tillage on additional land not classified as highly erodible. This situation has compensated for other counties that are substantially helow the Conservation Compliance standard. Therefore, although Kentucky appears very close to compliance in its total number of acres using conservation tillage, many counties will need large changes in tillage use. The variation among farmers within a county will even be greater and many farms will require large changes.

Conservation Tillage Cropping Systems for the Texas Southern High Plains

J. W. Keeling, C. W. Wendt, J. R. Gannaway,
A. B. Onken, W. M. Lyle, R. J. Lascano, and J. R. Abernathy[1]

Introduction

The Southern High Plains of Texas are a major cotton producing area with annual plantings of 3.2 million acres. Over the last 20 years, a cotton monoculture system has evolved. Due to rising production costs, declining yields, and increased concern about soil erosion, interest in conservation tillage/crop rotation production systems has increased.

In conventional tillage cotton production, dinitroaniline herbicides incorporated prior to planting are utilized to control annual broadleaf weeds and grasses while perennial weeds and grasses are controlled by various spot applications and cultivation (5). However, continuous cotton production does not produce sufficient residue cover to prevent soil erosion during high spring winds. Crops such as sorghum *(Sorghum bicolor* (L.) Moench) or wheat *(Triticum aestivum* L.) provide sufficient residue to protect the soil from erosion, but conventional land preparation and preplant herbicide incorporation bury most of this residue, significantly reducing the amount of soil cover.

Several conservation tillage systems for cotton production have been reported for various regions (1, 2, 4). Conservation tillage has shown potential for reducing production costs (6) and increasing yields for cotton (3). Conservation tillage cropping studies were initiated in 1985 at three Texas locations: Lubbock, Halfway, and Wellman, all of which are typical of the hard; mixed- and sandy-land areas, respectively, of the Southern High Plains. Various conservation tillage/crop rotation systems were compared to conventional cotton production in terms of crop growth and development, yield, quality, and profitability under irrigated and dryland conditions.

Materials and Methods

Cropping systems evaluated at the three locations included continuous cotton using conventional, reduced and no-tillage systems, conservation tillage/crop rotations including sorghum-cotton, wheat-cotton, terminated wheat-cotton, forage sorghum-cotton, and fallow-cotton.

Tillage operations for the conventional production systems included stalk shredding, disking, chiseling, listing to form beds, rod weeding, rotary hoe, and three cultivations. For continuous minimum tillage cotton, listing to incorporate preplant herbicides, rod weeding, rotary hoe, and one cultivation were performed. For no-till cotton and conservation tillage-rotations, one cultivation to make water furrows for irrigation was the only tillage operation performed. Combination of early preplant, preemergence, and postemergence herbicide treatments replaced tillage operations to control weeds in all conservation tillage systems.

These herbicide treatments included 2,4-D amine for winter annual weed control, Roundup® and Caparol® or Sancap® at planting, and Fusilade® for volunteer sorghum control. Treflan® was applied preplant incorporated in conventional and minimum-till cotton. Cotton (Paymaster HS 26) was planted in mid-May at each location and Temik® was applied at 2 Ib/acre for thrip control. Fertilizer applications were based on soil tests recommendation for each cropping system. Furrow irrigation was applied preplant (3 inches) and at peak bloom (3 inches). Plots were harvested and ginned to determine cotton yields and lint quality.

Results and Discussion

The growing season in 1987 was characterized by a dry spring, excessive rainfall at planting, timely July rain, and warm, dry fall weather ideal for cotton maturity. Heat units for the growing season were near normal. Seasonal rainfall was also near normal, but crops benefited from moisture stored as a result of heavy rains in the fall of 1986.

Yields and net returns of irrigated and dryland cotton cropping systems at Lubbock in 1987 are summarized in Table 1. Excellent cotton yields were produced under both irrigated and dryland conditions. In continuous irrigated cotton, no significant difference in yields was determined between tillage systems. Cotton yields were significantly increased, compared to conventional cotton, with the conservation tillage cotton rotations with sorghum, wheat, and terminated wheat. These three rotational systems also produced significantly increased net returns. For dryland cotton, minimum and no-till continuous cotton systems produced significantly higher yield than conventional tillage production. Conservation tillage-rotation systems producing highest yields and highest net

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'Table 1. Cotton yield and value, production costs, and relative profitability of irrigated and dryland cropping systems at Lubbock, Texas, 1987.

	Irrigated				Dryland			
Cropping system'	Cotton yield (lb/a)	Crop² value ($/a)	Production cost ($/a)	Net3 returns ($/a)	Cotton yield (lb/a)	Crop value ($/a)	Production costs ($/a)	Net returns ($/a)
Continuous Cotton								
Conventional Till	801 b-d4	425	I50	275 b	691 d	360	103	257 c
Minimum Till	769 d	410	134	276 b	846 ab	435	95	340 a
No-Till	808 b-d	427	I40	287 b	833 a-c	425	86	339 a
Conservation Till-Rotations								
Terminated Wheat-Cotton	965 a	515	156	359 a	817 a-d	425	101	324 ah
Sorghum-Cotton	937 ab	499	156	343 a	753 a-d	388	84	304 ab
Wheat-Cotton	952 a	503	I45	358 a	874 a	445	90	355 a
Forage Sorghum-Cotton	889 a-c	473	I54	319 ab	844 ab	444	89	355 a
Fallow-Cotton	764 cd	400	139	261 b	709 cd	366	82	284 bc

'Denotes 1986-1987 crop sequences.
[2]Crop values calculated as per acre yield x loan price without deficiency payments included.
[4]Net returns do not reflect land costs or rent. Net returns = crop value – production cost.
[4]Means followed by the same letter are not significantly different at the 5% level of probability (Duncan's Multiple Range Test).

returns included wheat-cotton and forage sorghum-cotton rotations. Under both irrigated and dryland conditions at Lubbock, the fallow-cotton rotation produced the lowest yields of the conservation tillage systems compared.

At the sandyland site near Wellman, overall dryland cotton yields were higher than at Lubbock (Table 2). The terminated wheat-cotton and sorghum-cotton conservation tillage rotations produced significantly higher yields than the conventional cotton production system. In continuous cotton, highest cotton yields resulted with the minimum tillage system. In comparing the highest yielding conservation tillage system (sorghum-cotton) to conventional tillage cotton, average yields were increased by 33 percent and net returns by 46 percent.

Table 2. Cotton yield and value, production costs, and relative profitability for cropping systems at Wellman. Texas, 1987.

	Dryland			
Cropping system'	Cotton yield (lb/a)	Crop value ($/a)	Production costs ($/a)	Net3 returns ($/a)
Continuous Cotton				
Conventional Till	773 cd[4]	417	112	305 b
Reduced Till	845 bc	456	111	305 ab
No-Till	702 d	379	98	281 c
Conservation Till-Rotations				
Terminated Wheat-Cotton	902 abc	487	108	379 a
Sorghum-Cotton	1,026 a	554	108	446a
Forage Sorghum-Cotton	818 bc	434	97	337 b
Fallow-Cotton	754 cd	400	100	300 c

'Denotes 1986-1987 crop sequences.
[2]Crop values calculated as per acre yield x loan price without deficiency payments included.
[3]Net returns do not reflect land costs or rent. Net returns = crop value – production cost.
[4]Means followed by the same letter are not significantly different at the 5% level of probability (Duncan's Multiple Range Test).

Excellent yields of high-quality cotton were produced at Halfway in 1987 (Table 3). No significant differences in irrigated cotton yields were found, but net returns were increased when compared to conventional tillage cotton with minimum-till continuous cotton, terminated wheat-cotton, forage sorghum-cotton, and wheat-cotton conservation tillage rotations. Lowest yields and net returns resulted with the fallow-cotton rotation. When comparing the forage sorghum-cotton conservation tillage rotation to conventional tillage, irrigated cotton yields were increased by 7 percent and net returns by 14 percent.

Dryland cotton yields with all conservation tillage-rotation systems at Halfway were significantly higher than cotton yields with conventional tillage. In continuous cotton, minimum and no-till systems produced higher yields and greater net returns than conventional tillage cotton. Highest dryland yields resulted from the sorghum-cotton conservation tillage rotation. When compared to conventional tillage continuous cotton, this production system increased yields by 62 percent and net returns by 94 percent. As in Wellman and Lubbock locations, conservation tillage had the most positive impact on cotton yields under dryland conditions.

Results at all locations indicated that conservation tillage systems can reduce production costs through elimination of tillage operations. These systems also increased cotton yields, especially under dryland conditions, resulting in greater profitability.

In addition to these benefits, these conservation tillage systems, when combined with rotations of high residue crops and cotton, provide a means for reducing soil erosion and satisfying Conservation Compliance provisions of the 1985 Farm Bill.

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Table 3. Cotton yield and value, production costs, and relative profitability of irrigated and dryland cropping systems at Halfway, Texas, 1987.

	Irrigated				Dryland			
Cropping system[1]	Cotton yield (lb/a)	Crop[2] value ($/a)	Production costs ($/a)	Net[3] returns ($/a)	Cotton yield (lb/a)	Crop yield ($/a)	Production costs ($/a)	Net returns ($/a)
Continuous Cotton								
Conventional Till	992 a[4]	536	167	369 ah	672 d	353	108	245 c
Minimum Till	1,001 a	540	145	395 a	713 cd	383	88	295 c
No-Till	938 a	506	151	355 ah	862 ah	466	100	366 h
Conservation Till-Rotalions								
Terminated Wheat-Cotton	1,058 a	571	164	407 a	948 a	515	112	403 ab
Sorghum-Cotton	927	501	147	354 ah	1,085 a	582	108	474 a
Forage Sorghum-Cotton	1,061 a	573	154	419 a	944 a	509	101	408 ah
Wheat-Cotton	1,003 a	542	151	391 a	979 a	526	103	423 ab
Fallow-Cotton	916 a	495	150	345 b	862 a-c	467	97	370 h

[1]Denotes 1986-1987 crop sequences.
[2]Crop values calculated as per acre yield x loan price without deficiency payments included.
[3]Net returns do not reflect land costs or rent. Net returns = crop value – production cost.
[4]Means followed by the same letter are not significantly different at the 5% level of probability (Duncan's Multiple Range Test).

Influence of Long-Term No-Tillage on Crop Rooting in an Ultisol

W. L. Hargrove, J. E. Box, Jr., D. E. Radcliffe, J. W. Johnson, and C. S. Rothrock[1]

The Ultisols predominantly found in Georgia are sandy in texture with poorly developed structure. Our previous research has shown that continuous no-tillage over at least a 3-year period often results in greater bulk density and mechanical impedance in the soil surface (0 to 4 inches) compared to conventional tillage (NeSmith et al., 1987a,b; Tollner et al., 1984). Due to the sandy texture, low organic matter content, and poor structural stability, the surface soil tends to compact under no-tillage. However, it has been our observation that in long-term (11 years) no-tillage plots on a Cecil soil, summer crop performance has been good in years 5 through 11 even though dense compacted layers are present. It is our hypothesis that some large continuous pores through the compacted layers have been established and preserved through no-tillage management, which has allowed root proliferation into the subsoil.

Efforts to characterize the soil physical condition and, in particular, the pore size distribution, in these long-term studies have been made and are described in a companion paper in these Proceedings (Golabi et al., 1988). Results indicated that conventional tillage provided a superior rooting environment due to less density and mechanical resistance. This is difficult to reconcile with our observation of greater plant growth by summer crops with no-tillage. Greater soil water storage has also been documented with no-tillage compared to conventional tillage and may account for the greater plant growth (Golabi et al., 1988). However, the influence of soil compaction on root growth and the distribution of roots may influence the plant accessibility to the additional water stored under no-tillage.

The objective of this study was to measure doublecropped wheat ***(Triticum aestivum*** L.) and soybean ***(Glycine*** *max* L. Merr.) root growth in a long-term (11 years) field experiment comparing no-tillage and conventional tillage practices. Quantification of root growth was used to document whether the measured physical parameters indeed impede root growth.

Methods

This study was conducted in an on-going, long-term tillage study initiated in fall 1974. The experimental site was a Cecil sandy loam Typic Hapludult) located near Griffin, GA, which had been doublecropped to either wheat and soybeans or wheat and grain sorghum [*Sorghum bicolor* (L.) Moench] for 11 years prior to these observations. A detailed description of the experimental design and management of the study can be found in Hargrove et al. (1982). Briefly, the treatments were either continuous moldboard tillage (CT) or continuous no-tillage (NT) for all of the 11 years prior to these observations. The tilled treatment was plowed both before planting wheat and again before soybean.

Wheat (cv. Stacy) was planted on November 5, 1986 in 10-inch rows. The entire experimental area received 550 lb/acre of 10-20-30 fertilizer prior to planting. An additional 45 lb of N/acre as ammonium nitrate were applied as a top-dressing on March 4, 1987. Wheat grain was harvested on June 4. Due to rainy, wet weather in June, tillage treatments were not conducted nor soybeans planted until June 30. Soybeans were harvested on October 29.

Measurements of roots were made using a video camera/minirhizotron technique described by Upchurch and Ritchie (1983). Minirhizotron tubes were installed as described by Box and Johnson (1987) on December 10, 1986, for the wheat crop and on July 15 for the soybean crop. Root counts were made February 10, March 11, April 22, and May 5 for wheat, and August 2, 19, and 31, and September 20 for soybeans. Wheat top growth and soil water content were also measured on March 8 and 23. Soybean top growth and soil water content were measured August 4, 20, and 31, and September 9.

Results and Discussion

Wheat root counts per 4-inch depth increment for each of four dates are shown in Figures 1-4. On the first date (February 10) the plowed soil had a significantly greater root density on the face of the minirhizotrons than the no-till soil at a depth of 4 to 12 inches (Figure 1). Cone index measurements indicated the presence of a compacted zone at a depth of 4 to 8 inches in the NT treatment (Golabi, et al., 1988). Also, bulk density was significantly greater at this depth under NT compared to CT (1.60 vs 1.40 g/cm^3). This, coupled with the generally greater water content of the NT soil and cooler soil temperatures as a result of mulch cover, increases the likelihood of significant oxygen stress and/or root disease caused by *Pythium* spp. in the NT soil.

On the next measurement date (March 11), no significant differences were found for root counts, although the plowed

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soil had slightly higher root counts again in the 4 to 12-inch soil depth (Figure 2). On the two subsequent dates (April 22 and May 5), a proliferation of roots occurred in the surface 8 inches of the NT soil (Figures 3 and 4). The NT treatment also had more roots than the CT treatment at soil depths between 16 and 40 inches, though the numbers were not statistically significant. It was apparent that plants continued to produce roots during reproductive development in the NT treatment; whereas, the plants did not in the CT treatment. This partitioning of carbon to root growth during anthesis and grain formation is probably a detriment to grain yield.

Soybean root counts per 4-inch depth increment are shown for four dates in Figures 5-8. Initially, root counts were not very different between CT and NT with the exception that CT had more roots between a depth of 8 and 12 inches (Figure 5). By August 19 (about the time of flower initiation), the CT treatment had considerably more roots in the surface 16 inches of soil (Figure 6). We surmise that this was a result of low mechanical impedance in the plowed soil and a relatively high soil moisture content, which resulted from several small rainfall events during the first 2 weeks of August (3 inches total in five events). However, by the next measurement on August 31 and on September 20, the NT treatment had significantly more roots in the surface 12 inches of soil and tended to have more roots (but not statistically significant) at depths greater than 24 inches (Figures 7 and 8). In fact, counts on August 31 (Figure 7) show a considerable decline for the conventional tillage treatment compared to 12 days earlier (August 19, Figure 6). We believe that root death occurred as a result of a period of about 4 weeks with no rainfall (August 11 to September 5) in which the soil surface dried rapidly. However, soil moisture data (not shown) in-

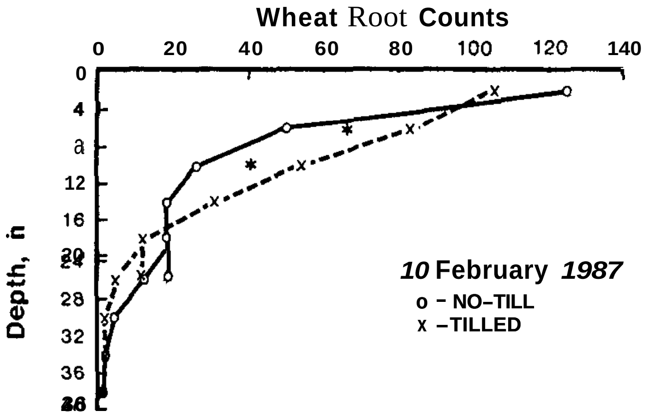

Figure 1. Wheat root counts per Cinch soil depth February 10, 1987. Asterisk (*) denotes a significant different at a = 0.05.

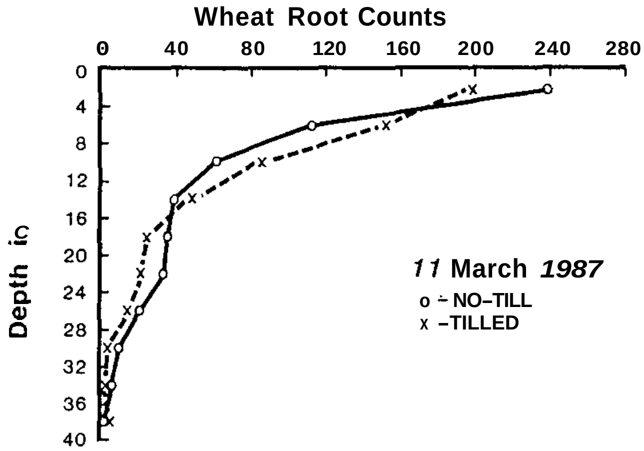

Figure 2. Wheat root counts per 4-inch soil depth March 11, 1987. Asterisk (*) denotes a significant difference at a= 0.05.

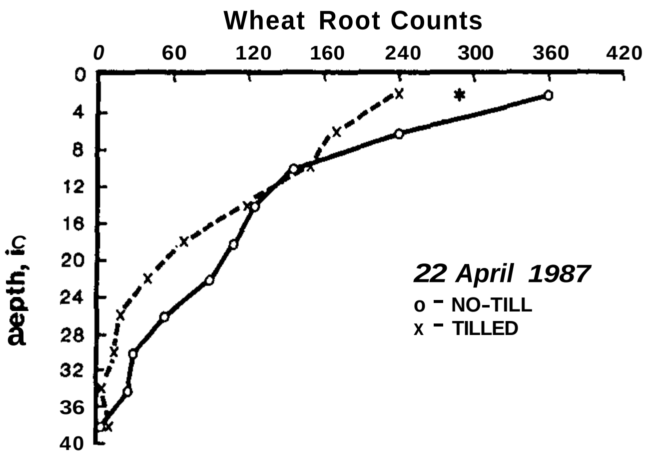

Figure 3. Wheat root counts per 4-inch soil depth April 22, 1987. Asterisk (*) denotes a significant difference at $\alpha = 0.05$.

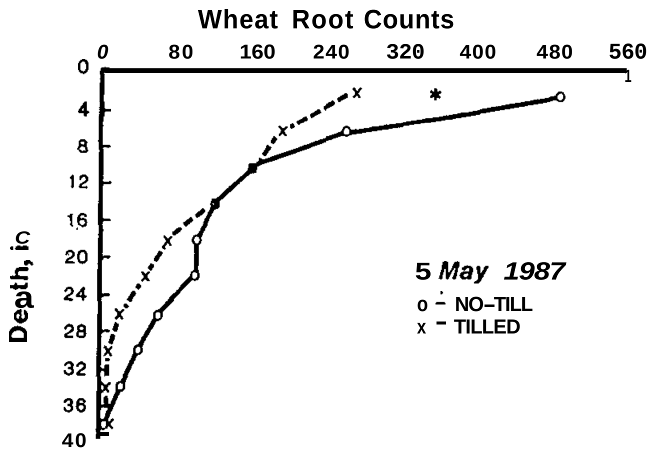

Figure 4. Wheat root counts per Cinch soil depth May 5, 1987. Asterisk (*) denotes a significant difference at $\alpha = 0.05$.

dicate that more water was stored under the no-tillage treatment. This apparently supported more root growth under the no-till treatment compared to the conventional treatment, but did not result in significant differences in top growth or N content (data not shown).

Perusal of crop yield data over the 10-year period of this experiment shows that for the summer crop, whether it be soybean or grain sorghum, NT results in greater yields than CT in years when significant moisture stress occurs (1979, 1981, 1983, 1985, 1986, 1987) and in equal yields in years when rainfall distribution is better (1982, 1984).

The reverse is true, however, for wheat. In years of high rainfall (1980, 1981, 1982, 1983, 1987), wheat yields were less with NT compared to CT, but in years with less than average rainfall in the winter and spring months (1984, 1985, 1986) yields were equal. The reason for less wheat yield with NT is probably related to a complex array of factors including oxygen stress, mechanical impedance, and root diseases (Box, 1986; Rothrock, 1986). In separate studies, fumigation with methyl bromide alleviated depressed wheat yields under NT, indicating the importance of root diseases. *Pythium* spp. were the most common pathogens isolated from roots of wheat seedlings and were isolated more frequently from plants under NT.

Results from this long-term experiment indicate that the greatest total production would be achieved with fall tillage prior to planting wheat in doublecropping followed by no-till soybeans or grain sorghum. Since the fall is the period of least erosion hazard in Georgia (because of less total rainfall and less rainfall energy), tillage should be done at this time to maximize production in doublecropping systems. No-till production of summer crops would both protect the soil from erosion and result in more rainfall capture for crop use.

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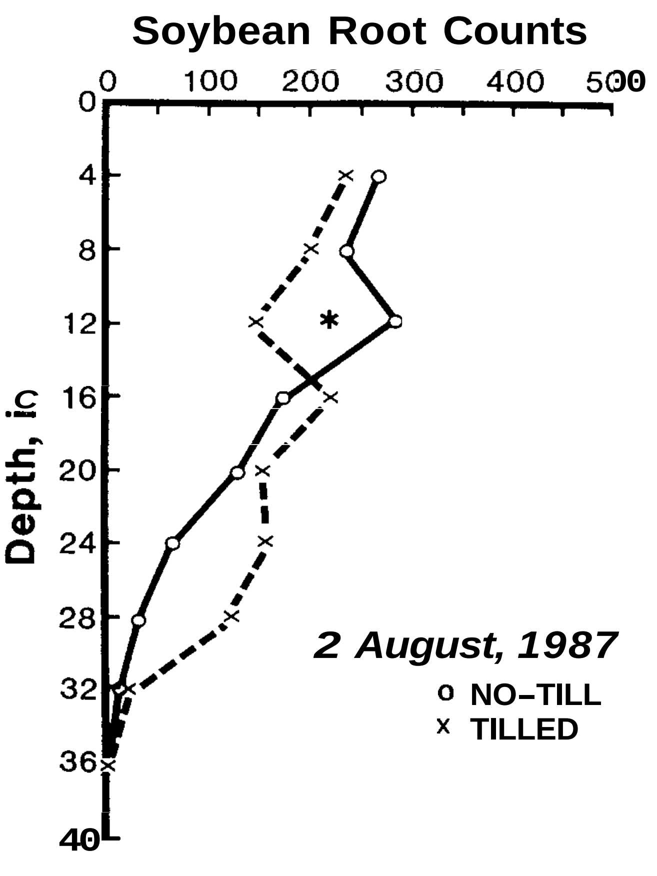

Figure 5. Soybean root counts per 4-inch soil depth August 2, 1987. Asterisk (*) denotes a significant difference at $\alpha = 0.05$.

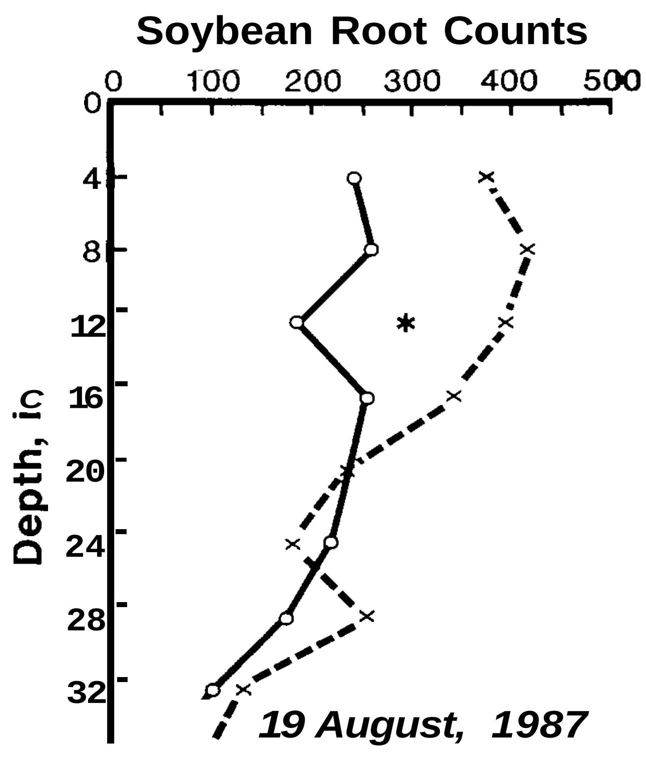

Figure 6. Soybean root counts per 4-inch soil depth August 19, 1987. Asterisk (*) denotes a significant difference at $\alpha = 0.05$.

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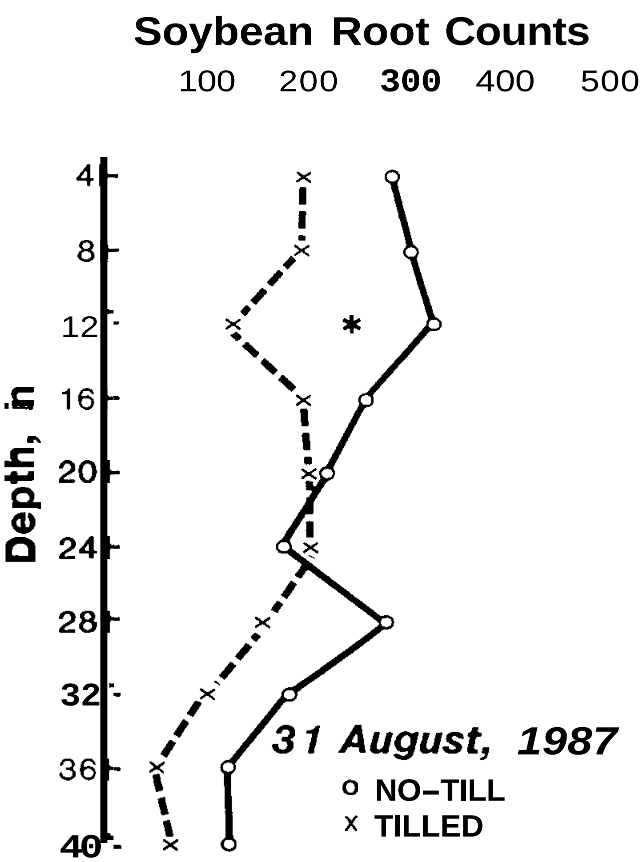

Figure 7. Soybean root counts per 4-inch soil depth August 31, 1987. Asterisk (*) denotes a significant difference at $\alpha = 0.05$.

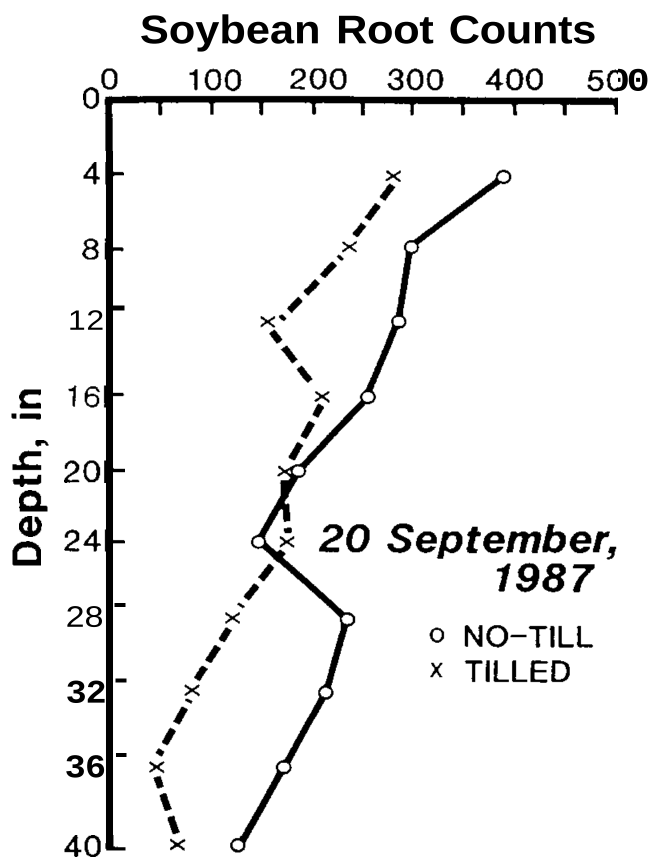

Figure 8. Soybean root counts per 4-inch soil depth September 20,1987. Asterisk (*) denotes a significant difference at $\alpha = 0.005$.

Influence of Long-Term No-Tillage on the Physical Properties of an Ultisol

M. H. Golabi, D. E. Radcliffe, W. L. Hargrove, E. W. Tollner, and R. L. Clark[1]

Introduction

No-tillage cultivation offers significant advantages over conventional tillage in terms of water, energy, and particularly soil conservation (Francis et al., 1987). However, continuous no-tillage farming on sandy Ultisols may lead to high bulk density that has a pronounced effect on soil strength due to traffic compaction and lack of plowing (NeSmith et al., 1987). This increase in soil strength under no-till cultivation might have a significant effect on root distribution. On sandy loam soils with good soil structure, greater root density has been reported in no-till as compared to conventional systems (Francis et al., 1987). In contrast, on structurally unstable soils, the presence of a high-strength, root-impeding layer can lead to proliferation of roots above this layer resulting in a greater root density in the top soil of plowed than in no-till soils (Francis et al., 1987).

Infiltration of rainfall into the soil is important, both in supplying water to the root zone and in preventing excessive erosion due to high runoff volumes. In the southeastern United States, infiltration rates on bare soils are typically low, due to crusting of the highly weathered, poorly structured soils (Miller and Bahruddin, 1986). However, infiltration of water into these soils is usually higher under no-tillage than in conventional tillage (Hargrove, 1985).

The objective of this paper is to examine the effect of long-term continuous no-tillage on physical properties, with emphasis on the effect of no-tillage on infiltrability of these soils.

Methods and Materials

The long-term tillage experiment was established in the fall of 1974 on a Cecil sandy loam (clayey, kaolinitic, thermic Typic Hapludult) in Georgia, and consisted of three tillage treatments, replicated four times in a winter wheat-soybean doublecropping system. The fall/spring tillage treatments were as follows: moldboard plow and disk/moldboard plow and disk (CT, conventional tillage); moldboard plow and disk/no-tillage (MT, minimum tillage); and no-tillagelno-tillage (NT, no-tillage). Details of the experimental design and management may be found in Hargrove et al. (1982).

On July 18 and 19, 1985, cone index was measured using a tractor-mounted, hydraulically driven cone penetrometer (Clark and Reid, 1984). The instrument measured mean cone index in one-inch depth increments to 24 inches below the soil surface. Five measurements were made along a transect in each treatment at 15-inch intervals starting where the tractor wheel passed during planting in the spring of 1985. Soil water content was measured gravimetrically by sampling randomly from inter-row and in-row positions, in 6-inch depth increments to 30 inches below the surface.

Sprinkler infiltration measurements (Peterson and Bubenzer, 1986) were conducted during the summer of 1987. A square metal enclosure with dimensions the same as row width (30 inches) was used. Water was applied for one hour and any runoff that accumulated at the downslope end of the enclosure was pumped off and the amount recorded during alternate minutes. Two measurements were made in each CT and NT plot; one with a straw cover and one without. Before these measurements, the surface of the plowed soil was raked to destroy any crust that might have been present. In the NT plots, for the uncovered measurements, the straw was removed by hand, the surface was raked and the top 0.8 inch of soil and fine organic litter was removed so that the mineral soil was exposed. The surface was then raked. In the CT plots, the bare soil measurements were made after raking the surface. For the covered run, the surface was raked and straw (4,635 Ib/acre) was added. A sprinkling rate of 2.8 inches per hour was used to rain on the enclosure.

Single-ring infiltration measurements (Bouwer, 1986) were conducted during April and May of 1988. Thirty-eight-inch diameter cylinders were pressed into the soil to successive depths of 2, 4, and 8 inches in NT and 4, 8, and 12 inches in CT. At each depth, infiltration rate was measured over a 2-hour period, which was sufficient to attain a constant rate. Care was taken not to disturb the surface in NT so that any macropores that were present would not be plugged. The surface of the CT plots was raked before making the measurements to remove any crust that was present. Two sets of measurements were made in each plot.

Results

Soil Strength

Soil water content measured at the same time cone index was measured was not significantly different between tillage

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treatments (data not shown). Statistical analysis indicated that cone index was significantly affected bytillage and row position (in-row, non-traffic between row, or traffic between row). Tillage had a significant effect on cone index in the row and non-traffic between row positions, but not in the traffic position. In the row position (Figure l), cone index was low in CT and MT above 10 inches, but in NT there was a high strength zone at 10 inches. Cone index exceeded 40 bars at the center of the high strength zone in NT, well above the 20 to 30-bar range that is reported to prevent root growth (Taylor and Gardner, 1963; Taylor and Burnett, 1964). The compacted zone in NT may have been due to traffic or it may have been an old tillage pan. The low organic matter content and expanding clay minerals in these soils, combined with a shallow depth of freezing during winter may have allowed a compacted layer, once formed, to presist for many years (Elkins et al., 1983).

Sprinkler Infiltration

The first set of sprinkler infiltration measurements conducted in July, 1987, showed that infiltration was higher in NT (Figure 2). Using a sprinkling rate of 1.6 inches per hour, runoff occurred in only one of four replicated NT plots, producing a mean final infiltration rate (infiltration rate after 60 minutes of sprinkling) of 1.45 inches per hour for NT compared to 0.63 inch per hour for CT. At this point, it was not clear whether the difference in infiltration was due to the presence of large macropores in NT or a surface crust in CCT. To determine if surface crusting was responsible for the low infiltration rate in CT, the second set of infiltration measurements was made in August 1987.

Infiltration was sharply reduced in NT when the mineral soil was exposed to raindrop impact (Figure 3). The final infiltration rate of NT without cover (0.03 inch per hour) was

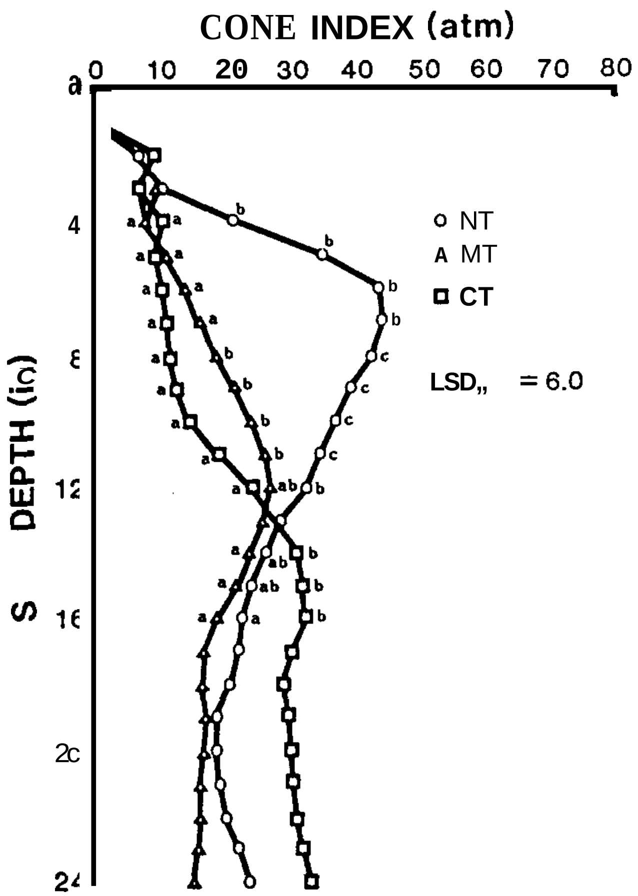

Figure 1. Cone index with soil depth for three tillage treatments measured on July 18 and 19, 1985 (NT = no-till; MT = minimum till; C T = conventional till).

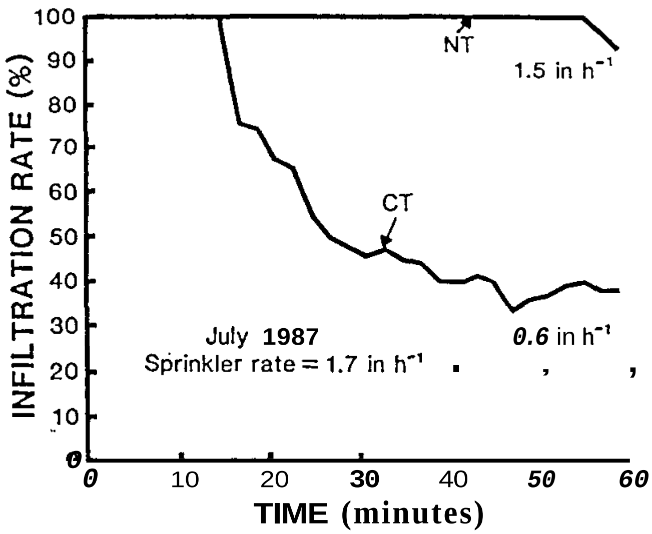

Figure 2. Infiltration measured by sprinkler infiltrometer for the no-till (NT) and conventional till (CT) treatments.

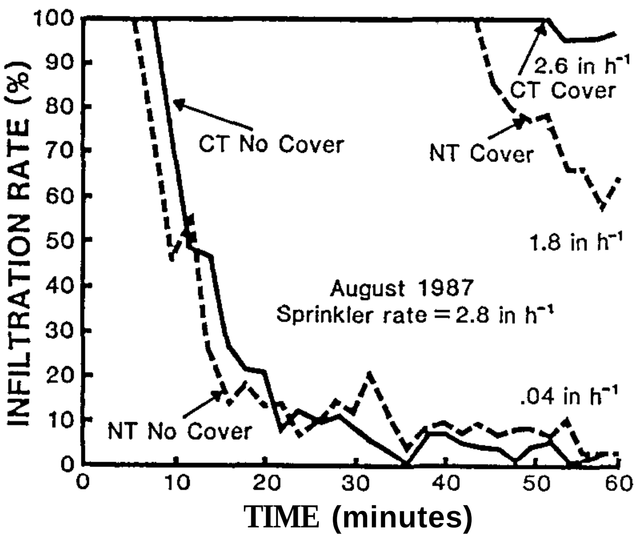

Figure 3. Infiltration measured by sprinkler infiltrometer for no-till (NT) and conventional till (CT) treatments with and without surface mulch.

identical to that of CT without cover. Statistical analysis showed that cover was significant factor in controlling the rate of infiltration. Adding a surface mulch to CT increased infiltration to the point that runoff was minimal after one hour with a sprinkling rate of 2.75 inches per hour. These results indicate that a surface crust rapidly developed when the mineral soil was exposed to raindrop impact. The final infiltration rate (0.03 inch per hour) in CT without cover was lower that observed in the earlier measurements (0.63 inch per hour). This was because the higher sprinkling rate was more effective in producing a crust.

The surfaces of all the treatments in the later measurements were raked before starting the sprinkler, so we were not measuring the effect of a crust that was already in place in this study. A straw mulch at a rate of 4,462 pounds per acre was sufficient to prevent the formation of a crust, as shown in the CT with cover treatment. The surface layer of fine organic litter may also be sufficient to prevent crusting from raindrop impact. In preliminary measurements, we did not see a drop in infiltration in NT if we removed the straw mulch, but did not remove the top 0.8 inch of organic litter and soil. The decrease in infiltration in NT with cover after about 45 minutes may indicate that sufficient water had been applied at this point (about 2.08 inches) for the compacted zone in NT to impede infiltration.

Single-Ring Infiltration

Rooting measurements in this experiment had shown that vigorous subsoil root growth occurred in NT, in spite of the hardpan at 4-10 inches (Hargrove et al., these proceedings). To determine if macropores had developed in NT that allowed roots to grow through the hardpan, we measured infiltration rate with cylinder infiltrometers.

It was apparent from our measurements that a cylinder infiltrometer overestimated infiltration unless the ring is driven to the depth of the least permeable horizon. In NT, the final infiltration rate (infiltration rate after approximately 2 hours) was much higher at a depth of 2 inches compared to 4 and 8 inches (Table 1). With the ring driven into the soil to a depth of 2 inches, most of the water entering the soil moved laterally when it encountered the hardpan starting at about 4 inches (Figure 1). The fact that there was little difference in infiltration rate between 4 and 8 inches in NT, indicated that lateral movement of water ceased once the cylinder extended to 4 inches. In CT where the hardpan occurred at a deeper depth (Figure 1), driving the rings into the soil to 8 inches was not sufficient to eliminate lateral movement as indicated by the drop in infiltration rate when the rings were lowered to 12 inches (Table 1).

The measurements also indicated that macropores had developed through the hardpan in NT. Infiltration rates at the 8-inch depth were not significantly different between tillage treatments (Table 1) in spite of the higher cone index at this depth in NT (Figure 1). The coefficient of variation in CT was remarkably constant with depth, but in NT, there was a sharp increase in variation once the rings extended to the hardpan. The higher coefficient of variation at the depth of the hardpan in NT is evidenced that macropores provide a low impedance pathway through the pan for water movement and root growth.

Not only were the final infiltration rates variable in NT, but infiltration rates during the 2-hour measurement period were less steady. In about one-third of the subplot comparisons between NT and CT, the infiltration rate at 4 or 8 inches in NT increased sharply for short intervals (Figure 4a). This did not occur in CT (Figure 4b). We believe that this was caused by macropores in NT that were not continuous to the surface. These pores could not fill until matric potential at the depth where the pore began, rose to a level where water could enter the pore. When this happened, infiltration rate increased sharply. The higher infiltration rate drained the soil so that matric potential fell below the critical value for the pore to fill and the infiltration rate decreased again.

Table 1. Single-ring final infiltration rates and coefficients of variation as a function of depth and tillage.

Ring installation depth (inches)	Infiltration rate (inches/hr)		Coefficient of variation (%)	
	NT	**CT**	**NT**	**CT**
2	5.47		**41.7**	
4	**1.73**	6.49**	**119.8**	52.7
8	1.78	**1.02**	87.6	56.3
12		**0.35**		***58.6***

****Significant difference between tillage treatments at 0.01 level of probability.**

Conclusions

It has been suggested that the full beneficial effect of NT may not be evident until several years after establishment in the Southeast (Hargrove et al., 1982). Our results show that the higher infiltration rate in NT is largely an effect of a surface mulch. Therefore, one would not expect to see the full extent of improved infiltration until surface residue cover approaches 100 percent on a continuous basis, a process that may take several years in this region. Macropore development may also be a process that enhances productivity of NT in the long term.

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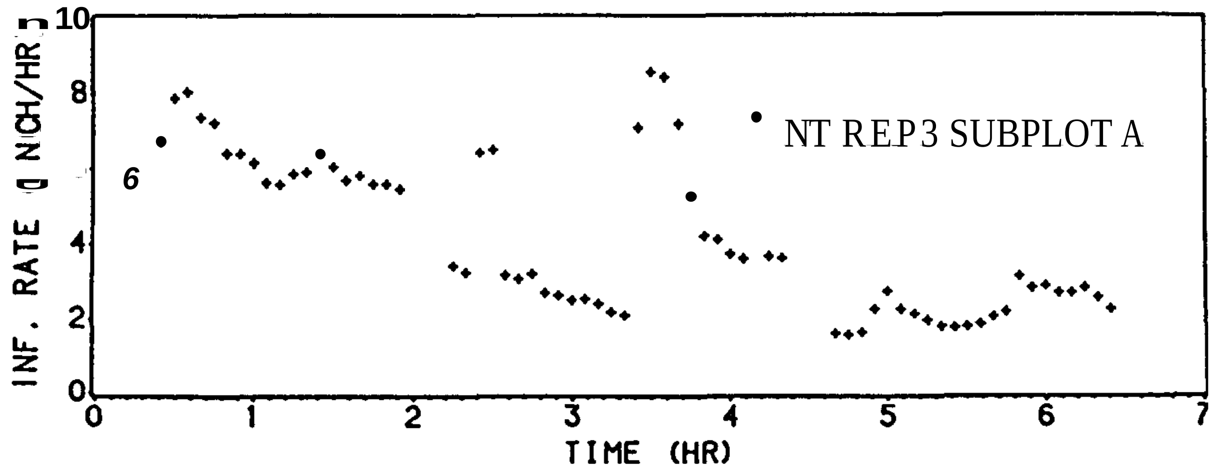

Figure 4a. Cylinder infiltration rate during 2-hour periods at successive ring depths of 2, 4, and 8 inches in NT rep 3, subplot A.

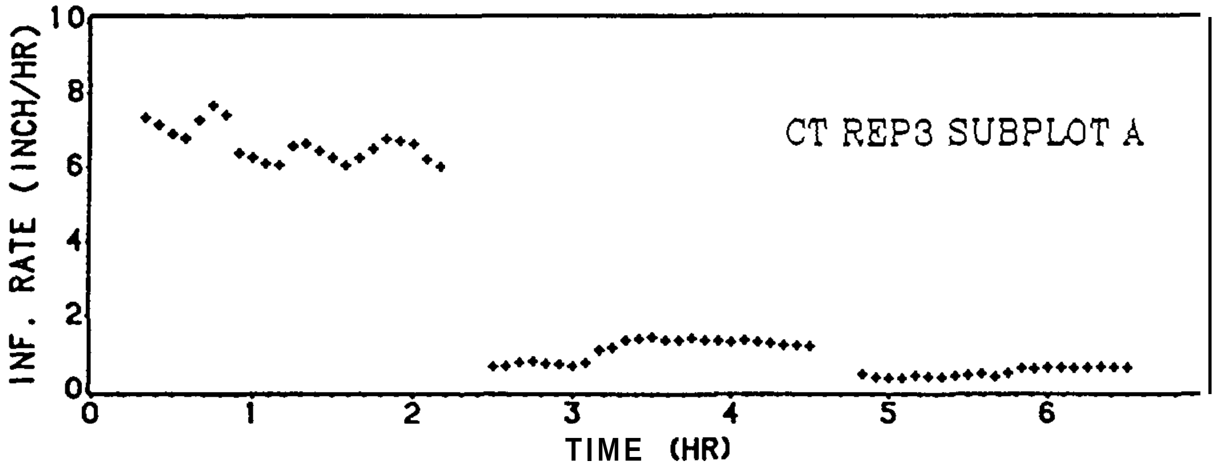

Figure 4b. Cylinder infiltration rate during 2-hour periods at successive ring depths of 4, 8, and I2 inches in CT, rep 3, subplot A.

Effect of Traffic and Tillage on Mechanical Impedance in a Layered Soil

D. E. Radcliffe, G. Manor, G. W. Langdale, R. L. Clark, and R. R. Bruce[1]

Introduction

In several studies of the physical properties of southeastern soils under no-tillage systems, a compacted layer at a depth of about 6 to 10 inches below the surface has been identified (NeSmith et al., 1987, Radcliffe et al. 1988; Tollner et al., 1984). Fall tillage with a disk harrow can create a tillage pan (NeSmith et al., 1988), but the role that uninterrupted wheel traffic may play in creating these pans has not been shown. In-row chiseling with a coulter planter may be sufficient to disrupt these pans, but there is little information on the efficacy of this system (Radcliffe et al., 1985). The purpose of this study was to determine the effect of controlled wheel traffic and shallow in-row chiseling on mechanical impedance in a no-tillage cropping system.

Materials and Methods

An experiment had been established in the fall of 1979 at the Southern Piedmont Conservation Research Center, Watkinsville, GA to test the effect of crop rotation in a double crop system under various tillage treatments. There were 10 cropping sequences consisting of various combinations of soybeans *(Glycine mwc* L. Merr., "Ransom") and grain sorghum *(Sorghum bicolor* L. Moench, DeKalb BR-64) following winter wheat *(Triticum aestivum* L. Thell, Coker 747). Only the continuous soybean and continuous grain sorghum sequences were examined in this study. Information on the other rotations is given elsewhere (Langdale and Wilson, 1987).

The tillage treatments were imposed in the spring of each year and consisted of coulter planting, coulter planting with in-row chisel to a depth of 9 inches, and conventional tillage with an offset disk harrow to a depth of 4 to 5 inches followed by coulter planting. These tillage treatments will be referred to as no-tillage (NT), minimum tillage (MT), and conventional tillage (CT), respectively. In the fall, before planting wheat, all plots were tilled with an offset disk harrow to a depth of 4 to 5 inches.

A randomized complete block split plot design was used with tillage treatments as main plots and crop sequences as subplots. Each plot consisted of four rows at 30-inch spacing with wheel traffic confined to the areas between the first and second rows and between the third and fourth rows (Figure l). Small-plot combine traffic was not controlled. A 135-hp tractor was used for disking all plots in the fall and the CT plots in the spring. The same tractor was used to plant the MT treatment in the spring when the in-row chiseling was accomplished. A 75-hp tractor was used for all fall and CT and NT spring planting.

Cone index was measured in November 1987 at the end of the eighth year of the experiment. A hydraulically driven penetrometer, mounted on a transverse boom behind a tractor, was used to measure cone index (Clark et al., 1986). Three transects perpendicular to the rows were taken in each plot. Nine positions were measured along each transect starting in the wheeltrack between the first and second row and ending in the wheeltract between the third and fourth row (Figure 1). Positions 6 through 9 were mirror images of positions 1 through 4 in terms of location relative to wheel traffic.

After analysis revealed that these positions were statistically similar, they were combined into five positions relative to wheel traffic: (1) in the wheeltrack center, (2) 6 inches from the row toward the wheeltrack center, (3) in the row, (4) 6 inches from the row toward the nontraffic center, and (5) in the nontraffic center. Cone index was measured in one-inch increments to a depth of 24 inches. A rigid aluminum bar was laid along the transects and used to trip the switch that normally indicates the actual soil surface. As such, depths of all penetrometer measurements were relative to the same horizontal plane and not the actual soil surface, which was several inches lower in the wheeltrack positions.

Water content was measured gravimetrically on samples taken at the time cone index was measured. Samples were

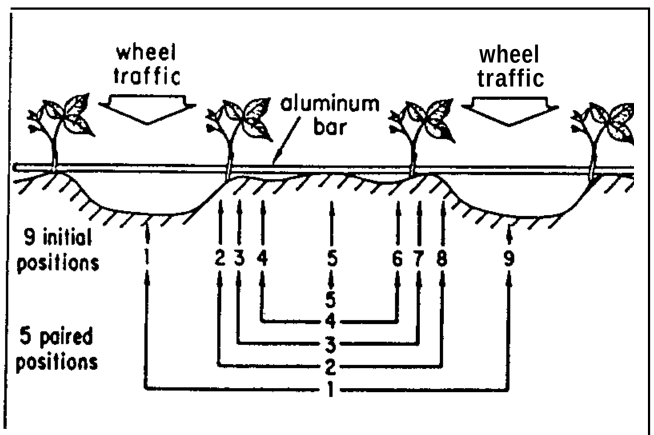

Figure 1. Sampling scheme for penetrometer measurements.

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Table 1. Profile characteristics of Cecil soil from plot 3. (Bruce et al. 1983).

Horizon	Depth (in)	Clay (%)	Silt (%)	Sand (%)	Bulk density (g/cm^3)
Ap	0-8	6	20	74	1.43
BA	8-12	23	23	54	1.68
Bt1	12-33	49	19	32	I.46
Bt2	3349	43	25	32	1.62

taken in the wheeltrack, row, and non-traffic positions in 3-inch increments to a depth of 18 inches.

The soil in this experiment was Cecil sandy loam (clayey, kaolinitic, thermic, Typic Hapludult). Profile characteristics from a nearby site are given in Table 1 (Bruce et al., 1983). The soil typically has a sandy topsoil and clayey subsoil with a transition zone of high bulk density.

Results

Water contents at the time cone index was measured were similar between treatments and positions. Because more than 2 inches of rainfall occurred in the week prior to the measurements, it can be assumed that the top 12 inches of profile were near field capacity.

The first step in the analysis of the penetrometer measurements was to determine if the nine samples along each transect could be combined into five positions relative to wheel traffic. We found that the pairs of samples (1 and 9, 2 and 8, 3 and 7, 4 and 6) were not significantly different except in the minimum tillage treatment with grain sorghum. The summer crop in 1987, had to be replanted because the wrong seed was placed in the hoppers the first time. To do this, planting was offset approximately 4 inches from the previously planted rows. When we made our penetrometer measurements in the fall of 1987, we used the replanted rows as our reference, thereby displacing each sample relative to wheel traffic that occurred in all but the last summer. In view of these facts, the MT grain sorghum treatment was eliminated from further analysis. The detection of a 4-inch offset in tillage with our penetrometer analysis reflects the precision of the measurement.

When the penetrometer measurements were combined into five positions, overall analysis indicated there was a tillage by position by depth interaction. To compare positions at a given depth, an LSD (0.05) was computed for each depth and tillage treatment. For clarification purposes, only three of the five positions are shown in the figures that follow. These are in the wheeltrack center (position I), in the row (position 3) and in the nontraffic center (position 5).

Cone indexes fc: the three positions in CT soybeans are shown in Figure 2. All positions indicated that there was a layer of high strength 6-12 inches below the surface. The effect of wheel traffic on soil compaction can be seen by comparing the wheeltrack position (one) with position five, which was free of traffic (other than that of the small-plot combine) and planter disturbance. Wheel traffic caused compaction to a depth of 12inches (significant at the .05 level). Traffic not only increased maximal cone index, but also caused it to occur at a shallower depth. There appeared to be little lateral compaction from wheel traffic in the row in that positions 3 and 5 were not significantly different. There was an effect of traffic 6 inches away from the row on the side where traffic occurred, in that cone index in position 2 was higher than that in position 4 (data not shown). The results for CT grain sorghum (not shown) were similar hut the effect of wheel traffic was not quite as deep (10 inches).

Traffic rffects in NT were identical for the two crops so only the grain sorghum data are shown (Figure 3). Cone index in position 1 was significantly higher than that in position 5 to a depth of 8 inches. Positions 3 and 5 were similar, indicating little lateral effect of wheel traffic in the row.

The effect of in-row subsoiling was apparent in MT soy-

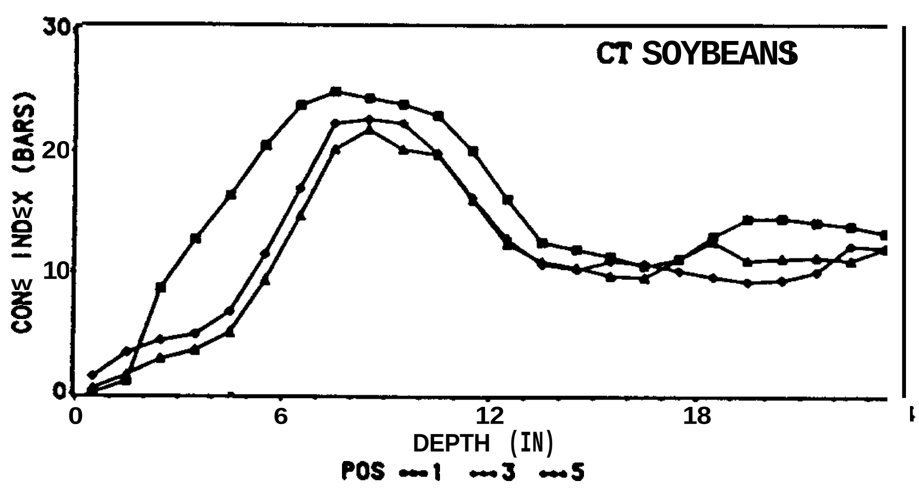

Figure 2. Cone index with depth in conventionally tilled soybeans in positions one (squares), three (diamonds), and five (triangles).

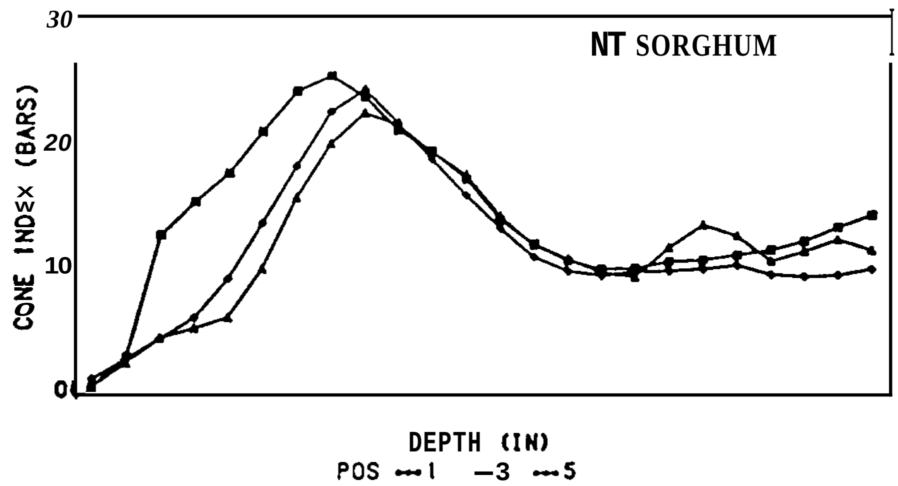

Figure 3. Cone index with depth in no-till grain sorghum in positions one (squares), three (diamonds), and five (triangles).

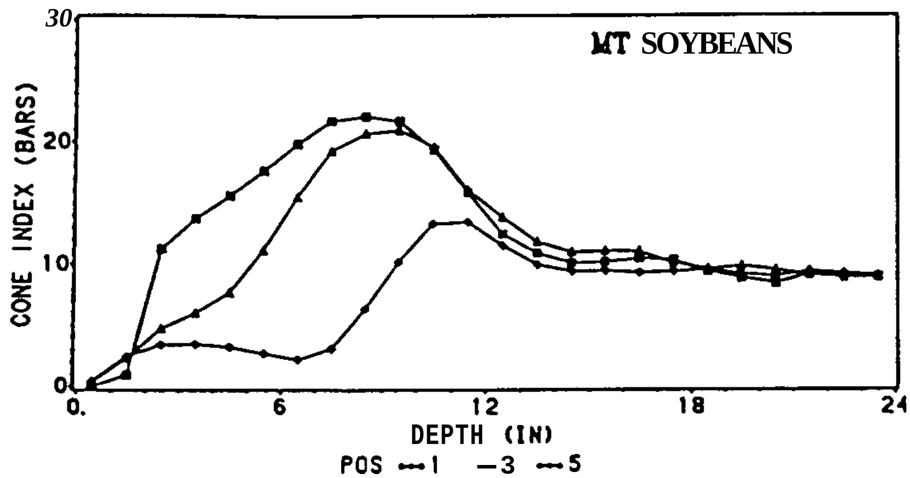

Figure 4. Cone index with depth in minimum tillage soybeans in positions one (squares), three (diamonds), and five (triangles).

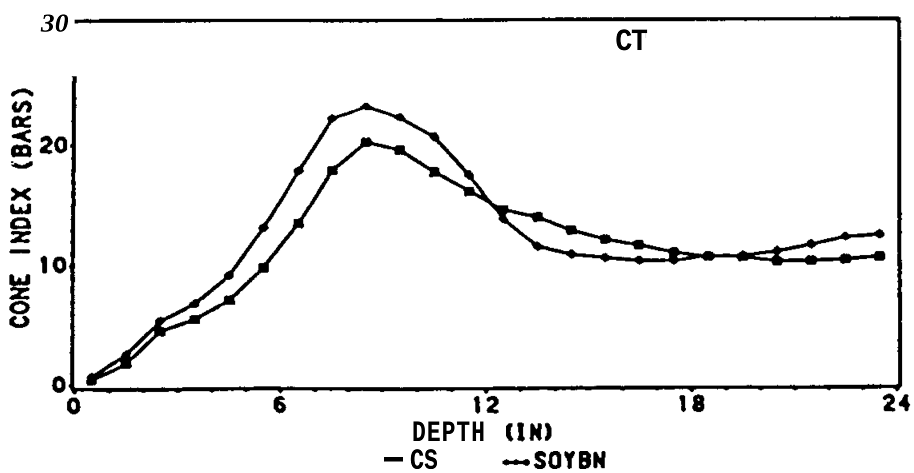

Figure 5. Cone index with depth in conventionally tilled soybeans (diamonds) and grain sorghum (squares) averaged over all five positions.

Table 2. Effect of crop and tillage on organic carbon percentage in November, 1987.

Depth (in)	% Organic Carbon			
	CT		NT	
	Grain sorghum	Soybeans	Grain sorghum	Soybeans
0-3	1.169	1.093	1.011	0.971
3-6	1.015	0.851	0.800	0.807
6-12	0.529	0.362	0.440	0.459
12-18	0.285	0.259	0.254	0.280

Table 3. Effect of tillage on 8-year mean crop yield.

Tillage	Yield (bu/acre)	
	Grain sorghum	Soybeans
CT	73 a	33 a
MT	78 b	32 a
NT	70 a	32 a

Values in the same column followed by different letters are significantly different at the 0.05 level.

beans (Figure 4). Cone index in the row position (3) was significantly reduced compared to both positions 1 and 5 to a depth of 10 inches. Chiseling to an approximate depth of 9 inches was sufficient to break through the hardpan in this soil. The apparent effect of traffic was less in this treatment in that the differences between positions 1 and 5 were confined to the top 6 inches. This may have been due to a reduction in cone index under the wheeltrack caused by the shattering effect of subsoiling.

Analysis of the penetrometer measurements also indicated that there was an interaction between crop and depth in CT. Cone index averaged over all positions tended to be lower in grain sorghum compared to soybean. Organic carbon levels were slightly higher in grain sorghum compared to soybean under CT (Table 2) and this was probably due to the higher levels of residue which were being incorporated into the soil.

Discussion

The compacted layer at 6 to 12 inches in this study is a common feature of soils of the Southern Piedmont. Cone index in the pan exceeded 20 bars and was in the range that could reduce root growth (Taylor and Gardner, 1963). Since these measurements were made at a time when water contents were near field capacity, the values of soil strength represent seasonal minimums. Soil strength was high enough to reduce yield in grain sorghum in the NT and CT treatments compared to MT, but there was no effect in soybeans (Table 2). This may have been due to an added response to subsoil nitrogen in grain sorghum under MT, or it may have been due to a difference in root growth characteristics of the two crops under high mechanical impedance.

Our results show that wheel traffic contributed to the formation of the hardpan at 6 to 12 inches below the surface because cone index was higher in the traffic position in this depth range in CT and NT. Fall disk tillage very likely contributed to the formation of the pan. There may have also been a natural component to formation in that the transition zone between the A and B horizons, which often occurs at 6 to 12 inches, may have the optimal combination of sand and clay to be easily compacted. Once a denser layer starts to form at a depth, either by tillage or natural consolidation, the stresses caused by wheel traffic will be confined in part, above the layer and more severe compaction will result than if there was no confining layer (Taylor et al., 1980). In this manner, traffic can be expected to interact with tillage and natural consolidation in the formation of hardpans in these soils.

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Interseeding Conservation System: Compaction and Plant Response

A. Khalilian, C. E. Hood, J. H. Palmer and F. Holbrook[1]

Introduction

Doublecropping with intensive management practices is a viable economic alternative for obtaining greater net returns per acre. Major problems with current doublecropping systems include inadequate moisture for germinating the row crop following grain harvest, excessive crop residue, and reduced yield of the soybeans due to delayed planting. In addition, current methods induce excessive soil compaction resulting in hardpans that require energy-intensivedeep tillage under less than optimum moisture conditions in early June.

A new interseeding system developed at Clemson University allows planting of soybeans into standing small grain with a controlled-traffic scheme. This improves moisture availability for seed germination and increased soybean yields, allows better management of crop residues, and has the potential to reduce energy for deep tillage. This low-power system operates at 4 to 6 mph and utilizes danish tines as seedbed preparation devices. Small spring-mounted fingers mounted behind the seed-drop tubes help with soil coverage of the seed (Figure 1). The idea is to plant wheat in the fall in 13-inch rows (with a 24-inch spacing between third and fourth rows and eighth and ninth rows to allow passage of tractor and combine tire between rows). Soybeans are then interseeded between rows of standing wheat in late April or early May when conditions are usually more desirable for optimum stands and early crop growth.

Intercropping of soybeans into wheat has been successful in the Midwest. Chan et al. (1980) reported that interseeding soybeans into small grain did not affect small grain yields. In a 3-year study, Reinbott et al. (1987) indicated that intercropped soybeans yielded 28 percent more than conventional doublecropped soybeans.

Research is needed to determine the feasibility of intercropping soybeans into standing wheat for Coastal Plain soils. In addition, studies are needed to optimize intercropping tillage practices using controlled-traffic production methods. This study focused on performing primary tillage in the fall prior to wheat planting.

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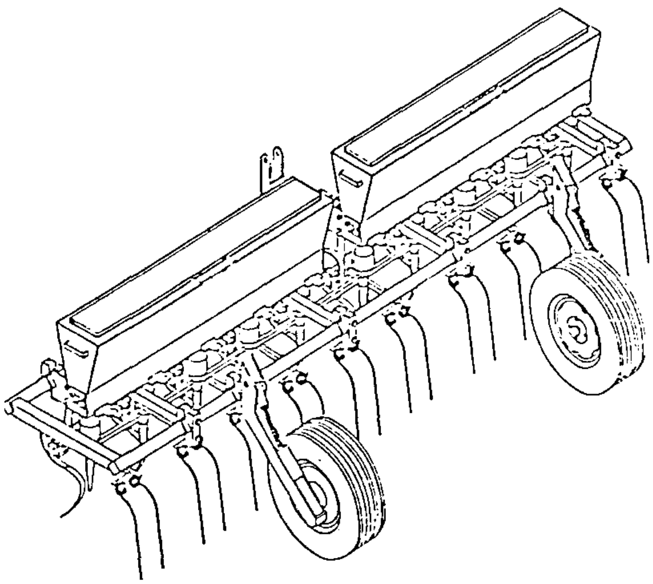

Figure 1. The Clemson Interseeder.

Objectives

The objectives of this study were:

(1) To determine proper tillage system for interseeding soybeans into standing wheat;

(2) To compare yields of wheat and soybeans planted in 13-inch rows with conventional double-cropping methods; and

(3) To determine the effects of the new tillage/planting system on wheat root and shoot growth and soil hardpan formation.

Methods and Materials

The test was conducted on Dothan sandy loam at the Edisto Research and Education Center, Blackville, South Carolina. Tillage tools included a four-shank paraplow with a 20-inch horizontal spacing of the legs, operating 12-13 inches deep; an 11-foot wide chisel plow with the chisel shanks spaced on 12-inch centers, operating 11 inches deep; a four-row KMC subsoiler-planter with 38-inch subsoiler shank spacing, operating 12-13 inches deep; and a 15-foot wide tandem disk.

A randomized complete block design with six replications was the statistical model selected for evaluating the tillage/planter treatments. The six treatments are outlined in Table 1.

Wheat was planted November 25, 1986 immediately after tillage. Seeding rate was 90 Ib/acre. Shoot growth was measured by clipping the wheat plant 2 months after planting.

Table 1. Tillage/plantinp: treatment combinations.

Treat. no.	Tillage before wheat			Wheat planting method		Tillage before soybeans	Soybean planting method	
	Disk	Chisel	Para	Clem	Drill	Paraplow	Clem	KMC/Sub
1.	x			x			1*	
2.	x			x			2**	
3.	x	x		x			1	
4.	x		x	x			1	
5.	x		x	x		x	2	
6.	x	x			x			2

*1 - Soybeans interseeded on May 20 and replanted on June I8
**2 - Soybeans planted on June 9 after wheat harvest.

Clem = Clemson interseeder; Drill = conventional grain drill with 7-inch rows; KMC/sub = subsoiler-planter with 38-inch rows; para = paraplow.

Root growth was measured by taking core samples at depths of 0 to 6, 6 to 12, and 12 to 18 inches. A total of 54 cores were taken per treatment. The roots were washed from the soil samples and oven dried for root dry weight determination.

A tractor-mounted, recording soil penetrometer was used to quantify soil resistance to penetration. Cone index values were calculated from the measured force required to push a 0.5-inch-square base area, 30-degree cone into the soil. Penetrometer data were taken prior to tillage and 2 months after planting.

The soybean variety Gordon was interseeded at a rate of 40 Ib/acre between rows of standing wheat on May 20, 1987. Only the plots in treatments one, three, and four were interseeded with soybeans (Table 1). An excellent stand of interseeded soybeans was obtained. Wheat from all plots was harvested on June 4, and soybeans were planted on June 9, in plots of treatment five (tilled with the paraplow 12-13 inches deep before planting), treatment two with the Clemson interseeder, and treatment six with the KMC subsoiler-planter. Because of damage to soybean plants caused by misapplication of an herbicide, it was decided to replant the interseeded plots (originally planted on May 20) on June 20, 1987. Penetrometer readings were taken from soybeans plots on July 10. Soybeans were harvested on November 4, 1987.

Table 2. Shoot weight, nitrogen uptake and average cone index 2 months after planting and wheat yield.

Tillage	Planter	Shoot weight (lb/a)	N uptake (% DM)	Av cone index* (psi)	Wheat yield (Bu/a)
Paraplow	Clem.	515 a	3.83 a	96 a	50.0 a
Chisel	Clem.	388 b	3.55 a	129 a	47.4 a
Chisel	Drill	306 c	3.66 a	178 b	47.3 a
Disk	Clem.	231 c	2.93 b	200 b	30.0 b

* Cone index values are averaged over the E horizon (hardpan area), depth = 8 to 11 inches.

Results and Discussion

Two months after planting, a big difference in growth rate of wheat was observed in different tillage plots. Paraplow plots had the highest shoot growth (515 lb/acre drymatter) followed by chisel plow (388 Ib/acre) and disk (231 Ib/acre). Also, there was a significant difference between chisel plots planted with the Clemson interseeder and chisel plots planted with a conventional grain drill (Table 2).

Figure 2 shows root distribution at different depths for tillage and planter combinations 2 months after wheat planting. The 12 to 18-inch (clay) zone contained about 15 percent of total roots in paraplow plots followed by chisel plow plots planted with Clemson interseeder (12percent), chisel with grain drill (9 percent), and disk plots planted with the Clemson interseeder (5 percent). There was a good relationship between root weight at this depth and shoot weight. The correlation coefficient was 0.96 (significant above 95 percent level). Shoot weight increased as root penetration of the clay layer increased. Cone index values at different penetrometer depths before tillage indicated that the test field had a hardpan about 8 to 11 inches deep. The data showed that initial soil conditions were similar for all treatments.

Figure 3 shows the effects of tillage/planting systems on the soil cone index 2 months after planting wheat. The paraplow greatly reduced soil compaction, especially in the E horizon or hardpan area. Results of the analysis of variance on cone index values averaged over depths of 8 to 11inches showed a significant difference between paraplow and disk plots (Table 2). Also, there was a significant difference between chiseled plots planted with the Clemson interseeder and grain drill. This may have been due to press wheels and double disk openers on the grain drill that compacted the soil.

Using generally accepted criteria that cone index values above 290 psi stop root growth (Taylor and Gardner 1963, and Carter and Tevernetti 1968), it is evident that all tillage tools greatly reduced soil compaction. Cone index values in

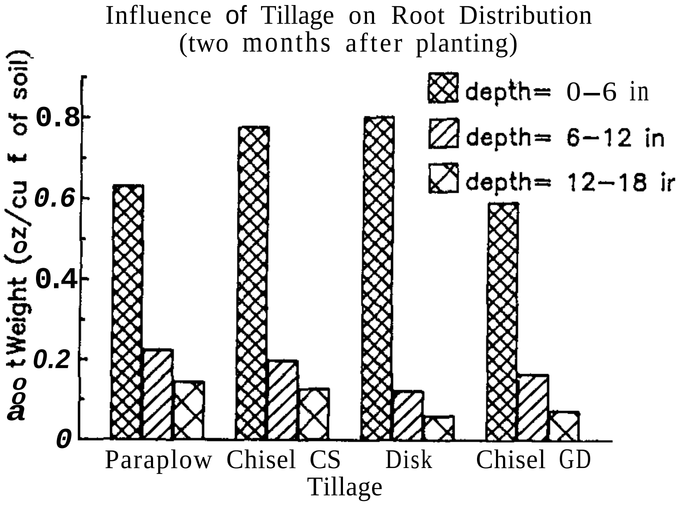

Figure 2. Root **distribution at different depths for tillage and planter combination 2 months after wheat planting.**

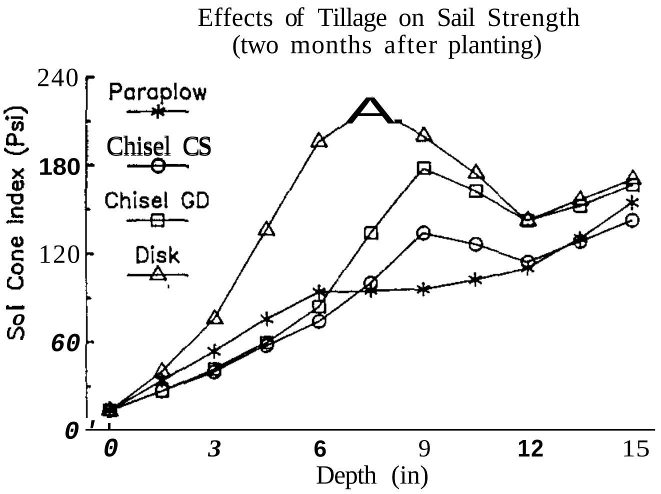

Figure **3.** Cone penetrometer profiles **2** months after tillage in the fall.

hardpan for disk plots were not high enough to completely eliminate root penetration into the clay layer.

A very good correlation between average soil cone index in the E horizon (hardpan) and root dry weight in clay was demonstrated. This indicates that hardpan in Coastal Plain soils acts like a root filter. The amount of roots in the B horizon depends on the hardness of this compacted layer.

Deep tillage increased nitrogen uptake by the wheat plant (Table 2). This resulted in a forage with higher protein content for winter grazing. The paraplow plots produced significantly higher wheat yields than any other tillage treatments. There was no significant difference in yield between chisel plots planted with the Clemson interseeder and those planted with a grain drill. Disk plots produced 27 percent less yield compared to paraplow. Interseeding soybeans into standing wheat 2 weeks before harvest did not reduce wheat yield.

Table *3* shows the soil cone index values averaged over the top 15 inches of soil depth for soybean plots one month after planting. Two sets of penetrometer readings were taken for each plot, one from the soybean rows and the other from the tractor tire tracks.

Results of the analysis of variance on cone index values averaged over the top 15inches showed significant difference between disk plots and other tillage treatments. There was no significant difference between paraplow plots tilled in fall, with those of conventional doublecropping plots (chisel plow in fall followed by subsoiler prior to planting soybeans). Paraplowing after wheat harvest significantly reduced soil compaction compared to other tillage treatments. However, there was no statistically significant difference between plots paraplowed only once in fall of 1986 and those which had extra tillage operation with paraplow in June, 1987.

Traffic significantly increased soil compaction as shown by penetrometer measurements within the soybean rows (Table 3).Figure 4 shows profiles of cone index versus depth for paraplow plots about 8 months after tillage operations. The biggest difference in soil compaction was experienced in the hardpan area. Similar trends were also observed in other tillage plots. This indicates that one tillage operation in the fall, deep enough to remove root inhibiting hardpans, in conjunction with controlled traffic, could eliminate deep tillage of any kind for soybeans.

Paraplowing prior to planting soybeans significantly increased crop yield (Table 3). Statistically, there was no significant difference among chisel plow plots planted with the Clemson interseeder, chisel plots planted with the KMC subsoiler/planter (conventional doublecropping) and paraplow plots with no deep tillage prior to soybean planting. Disk plots produced significantly less soybeans per acre than any other tillage/planter combinations.

Summary of Results

(1) Paraplow plots produced higher dry matter per acre than any other tillage tools. There were significant differences be-

Table **3.** Cone index values and yield from soybean **plots.**

Tillage		Planter		Av cone index (psi)		Yield
Wheat	**Soybean**	**Wheat**	**Soybean**	**Row**	**Tire**	**(Bu/a)**
Disk	**None**	**Clem.**	**Clem.***	**140a**	**156 a**	**18.7** *c*
Disk	**None**	**Clem.**	**Clem.****	**166 a**	**192 a**	**19.6 c**
Chisel		**Clem.**	**Clem.***	**114 h**	**138 a**	**21.5 h**
Chisel	**Subsoil**	**Drill**	**KMC****	**106 bc**	**146 a**	**25.9 ah**
Para.	**None**	**Clem.**	**Clem.***	**106 bc**	**128 a**	**23.5 ab**
Para.	**Para.**	**Clem.**	**Clem.****	**96 c**	**110 b**	**31.1 a**

*** Soybeans interseeded on May 20 and replanted on June 18.**
****Soybeans planted on June 9 after wheat harvest. Cone index values are averaged over the top 15 inches.**

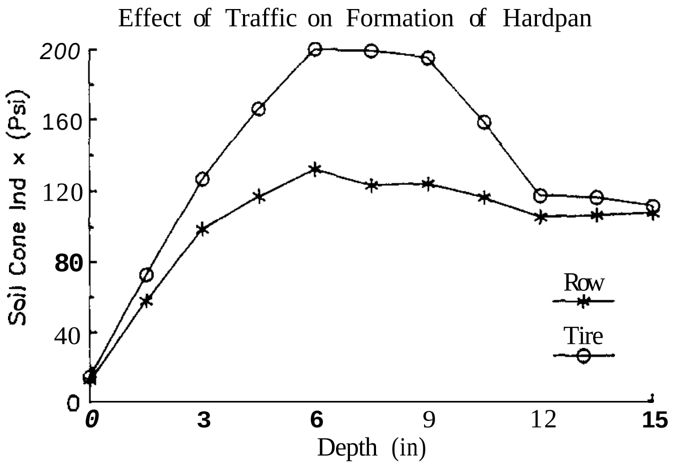

Figure **4. Effects** of traffic **on** formation **of** hardpan **8** months after tillage with paraplow.

tween chisel plots planted with the Clemson interseeder and chisel plots planted with a conventional grain drill

(2) Fifteen percent of the total roots in paraplow plots were at depths between 12to 18inches in clay, followed by 12 percent in chisel plots planted with the Clemson interseeder, 9 percent in chisel plots planted with a grain drill, and only 5 percent in disk plots.

(3) Shoot weight increased as root penetration of the clay layer increased. Also very good correlation existed between root dry weight and root length.

(4) The paraplow greatly reduced soil compaction, especially in the E horizon. Also, there were significant differences between chisel plots planted with the Clemson interseeder and those planted with a grain drill. A very good correlation between average soil cone index in the E horizon and root dry weight in the B horizon was demonstrated.

(5) Paraplow plots produced wheat with the highest levels of nitrogen uptake. Also, the paraplow plots produced higher wheat yields than any other tillage treatments. There was no significant difference in yield between plots planted with the Clemson interseeder and those planted with a grain drill. Interseeding soybeans in between rows of standing wheat did not affect wheat yield.

(6) Traftic significantly increased soil compaction as shown by comparing penetrometer readings within the soybean rows and between rows.

(7) Using controlled traffic, one deep tillage operation in the fall appeared adequate for doublecropping.

(8) There was no significant difference in the soybean yields between the plots subsoiled after wheat harvest and the paraplow plots planted with the Clemson interseeder. Disk plots produced significantly less soybeans than all other treatments.

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Nitrogen Fertilizer Requirements for Corn with No-Tillage and Cropping Systems

L. J. Oyer and J. T. Touchton[1]

Introduction

The need to develop alternate and renewable sources of energy due to the rising cost and potential shortage of fossil fuel, and the need to reduce crop production costs, have promoted a renewed interest in utilizing legumes as a source of nitrogen (N) for non-leguminous summer crops.

Early-maturing winter legumes can often be used as the sole nitrogen source for summer crops that have a low N requirement or that have a relatively late optimum planting date. These legumes, however, do not provide sufficient N for corn, a crop with a high N requirement that must be planted early. In addition, comparing current legume seed and seeding costs to commercial N prices shows that the legume must provide about 80 lb/acre to cover production costs. If reseeding legumes can be used, however, production costs can be greatly reduced (Touchton et al., 1982).

A good crop of soybeans can provide one-fourth to one-third of the total N needed by a subsequent corn crop. Since soybeans in Alabama do not need to be planted until mid-May, it is possible to reseed legumes in a soybean - winter legume - corn rotation.

The major objective of this study was to determine the effects of a winter legume reseeding system in combination with a soybean-corn rotation on N fertilizer requirements of corn grown in a no-tillage system.

Review of Literature

Numerous researchers have found that winter legumes can replace some or all of the nitrogen necessary for maximum yields of subsequent non-leguminous crops (Ebelhar et al., 1984; Hargrove, 1986; Mitchell and Teel, 1977; Neely et al., 1987; Touchton et al., 1982; Touchton et al., 1984).

Selection and management of winter legume crops are several of the most important considerations in no-tillage crop production. More research has focused on these in the last several years in order to reduce legume establishment costs and improve legume cover crop yield and subsequent N production.

Crimson clover appears to be a suitable species to include in no-tillage corn production systems in Ultisol soils of Alabama, Georgia, and Florida. The suitability of crimson clover is based on its relatively high acid tolerance, relatively early date of full bloom, high dry matter production, high N production, and reseeding capability (high percentage of hard seed) (Donnelly and Cope, 1961; Fleming et al., 1981; Hargrove, 1986; Leidner, 1987, Stanley and Wright, 1984; Touchton et al., 1982).

One approach being investigated to allow for perenniation of legume cover crops, and thus reduce legume establishment costs, includes natural reseeding systems. Reseeding systems have worked best in the Deep South where legume seeds lying in the surface mulch germinate in late summer. Since germination occurs prior to harvest of the summer crop, this allows the legume to produce considerable growth before winter dormancy. The additional fall growth of these reseeded legumes results in better tolerance to severe winters and high N production by early spring (Rickerl and Touchton, 1986; Touchton and Wells, 1985). Unfortunately, the optimum planting date for corn often occurs prior to maximum N accumulation and seed set by the winter legume cover crop.

In Alabama, several cropping systems, which will permit corn to be planted during the optimum period without losing the reseeding potential of the legume, have been investigated. Strip killing narrow bands of crimson clover over the corn row at planting allows clover in the row middles to continue growing, accumulate N, and produce seed (Touchton and Whitwell, 1984). However, higher corn yields in dry years were obtained when the clover was completely killed, probably due to soil moisture depletion by the clover.

In another system, grain sorghum or soybeans are planted into the first mature legume crop. 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 before planting sorghum or soybeans (Touchton and Wells, 1985). Corn yields grown under this system, with vetch as reseeding legume and soybean as full-season legume in the rotation, were adequate.

Materials and Methods

This study was conducted for 4 years (1984, 1985, 1986, and 1987) at two locations in Alabama. The Appalachian Plateau soil at the Sand Mountain Substation was a Wynnville sandy loam and the Coastal Plain soil at the Wiregrass Substation was a Dothan fine-sandy loam.

Two-year cropping systems consisted of (1) continuous corn with no winter crops; (2) soybean-corn rotation with no

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winter crops; (3) continuous corn with fall-planted crimson clover; and (4) soybean-corn rotation with reseeding crimson clover. As a split plot treatment, each cropping system received nitrogen fertilizer at rates of 0, 60, 120, and 180 lb N/acre as ammonium nitrate, sidedressed approximately 4 weeks after corn planting.

Crimson clover was killed with 2 qt/acre Roundup@ just prior to corn planting. Ring Around 1502 corn was planted in mid-April in 36-inch rows at the Sand Mountain Substation and Dekalb TI230 was planted in late March in twin 7-inch rows on 36-inch centers at the Wiregrass Substation. Irrigation was not available at the Sand Mountain Substation nor at the Wiregrass Substation during the 1987 growing season.

Results and Discussion

Reseeded clover behind soybeans produced greater dry matter and total N than planted clover following corn at both locations (Tables 1 and 2). This is probably due to earlier establishment and more fall growth obtained with the reseeded clover than planted clover.

At the Sand Mountain Substation, corn grain yields in 1985 peaked at 120 Ib N/acre with each cropping system (Table 3). However, the soybean - reseeded clover - corn cropping system increased the yield potential, producing 156 bu/acre compared to 110 bu/acre for continuous corn. In 1987, when precipitation was limiting during grain fill, yields at Sand Mountain Substation (Table 4) peaked with 180 lb N/acre on the continuous corn and soybean-corn systems and 120 Ib N/acre on the clover-corn and soybean-clover-corn systems. The soybean-clover-corn system reduced the N fertilizer requirement for corn by 60 to 120 Ib/acre.

At the Wiregrass Substation, corn grain yields in 1985 (Table 5) were not greatly affected by cropping systems when N was at optimum levels (180, 180, 180, and 120 lb/acre for the cropping systems, respectively). It appears that the soybean-reseeded clover system, but not the clover only or

Table 1. Clover weight and N content as affected by previous crop at Sand Mountain Substation.

Year/ Previous crop	Weight	N	N
	lb/a	%	lb/a
1985			
Corn	3,198	2.91	93
Soybeans	4,237	2.86	121
1987			
Corn	1,618	4.06	66
Sovbeans	2.796	4.05	113

Table 2. Clover weight and Ncontent as affected by previous crop at Wiregrass Substation.

Year/ Previous crop	Weight	N	N
	lb/a	%	lb/a
1985			
Corn	1,103	4.19	46
Soybeans	2,425	3.76	91
1987			
Corn	1,213	3.92	48
Soybeans	2,812	4.04	I14

Table 3. Corn grain yields at Sand Mountain Substation, 1985.

	N applied (lb/a)			
Cropping system	**0**	**60**	**120**	**180**
	bu/a			
Continuous corn	12	67	110	110
Soybean-corn	39	102	123	135
Clover-corn	53	104	132	131
Soybean-clover-corn	81	135	156	155

Int. FLSD (0.10) = 14.

Table 4. Corn grain yields at Sand Mountain Substation. 1987.

	N applied (lb/a)			
Cropping system	0	60	120	180
	bu/a			
Continuous corn	11	71	101	114
Soybean-corn	53	108	132	141
Clover-corn	79	119	126	120
Soybean-clover-corn	104	125	I29	123

Int. FLSD (0.10) = 18.

Table 5. Corn grain yields at Wiregrass Substation. 1985.

	N applied (lb/a)			
Cropping system	0	60	120	180
	bu/a			
Continuous corn	61	138	155	186
Soybean-corn	89	125	165	171
Clover-corn	85	139	152	164
Soybean-clover.com	139	170	182	I63

Int. FLSD (0.10) = 26

Table 6. Corn grain yields at Wiregrass Substation, 1987.

	N applied (lb/a)			
Cropping system	0	60	120	180
	bu/a			
Continuous corn	6	57	78	87
Soybean-corn	20	65	82	80
Clover-corn	39	65	69	76
Soybean-clover-corn	75	96	92	85

Int. FLSD (0.10) = 20.

soybean only systems, reduced N fertilizer requirements for corn by at least 60lb/acre. In 1987, grain yields (Table 6) were reduced by rainfall limitations during grain fill. The soybean-clover-corn system reduced the N fertilizer requirement for corn by 60 to 120 lb/acre.

Conclusions

The reseeding crimson clover system in combination with a soybean-corn rotation appears to be **an** agronomically viable system for no-till corn production in Alabama. The soybean-clover-corn system consistently produced the highest yields of the systems studied, in both optimal and inadequate rainfall years, and precluded a 60 to 120 lb/acre N fertilizer requirement for corn. Further evaluation of the potential benefits of reseeding systems, production cost reductions, increase in yield potential, and reduction in N fertilizer requirements, will be continued.

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Response of Corn Hybrids Differing in Root Morphology to Conservation Tillage Systems

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Introduction

In recent years, research has begun to address the possibility that corn hybrid performance can vary with tillage practice. The majority of these studies, however, have been conducted in the Midwest and not in the southern United States.

Mock and Erbach (1977) evaluated the performance of eight corn genotypes in Iowa under conventional and three conservation tillage systems, including till-plant and no-till ridge with and without stalk shredding. Genotypes that produced the most vigorous seedling and juvenile plant growth resulted in the highest grain yields regardless of tillage system. Similar studies, also in Iowa, demonstrated no interaction between hybrid and tillage (Hallauer and Colvin, 1985).

Newhouse and Crosbie (1986) tested 60 commercial hybrids from northeastern Iowa in field experiments with no-till and conventional tillage. They found no hybrid x tillage interaction and concluded that evaluation of hybrids in conventional tillage environments was adequate for selection of hybrids for use with conservation tillage.

In a later study (1987), Newhouse and Crosbie did find significant interactions with tillage for hybrid lines derived from one corn synthetic (BS22(R)C1). They recommended that corn selection trials be conducted using conservation and conventional tillage in the proportions expected to be used in the targeted commercial environment.

Kaspar et al. (1987) tested four corn hybrids in Iowa under no-till, moldboard plowing, and disking. Although hybrids responded differently to tillage systems during vegetative growth, there were no differences among hybrids caused by tillage for mature plant height, final stand, grain moisture, or yield.

In Wisconsin, Carter and Barnett (1987) tested 15 hybrids under conventional tillage and no tillage. Superior yielding hybrids under conventional tillage also performed well with no tillage, but yield potential of later maturing (100-115 days) hybrids was reduced with no tillage. The reduction in yield potential was attributed to delayed growth with no tillage.

Generally, differential effects of tillage on hybrids in studies in the cornbelt are related to the tolerance of hybrids to the colder, wetter soils found with no-till. For conservation tillage systems in the southern United States, however, soil compaction and resultant water stress from restricted root growth are probably more limiting than reduced soil temperature and increased soil moisture associated with no tillage. When soil compaction is a limiting factor, the morphology and orientation of a crop's root system can affect the uptake of water and nutrients by the manner in which it exploits the soil.

Williams et al. (1981) demonstrated that the performance and survival of tall fescue (*Fescue arundinacea* Schreb.) genotypes in a soil containing a tillage pan was affected by inherent morphological differences in the genotype's root system.

Irwin et al. (1985) identified distinct morphological differences in root systems of corn hybrids from field evaluations conducted by the Alabama Agricultural Experiment Station. The degree of variation among hybrids suggested that these inherent characteristics could play a role in the adaptation of corn hybrids to specific tillage practices common in the southern United States. A field study was initiated in 1986 to determine if these inherent variations in root systems would cause differential responses under conservation tillage practices common to highly compactible soils in the South.

Materials and Methods

This ongoing study has been conducted for 2 years (1986 and 1987) on a Norfolk sandy loam (fine, loamy, siliceous, thermic Typic Paleudultsl located near Shorter, Alabama. The soil has a 1 to 2.5-inch thick tillage pan located 7 to 10 inches below the surface.

The experimental design is a split plot with five replications. Main plots are tillage treatments and subplots are corn hybrids. Tillage treatments are: (1) strict no-till, (2) no-till with in-row subsoiling (14-inch depth), and (3) conventional tillage (disk-chisel plow-disk + in-row subsoiling).

Corn hybrids are Stauffer S7759, Sunbelt 1827, and Ring Around 1502M. The three hybrids were selected from a preliminary study which identified differences in root morphology and anatomy. Stauffer ,57759 and Ring Around l502M have nodal roots oriented horizontally to the stem axis while Sunbelt 1827 has roots oriented vertically to the stem axis. When grown in nutrient solution, mean root diameter and metaxylem diameter were largest in Stauffer S7759. Sunbelt 1827 and Ring Around l502M were equal in root diameter although Ring Around 1502M had a larger mean metaxylem vessel diameter than Sunbelt 1827.

Planting dates were March 28, 1986 and April 16, 1987. Rye (*Secale cereale* L.) was grown as a cover crop both years. Row width was 36 inches and stand was thinned to 24,000

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plants per acre 2 weeks after emergence. A starter fertilizer consisting of 60 Ib/acre ammonium nitrate, 120 Ib/acre potassium-magnesium sulfate, 45 Ib/acre triple superphosphate, 14 Ib/acre zinc sulfate, and 8.75 lb/acre Solubor® was applied over the row. Nitrogen rate was 180 Ib/acre in addition to the 20 Ib-N/acre in the starter. One third of the N was applied at planting and the remainder was applied 4 weeks after emergence. Plots were irrigated, except during the period from tasseling through silking, to supply a minimum of one inch of water per week during 1986. In 1987, plots were only irrigated twice, early in the season, in order to obtain a stand.

Data collected included whole plant samples for dry weight and tissue nutrient analyses at 2, 4, 6, and 8 weeks after emergence and at black layer. Grain yield and stomatal conductance from tasseling to late silking (a measure of the plants water stress) were also determined.

Table 1. Corn dry matter accumulation during the 1986 and 1987 growing season as affected by tillage.

Tillage	Days after planting 21	41	51	63	93
	lb/acre				
1986					
Conventional + subsoiling	51	938	3,580	5,802	17,849
No-till + subsoiling	44	691	3,540	5,105	16,780
No-till	36	455	2,256	4,489	15,766
LSD (0.10)	6	188	492	252	1.223
1987					
Conventional + subsoiling	31	628	2,610	4,266	16,196
No-till + subsoiling	29	575	2,507	4,828	14,761
No-till	20	367	1,394	3,435	16,608
LSD (0.10)	7	92	356	578	*2,090*

Table 2. Corn dry matter accumulation during the 1987 growing season as affected by hybrid selection.

Hvbrid	Davs after planting 21	41	51	63	93
	lb/acre				
Sunbelt 1827	30	647	2,252	4,511	18,467
Ring Around 1502M	26	453	2,043	3,581	14,927
Stauffer S7759	23	468	2,215	4,115	14,172
LSD (0.10)	5	88	300	472	1.320

Table 3. Corn grain yield in 1987 as affected by tillage and hybrid selection.

Tillage	Hybrid: Stauffer S7759	Sunbelt 1827	Ring Around 1502M
		bu/aere	
Conventional + subsoiling	136	156	128
No-till + subsoiling	128	149	134
No-till	128	129	121
LSD (0.10) for any two values = 13 bu/acre			

Results and Discussion

Plant growth, as indicated by dry matter accumulation, was influenced by tillage in both years Table 1). In general, strict no-tillage produced less dry matter over time than in-row subsoiling. There was little difference in dry matter accumulation between corn grown with conventional tillage + in-row subsoiling and corn grown with no tillage + in-row subsoiling.

In 1987, when soil moisture was limited, the selection of hybrid was important. Sunbelt 1827, a cultivar with small diameter, vertically oriented roots, consistently had the greatest production of dry matter regardless of tillage treatment (Table 2). In this year, dry matter production was also a good indicator of grain yields produced by the three hybrids.

In 1986, when moisture was not limiting because of supplemental irrigation, grain yield was not affected by tillage or hybrid (average yield, 120 bu/acre). Without supplemental irrigation, in 1987, there was a tillage x hybrid interaction (Table 3) . Sunbelt 1827 demonstrated the largest yield potential of the three hybrids. The vertically oriented, small diameter root system of this hybrid responded dramatically to subsoiling with a 15 percent yield increase. Additional surface tillage resulted in another 5 percent yield increase for Sunbelt 1827.

There was a nonsignificant trend for the horizontally oriented root system of Stauffer S7759 to respond to surface tillage in the conventional + in-row subsoiled plots. This hybrid did not respond to subsoiling. No-tillage + in-row subsoiling resulted in maximum yields for Ring Around 1502M, while strict no-tillage resulted in the lowest yields for this hybrid. Ring Around 1502M, with horizontally oriented, small diameter roots,generally maintained greater stomatal conductances from silking through black layer formation than either Stauffer S7759 or Sunbelt 1827 (data not shown). This evidence of plant water status was not indicative of hybrid performance for grain yield production, however.

Conclusions

Preliminary results from this test suggest that variation in inherent root characteristics can affect corn hybrid performance in different tillage systems. The effect of this variation may be especially notable when corn is subjected to periods of drought stress, which is frequently the case for corn grown in the southern United States. Although factors other than root characteristics are crucial to hybrid performance, our results suggest that root characteristics could serve as important criteria for selection of corn hybrids adapted to reduced tillage systems developed for highly compactible soils.

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Influence of Irrigation and Conservation Tillage on Corn and Soybean Yields

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Corn and soybean are sometimes grown in sequence in crop rotation systems for the purpose of maintaining higher yields as a result of reduced buildup of crop pests in comparison to monocropping systems. Corn consistently responds to irrigation, even with short intervals of hot dry conditions between rainfall events. Corn yield losses due to stress in excess of 2 bushels per acre per day of stress have been recorded (Rhoads, 1982). Conservation tillage has not been extensively evaluated under irrigation.

One advantage of conservation tillage is a lower fuel requirement for tillage operations, although, yields may not be different from those obtained with conventional tillage (Forbes et al., 1984). Corn yield in Kentucky with conservation tillage was superior to conventional tillage when planting data was delayed (Herbeck et al., 1984). Soybean varieties responded differently to conservation tillage in Alabama (Granade and Akridge, 1984). Some soybean varieties yielded higher with conservation tillage than with conventional tillage, while others gave the opposite response, and still others did not respond to tillage variables. Where soil compaction was a problem, subsoiling was necessary for soybeans to produce yields with conservation tillage equal to those with conventional tillage (Hovermale, 1984). Furthermore, subsoiling improved soybean yield in a conventional tillage system on a soil containing a traffic pan in North Florida (Rhoads, 1978).

Objectives of this experiment were to determine corn and soybean yields with different tillage systems for both irrigated and unirrigated cropping systems.

Materials and Methods

This experiment was conducted in 1986 and 1987 on an Orangeburg loamy fine sand on the North Florida Research and Education Center at Quincy.

Fertilizer rates were 500 pounds of 0-10-20 per acre each year for both corn and soybeans, irrigated and unirrigated. Irrigated corn received 600 pounds of ammonium nitrate per acre each year. Unirrigated corn received 400 pounds per acre of ammonium nitrate in 1986 and 600 pounds per acre in 1987. Nitrogen was not applied to soybeans. Row width was 30 inches each year for both corn and soybeans. Plant population was 30,000 plants per acre for irrigated corn and 20,000 plants per acre for unirrigated corn. Soybeans were planted about 2 inches apart in the drill.

Dekalb-Pfizer (DK-748) corn was planted in irrigated treatments and DK-689 corn was planted in unirrigated treatments on March 13, 1986. Dekalb-Pfizer (DK-689) corn was planted on March 17, 1987 in both irrigated and unirrigated treatments. Soybeans (Braxton cv.) were planted in both irrigated and unirrigated treatments May 27, 1987. Unirrigated soybeans were replanted June 30, 1987 because of poor germination due to lack of rainfall.

Irrigation was applied with a center pivot system in half-inch increments when soil-water suction at the 6-inch depth exceeded 20 centibars. Unirrigated plots were outside of the area irrigated with the center pivot and adjacent to the irrigated plots.

Tillage treatments are shown in Table 1. Conventional tillage (CT) included disking until weeds and crop residues were buried and using an S-tine cultivator with a crumbler attachment to level the seedbed before planting. Conservation tillage (MT) was accomplished with a subsoiler having fluted coulters to prepare a seedbed over the subsoiler slot. A two-row John Deere 71® planter was used to plant both conventional and conservation tillage systems. Three procedures were used to increase soil-water infiltration in 1986: (1) mid-

Table 1. Tillage treatments applied to corn in 1986 and to corn and soybean in 1987.

	1986		1987	
Nu.	**Unirrigated**	**Irrigated**	**Unirrigated**	**Irrigated**
1	CT*	CT	CT	CT
2	CT+IRSS	CT+IRSS	MT+IRSS	MT+IRSS
3	CT+IRMSS	—	—	—
4	CT = IRMSSDD	—	—	—
5	CT+RS	—	—	—
6	Same as No. 4 Fall and Spring	—	—	—
7	MT+IRSS	MT + IRSS	—	—
8	MT+IRMSSDD	—	—	—
9	Bottom Plow	—	—	—
10	CT+MB at layby	CT+MB at layby	—	—

* CT = conventional tillage, MT = conservation tillage, MB = middle buster, IRSS = in-row subsoil, IRMSS = in-row and middle subsoil, IRMSSDD = in-row and middle subsoil with Dammer Diker, RS = rain saver. The Dammer Dikef is made by Ag Engineering and Development Co., P.O. Box 2814, Tri-Cities, WA 93302. The Rain Saver® is made by Sam Stevens, Inc., Route B, Lamesa, TX 79331.

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dles were subsoiled after corn was planted; (2) a paddle wheel type implement (Dammer Diker®) was attached behind the subsoiler as it was pulled through the middles to dig about 12,000 gallon-sized holes per acre to catch rainfall and reduce runoff; and (3) a second paddle wheel implement (Rain Saver®) was attached behind cultivator sweeps to build dikes in middles to reduce runoff. The Dammer Diker was used in the fall on one treatment to reduce runoff during winter rains and also after planting to reduce runoff during summer thunderstorms.

Roundup® was used to control weeds on conservation tillage plots before crop emergence. Lasso@ and atrazine were applied postemergence to corn plots at the two-leaf stage and Lasso was applied premerge to soybean.

Yield data are reported at 15.5 percent moisture for corn and 12 percent moisture for soybeans. Orthogonal contrasts were used for statistical comparison of treatment means (Steel and Tome, 1960). The experimental design was a randomized complete block with four replications.

Results and Discussion

Irrigated corn did not respond to tillage methods in 1986 (Table 2). Subsoiling in-row and middle was superior to subsoiling in-row only for unirrigated corn with conventional tillage. However, subsoiling in-row and middle was no better than subsoiling in-row only with conservation tillage. Subsoiling in the middle between rows obviously increases water movement into the soil from rainfall. Mulch from crop residue increases water infiltration into the soil and reduces evaporation from the soil surface in conservation tillage systems in

Table 2. Influence of tillage and irrigation on grain yield of eorn in 1986.

Tillage treatments	Yield (bulac) Unirrieated	Irrieated
CT[1]	14a[2]	190a
CT + IRSS	22a	187a
CT + IRMSS	38b	—[3]
CT + IRMSSDD	41b	—
CT + RS	28ab	—
CT + IRMSSDD Fall and Spring	36b	—
MT + IRSS	37b	186a
MT + IRMSSDD	37b	—
Bottom Plow	37b	—
CT + MB layby	27ab	199a

[1] See Table 1 for treatment description.
[2] Treatment not included under irrigation.
[3] Means within columns followed by same letter are not significantly different (P>0.05).

Table 3. Influence of tillage and irrigation on grain yield of corn and soybean in 1987.

Tillage treatment	Corn Unirrigated	Corn Irrigated	Soybean Unirrigated	Soybean Irrigated
		bu/acre		
CT[1]	107a[2]	192a	35a	3Ya
MT+ IRSS	111a	181a	3Yb	39a

[1] See Table 1 for treatment description.
[2] Means within columns followed by the same letter are not significantly different (P>0. 10).

comparison to conventional tillage systems. Therefore, increased water movement into the soil as a result of subsoiling in middles is not as important in conservation tillage systems as in conventional tillage systems. In-row subsoiling only did not increase yield with conventional tillage. The Dammer Diker did not increase yield over subsoiling in middles alone in either tillage system. A 14 bu/acre yield increase occurred from use of the Rain Saver in the conventional tillage system. Power requirement is less for the Rain Saver than for a subsoiler. Yield difference between conservation tillage and conventional tillage was not significant (P>0.10) with in-row and middle subsoiling.

Tillage practices that increase rooting depth and/or total water infiltration result in yield improvement only if soil conditions and rainfall distribution complement each other. For example, if rainfall events are spaced close enough to prevent water stress without such tillage practices or if they are spaced far enough apart to severely stress the crop with these tillage practices, then no response is likely to occur. A yield response is expected when rainfall events are spaced such that plants with restricted rooting depth or restricted water infiltration become stressed while plants treated with tillage practices to relieve these problems are not stressed. Rainfall intervals that favor a yield response to tillage are greater for soils with high water holding capacity than for soils with a low water holding capacity.

Irrigation improved corn yields with both conventional and conservation tillage systems in 1987 (Table 3). The yield increase was 79 percent for conventional tillage and 63 percent for conservation tillage. However, there was no corn yield response to tillage with either irrigated or unirrigated treatments. Soybeans did not respond to irrigation, although, planting date was delayed about 30 days for the unirrigated plots due to lack of rainfall. Irrigated plots produced larger plants, but rainfall was adequate after unirrigated plots were planted the second time. There was, however, a slight response to tillage in the unirrigated plots of about 5 bu/acre (P>0.10).

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Cover Cropping and N Fertilization for No-Tillage Corn Production in Mississippi

J. J. Varco and L. K. Marshall[1]

In a recent study of 10 cropping systems in Mississippi, including monocropped soybean, corn, grain sorghum, sunflower, and wheat, and various doublecrop sequences, monocrop corn had the highest net returns (Sanford et al. 1986). All monocrops in this study were planted into prepared seedbeds.

Current acreage of corn in Mississippi is around 210,000 acres and is not projected to increase even though the demand for grain is greater than the supply within the state. Corn yield in Mississippi is primarily limited by lack of rainfall, especialy during grain fill.

The use of no-tillage and cover crops could improve soil moisture conservation, while at the same time reducing soil erosion. Also, if a legume cover crop is included, a considerable quantity of biologically fixed N could be introduced into the system. This system could bring erodible farmland into compliance with the mandates of the 1985 Food Security Act. However, little work has been done in the state on no-tillage corn production. Thus, one of the primary objectives of this study was to determine the response of no-tillage corn to cover cropping and N fertilization.

Methods

The experiment was initiated in fall of 1986 at the Northeast Mississippi Branch Station in Verona, MS on a Prentiss tine sandy loam soil with 2 to 5 percent slope. The site had previously been in bermudagrass sod. The sod was sprayed with 0.2 Ib/acre fluazifop to kill the bermudagrass. The killed sod was then chisel plowed and disked. Hairy vetch and Marshall ryegrass were each broadcast seeded at 30 Ib/acre and then cultipacked. Corn (Pioneer Hybrid 3165) was planted into live cover crops on 15 April 1987 at 26,000 kernels/acre in 30-inch rows using a six-row planter equipped with rippled coulters. After planting, the area was sprayed with 0.5 Ib/acre paraquat, 2.0 lb/acre alachlor, and 2.0 Ib/acre cyanazine to kill existing vegetation and to provide residual weed control. Ammonium nitrate was surface broadcast after planting at rates of 0, 58, 116, and 174 Ib N/acre. The experiment was arranged as a randomized complete block

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Results

Estimates of cover crop dry matter yields just prior to planting were 2,200 Ib/acre for hairy vetch and 1,780 lb/acre for ryegrass. Since this was the first year of the study, the cover crops provided the only source of surface residues. Once the cover crops were dessicated, approximately 80 to 90 percent of the soil surface was covered. With ryegrass, we did not get 100 percent kill and some regrowth occurred. Also, the killed ryegrass remained upright thus causing some of the corn to become etiolated.

The effects of cover crops and N fertilizer on corn are shown in Table 1. With ryegrass, the greatest grain yield increase was associated with the first 58 Ib N/acre applied. No significant advantage was observed with rates above 58 lb N/acre. With vetch cover and no N fertilizer, grain yield was about equal to that of the ryegrass cover with 174 lb N/acre, but was not significantly greater than 58 Ib N/acre with ryegrass cover. Fertilizer N did not influence grain yields with vetch cover. The advantage of vetch cover over ryegrass for corresponding N rates was apparent at the 0 and 58 lb N/acre rates, but not at rates higher than this. The only difference in stover yield was that all treatments were greater than the ryegrass cover with no N fertilizer treatment. All treatments produced considerable corn residue which when left on the soil surface should minimize soil erosion by water.

Table 1. Corn grain and stover yields as influenced by cover crop and four rates of fertilizer N.

Fertilizer N rate	Cover treatment	Yield*	
		Grain**	Stover
(lb/acre)		(bu/acre)	(lb/acre)
0	Ryegrass	94	7,300
58	Ryegrass	121	8,800
116	Ryegrass	127	9,600
174	Ryegrass	135	8,800
0	Hairy vetch	140	9,600
58	Hairy vetch	149	9,300
116	Hairy vetch	142	9,700
174	Hairy vetch	153	10,120
LSD (0.05)		20	1 ,400

*All values are a mean of 16 observations.
**Adjusted to 15.5% moisture.

In summary, excellent corn grain yields were obtained when no-tillage corn followed a sod crop. With ryegrass, rates above 58 lb N/acre were not advantageous, while with vetch, no response to fertilizer N occurred. The overall lack of response to fertilizer N is apparently related to the high organic matter content of the surface soil which through mineralization probably released considerable N. It would be premature to draw any conclusions with only one growing season of data, but it appears that no-tillage corn has the potential to be a viable cropping alternative in Mississippi especially on land requiring a conservation practice.

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In-row and Between-row Subsoiling for Sorghum Doublecropped with Winter Grains Grown in Various Tillage Systems

J. T. Touchton and H. H. Bryant[1]

Introduction

The need for in-row subsoilers in conservation tillage systems depends on many factors, such as the presence of a root-restricting plowpan, crop being grown, and previous tillage practices. In soils with severe root-restricting plowpans, the use of in-row subsoilers can greatly improve crop yields. However, there are disadvantages associated with in-row subsoiling, such as high horsepower requirements, slow planting speeds, high investment costs, and the creation of unfavorable seedbeds and more highly compacted soils.

These disadvantages can sometimes discourage the use of conservation tillage. Because of the disadvantages associated with the use of in-row subsoilers and the desperate need for conservation tillage, researchers throughout the Southeast have attempted to identify production practices that will eliminate the need for in-row subsoilers. Some of these practices have included variety selection (Granade and Akridge, 1984), previous crop tillage (Touchton and Johnson, 1982), slit tillage (Elkins and Thurlow, 1984), and starter fertilizer applications (Touchton *et* al., 1986). All of these practices have been successful with some crops on certain soils in some years, but none of them have resulted in a consistent cure for the need of in-row subsoiling.

When fibrous rooted plants are grown on highly compactible soils, some form of deep tillage will be needed either prior to or during the early part of the growing season. This tillage will help ensure that root growth can occur throughout the surface soil and that an acceptable amount of the rain received can infiltrate the soil.

Recently, Reeves and Touchton (1986) reported that between-row subsoiling may replace the need for in-row subsoiling for corn grown on a compactible soil. The potential advantages for between-row over in-row subsoiling include increased planting speeds, smaller tractors for pulling planting equipment (which would help reduce compaction problems when planting on a wet soil), and more favorable seedbeds. A disadvantage is that an extra tillage operation is required after crop emergence.

The objectives of this research were to determine: (1) if deep tillage prior to planting wheat influences the need for in-row subsoiling for subsequent grain sorghum; (2) if between-row subsoiling after sorghum emergence eliminates the need for in-row subsoiling at planting; and (3) if subsoiling operations for sorghum influence tillage needs for doublecropped winter grains.

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Materials and Methods

These field studies were conducted on Coastal Plain soils for 3 years (1984-1986) at Headland (Dothan fsl), Brewton (Benndale ls) and Monroeville (Lucedale fsl), Alabama. Data from previous studies have indicated that the Dothan and Benndale soils are highly compactible and crops grown on these soils without deep preplant tillage generally respond favorably to in-row subsoiling at planting. The Dothan soil at Headland contains a root-restricting plowpan 8 to 10 inches below the soil surface. The Benndale soil at Brewton, which is very similar to the Dothan soil in physical characteristics, contains a root-restricting plowpan 5 to 6 inches below the soil surface. The Lucedale soil is generally not as compaction prone as the Dothan and Benndale soils. Crops grown without deep preplant tillage on this soil, which does not have a well-defined root-restricting plowpan, do not always respond to in-row subsoiling at planting.

The experimental plots were located on the same area as a previous tillage test with doublecropped wheat and soybeans, which is also reported in these proceedings (see pages 76-78). The tillage systems prior to planting the winter grains for this study consisted of (1) no-tillage, (2) disk, (3) chisel-disk, (4) turn-disk, (5) subsoil, and (6) subsoil plus fertilizer. The chisel-disk treatment consisted of a double-gang chisel plow. The shanks on the front and rear tool bars were offset to give an effective shank spacing of 7½ inches. Depth of chiseling was 6 to 9 inches.

For the turn treatment, depth of turning was 8 to 10 inches. After chiseling and turning, the soil was leveled with a leveling disk. The subsoil treatment consisted of pulling a subsoiler commonly used for in-row subsoiling through the field. Distance between subsoil shanks was 36 inches and depth of subsoiling was 12 to 14 inches.

The subsoil plus fertilizer treatment was the same as the subsoil treatment except a solid fertilizer (150 lb/acre of

13-13-13) was dropped into the subsoil tracks at Brewton and Monroeville and a solution fertilizer (150 lb/acre of 20-17-0) was placed at the bottom of the subsoil track at Headland. Leveling after subsoiling was not needed or used.

The no-tillage, disk, chisel, and turn treatments used in this study are on the same plots as the previous 3-year test so they represent 4 to 6 years of the same tillage system for these plots. The subsoil treatments replaced leveling method treatments used on the previous test.

When the winter grains were harvested, the tillage plots were split. All of the grain sorghum was planted without preplant tillage but half of each tillage plot was planted with in-row subsoiling and the other half was planted without in-row subsoiling. The same planting implement was used for each split treatment, but subsoil shanks were removed for planting the non-subsoiled plots. Each year at Brewton and in the third year at Monroeville, the plots were split a second time and the row middles in half of each plot were subsoiled 4 weeks after planting. Depth of subsoiling for all operations was approximately 12 inches.

The winter grains, which were triticale (Beagle) at Headland and wheat (Coker 762) at the other locations, were drilled (6⅔-inch row widths) in November each year. The grain sorghum (Savanna 5) was planted in 24-inch row widths during the first week of June each year. All plots for each crop were harvested with a small farn-type combine modified for plot work

Except for the one treatment where fertilizer was applied prior to planting the winter grain, fertilizer and lime applications were in accordance with recommendations based on soil test data. Recommended pesticides were applied as needed to control weeds and insects.

Results and Discussion

Wheat and Triticale Yields

Small grain yields did not vary among subsoiling treatments for sorghum (in-row at planting or subsoiling in the row middles one month after planting). Therefore, data listed in Table 1 are averaged over subsoiling treatments for sorghum. Other studies have also shown that tillage prior to planting the summer crop may not affect wheat yields (Baker, 1987), but some studies have indicated that previous crop tillage can influence wheat yields on some soils (Touchton and Johnson, 1982).

Small grain yields were lowest with no tillage at each location and year (Table 1). When compared to the best yielding tillage treatment, no tillage resulted in a 75 percent yield reduction at Brewton, a 63 percent reduction at Monroeville, and a 49 percent reduction at Headland. Disk tillage resulted in considerable yield improvements over no tillage, however, yields from disk tillage were inferior to the best yielding deep tillage treatment each year at Brewton and Headland, and one year at Monroeville. When averaged across years within locations and compared to yields with the turn treatment, disk tillage resulted in 6, 3, and 8 bu/acre lower yields at Brewton, Monroeville, and Headland, respectively.

Chisel plowing resulted in lower yields than turning in one year at Brewton and in 2 years at Headland. In each of these years, however, subsoiling on 36-inch centers resulted in yields equal to turning, which indicates that depth of chiseling (6 to 9 inches) was too shallow. Depth of chiseling, however, is frequently a function of soil strength, which is directly influenced by soil moisture, a factor over which the operator has limited control. With only one exception, subsoiling resulted in yields equivalent to turning.

Since subsoiling is essentially a no-tillage system with channels cut 12 to 14 inches deep on 36-inch centers, it appears that the reported adverse effects of no-tillage on wheat yields (Hargrove and Hardcastle, 1984; Karlen and Gooden, 1987, Martin and Touchton, 1982) may be due to subsurface compaction and not entirely to surface soil compaction or residue effects. This hypothesis is supported by the occasional low yields with chisel plowing on the two sites with hardpans (Brewton and Headland). Chisel plowing on these sites would have eliminated surface soil compaction in the upper 6 inches of soil and would have incorporated heavy surface mulches, but would not have consistently eliminated plowpans. It should be noted that no-tillage wheat production does not reduce yields on some soils (Griffin and Taylor, 1986; Sanford, 1979; Undersander and Reiger, 1985).

Dropping fertilizers behind the subsoil shanks improved yields in only 1 of the 6 location years (Brewton in 1986).

Table 1. Wheat grain yields at Brewton and Monroeville and triticale yields at Headland as affected by tillage prior to planting.

	Loeation and Year								
	Brewton			Monroeville			Headland		
Tillage	1984	1985	1986	1984	1985	1986	1984	1985	1986
	bu/acre								
No-till	8	6	15	25	6	9	22	19	12
Disk	40	25	31	47	21	28	25	22	35
Chisel	40	27	38	51	28	28	25	23	41
Turn	50	30	34	49	28	29	33	31	42
Subsoil	46	24	36	46	26	28	33	29	40
Subsoil + fertilizer	46	28	45	50	30	26	32	29	39
LSD (0.10)	5	4	5	5	6	6	6	6	6

Evidently, starter fertilizers are not as effective with winter grains as with summer crops.

Gmin Sorghum Yields

Grain sorghum yields (Table 2) varied among years and were relatively low. The yields obtained, however, were actually higher than average yields of doublecropped sorghum in south Alabama.

Tillage prior to planting the winter grain crops had no effect on grain sorghum yields, and unlike soybean in previous studies, deep tillage prior to planting the winter crops did not eliminate the need for in-row subsoiling at sorghum planting.

In-row subsoiling at planting without subsoiling the row middles, which is the common practice, resulted in higher yields than no in-row subsoiling each year at Brewton and Headland and in one of the 3 years at Monroeville. When averaged over years, in-row subsoiling compared to no in-row subsoiling resulted in yield increases of 10, 6, and 24 bu/acre at Brewton, Monroeville, and Headland, respectively.

At Brewton, between-row subsoiling in addition to in-row subsoiling reduced yields one year, improved yields one year, and had no effect the other year; 3-year averages were equal (58 hu/acre). Between-row subsoiling without in-row subsoiling, compared to in-row subsoiling alone, resulted in laver yields the first year, equivalent yields the second year, and higher yields the third year. Averaged over the 3 years, between-row subsoiling compared favorably to traditional in-row subsoiling (55 vs 58 bu/acre) at this site. When comparing between-row subsoiling alone with no subsoiling, the between-row subsoiling improved yields 2 out of 3 years and resulted in 7 bu/acre higher yields for the 3-year average.

At Monroeville, between-row subsoiling was used only in the third year. Yield response in this year was due entirely to between-row subsoiling, and the average yields were 62 and 48 bu/acre with and without between-row subsoiling, respectively. In-row subsoiling alone resulted in yields of 47 bu/acre.

It is not known why yield responses to between-row subsoiling occurred. The responses could have been due to the elimination of between-row surface soil compaction, which could have resulted in improved root growth between rows, to increased water infiltration, or a combination of the two. In each year, subsoiling the middles of the relatively narrow rows (24-inch row widths) resulted in severe plant damage. Except for the 1984 growing season at Brewton, the sorghum plants were able to compensate for this early-season plant damage.

Table 2. Grain sorghum yields as affected by in-row subsoiling at planting and between-row subsoiling 4 weeks after planting.

	Subsoiling		Year			
	In-row	Between-row	1984	198.5	1986	Mean
			bu/acre			
Brewton						
	Yes	Yes	43	60	70	58
		No	50	53	70	58
	No	Yes	34	51	81	55
		No	35	46	62	48
	LSD (0.10)'		5	6	6	
Monroeville						
	Yes	Yes	—²	—	60	—
		No	79	53	41	60
	No	Yes	—	—	64	—
		No	65	50	48	54
	LSD (0.10)		*	ns	5	
Headland						
	Yes	—	90	42	62	65
	No	—	71	15	37	41
	LSD (0.10)		*	*	*	

'Statistics are for values in a column within years and locations. Where only two values occurred within a location year, * indicates that the two values are different at the 5% level of probability, and ns indicates no difference.

² — Indicates that treatments were not used.

Summary

No tillage and disk tillage for wheat production can result in severe yield reduction for both wheat and triticale. Generaly, chisel plowing, turn plowing, or subsoiling on 36-inch centers resulted in equivalent yields. Chisel plowing resulted in lower yields than turning where depth of chiseling was not adequate. Tillage prior to planting small grains had no effect on subsequent grain sorghum yields, and deep tillage prior to planting winter grains did not eliminate the need for in-row subsoiling for grain sorghum. It appears that between-row subsoiling after stand establishment may be an alternative to the requirement for in-row subsoiling at sorghum planting.

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Grain Sorghum and Soybean Rotations Evaluated in Conventional and No-Till Planting Systems

J. R. Johnson, W. E. Stevens, and H. D. Palmertree[1]

Rotating soybeans with grain sorghum was a popular recommendation for North Mississippi in the early 1980's. Research agronomists of the North Mississippi Branch Experiment Station, however, lacked data to support this recommendation. Consequently, many assumptions were made about benefits of this rotation using data from other areas with different environments and soil types.

Alternate year rotation of soybeans and grain sorghum seemed justifiable on paper but did not always fit into a grower's schedule or take advantage of best yearly market prices. Moreover, growers in north Mississippi have a tendency to rotate only when they have to because of pests. Usually, growers will plant the crop that has the highest market price potential that year.

The lack of local research to justify how much annual benefit one could gain by crop rotation, coupled with which crop could be the most profitable that particular year, created a problem for some growers. Consequently, we felt that we should not only evaluate alternate year rotation, but also determine if soybean and grain sorghum rotations have any carryover effect for yield past the first year of rotation. Another objective was to determine if a rotational system provided any pest control. Since no-till farming was also a popular subject, these evaluations were made using both tilled and no-till farming practices.

Procedures

Two experiments were established on a Grenada silt loam soil with less than 2 percent slope. Soybeans had been grown on both sites in 1980-83 prior to the study. Rhizome johnsongrass had been a problem on both site areas in past years but was controlled 2 years prior to the study with Poast® herbicide applied over-the-top (OT) of soybeans. The identity of each plot was maintained throughout the study. The experimental design was a randomized complete block with four replications. Plots consisted of four rows on 36-inch spacing 50 feet long. The rotation plan used in Experiments 1 and 2 is shown in Table 1. All data for the 1984 season are omitted in order to establish an orderly rotation scheme.

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Table 1. Cropping treatments for grain sorghum-soybean rotations North Mississippi Branch.

Trt. no.	Rotation	1984	1985	1986	1987
1.	Continuous GS	GS	GS	GS	GS
2.	Continuous SB	SB	SB	SB	SB
3.	1-year rotations	GS	SB	GS	SB
4.	I-year rotations	SB	GS	SB	GS
5.	2-year rotations	SB	SB	GS	GS
6.	2-year rotations	GS	GS	SB	SB
7.	3-year rotations	SB	SB	SB	GS
8.	3-vear rotations	GS	GS	GS	SB

GS = Grain sorghum; SB = Soybeans

Experiment 1

Grain Sorghum

Plots were disked and chiseled at least 2 weeks prior to planting, then redisked and do-alled immediately before planting each year using a John Deere 7000® planter. Seeding rate was 6 lb/acre using Funk's 522 DR® brand seed treated with Concep® herbicide safener. Fertilizer, at the rate of 65-65-65 (N-P-K), was applied at planting. Bicep® herbicide at 3.0 Ib ai/acre was sprayed broadcast over the plots immediately after planting. Plots were topdressed with 60 Ib N/acre in 4- or 5-leaf stage. Each year all plots were cultivated twice, soil samples for nematodes were taken in early August, and johnsongrass stem counts were made before harvest. Two center rows of each plot were harvested with a plot combine.

Soybeans

Preplant tillage and planting equipment was the same for soybeans as described above for grain sorghum. Seeding rates were adjusted each year to obtain 8-10 plants per foot of row. Essex, Centennial, Asgrow 5980® , and Essex varieties were planted in 1984, 1985, 1986, and 1987, respectively. Essex is susceptible to soybean cyst nematode (SCN) Races 3 and 4; Centennial is resistant to Race 3; and Asgrow is resistant to Races 3 and 4.

Fertilizer was applied at planting at the rate of 0-60-60 (N-P-K). Dual® herbicide was applied preemerge in 1984 and 1985 at the rate of 2.0 Ib ai/acre. Dual and Canopy@ were both applied preemergence in 1986 and 1987 at the rate of 2.0 Ib ai/acre and 1.0 ai/acre, respectively. An application of Basagran® at 0.75 ai/acre was made OT in early season to control escaped broadleaf weeds. Applications of Poast® were made OT in early and mid-season at the rate of 0.3 and 0.2 lb ai/acre, respectively, to control johnsongrass.

Plots were cultivated twice during the growing season. Soil samples for nematodes were taken in the row from the plots in early August each year. Two center rows of each plot were harvested with a plot combine.

Results and Discussion

Rhizome johnsongrass in grain sorghum became more abundant when rotation intervals were more than one year. Effective control of rhizome johnsongrass was achieved with one-year rotations with soybeans. Grain sorghum yields were not increased by rotating it with more than one consecutive year of soybeans (Table 2). Since johnsongrass culm counts were made at harvest, they represent both seedling and rhizome plants. Yields of grain sorghum were adversely affected after the second year of continuous grain sorghum following soybeans due to uncontrolled seedling johnsongrass becoming rhizome johnsongrass.

Soybean yields were always higher each year on a one-year rotation than with continuous soybeans. Soybeans in rotation with grain sorghum, however, did not produce significantly higher yields than continuous soybeans (Table 3).

Table 2. Annual yield for grain sorghum and number of johnsongrass culms per 15 feet of row grown in a rotational system with soybeans.

Rotational system	Grain yield (JG culms/l5 ft)		
	1985	1986	1987
	lb/a		
Continuous GS	3,405 (12)	908 (88)	651 (124)
GS following SB previous year	4,599 (5)	3,056 (5)	1,694 (19)
GS following SB, 1984 and 85		3,113 (5)	1,869 (58)
GS following SB, 1984, 85, 86			1,676 (20)
LSD (0.05)	ns (ns)	315 (45)	362 (42)
C.V. (%)	34 (136)	8 (78)	15 (48)

GS = Grain sorghum; SB = Soybeans; JG = Johnsongrass.

Table 3. Annual yield for soybeans grown in a rotational system with grain sorghum.

Rotational system	Grain yield		
	1985	1986	1987
	bu/a		
Continuous SB	41	32	20
SB following GS previous year	42	35	21
SB following GS in 1984 and 1985		34	17
SB following GS in 1984, 1985, 1986			18
LSD (0.05)	ns	ns	ns
CV(%)	5	16	14

SB = Soybeans; GS = Grain sorghum

Table 4. Effects of crop rotations on the populations of three types of soil nematodes.

Treatment	1987 crop[1]	Nematodes (no./pt of soil)		
		cyst[2]	Lesion	stunt
Continuous GS	GS	19	279	109
Continuous SB	SB	341	47	31
I-year rotations	GS	3	93	139
I-year rotations	SB	238	109	31
2-year rotations	GS	0	46	0
2-year rotations	SB	322	16	46
3-year rotations	GS	47	186	278
3-vear rotations	SB	46	108	78

[1]Grain sorghum and soybeans are represented by GS and SB, respectively.
[2]Each number is a composite of the number of cyst nematodes in the free larvae hatched, and cyst stages.

Data from nematode analysis were extremely hard to interpret due to high variability. It appeared that the SCN populations were highest in the continuous soybean crop and the lesion nematode numbers were highest in the continuous grain sorghum crop (Table 4).

Conclusion

Johnsongrass in grain sorghum became a greater pest with succeeding years in a continuous till cropping system. A one-year rotation from soybeans to grain sorghum with effective johnsongrass control in soybeans was sufficient in reducing rhizome johnsongrass in grain sorghum. In this study, grain sorghum yields were significantly improved by alternate year rotations over continuous grain sorghum. In the soybean crop, johnsongrass was controlled and yields were not significantly improved in rotation with grain sorghum. In rotation schemes of greater than one year for this study, there appears to be no carryover effect for yield from crop rotations.

Experiment 2

Grain Sorghum

Plots were planted using a John Deere 7000 planter equipped with ripple coulters and cast iron press wheels. Funk's 522 DR brand seed treated with Concep herbicide safener was planted at the rate of 6.0 lb/acre. Fertilizer, at the rate of 65-65-65 (N-P-K) was applied at planting. Roundup@ at the rate of 0.75 lb ai/acre, mixed with Bicep at 3.00 lb ai/acre, was sprayed broadcast over the entire plot area immediately after planting. Plots were topdressed with 60 lb N/acre when plants were in the 4-or 5-leaf stage. Soil samples for nematodes were taken in early August and johnsongrass counts were made before harvest each year. Plots were harvested using a plot combine.

Soybeans

Plots were planted using a John Deere 7OOO planter equipped with ripple coulters and cast iron press wheels. The seeding rate was adjusted each year to obtain 8 to 10 plants perfoot of row. Essex, Centennial, Asgrow 5980, and Essex varieties were planted in 1984, 1985, 1986, and 1987, respectively. Roundup at the rate of 0.75 lb ai/acre mixed with Dual at 2.0 lb ai/acre was sprayed in 1984 and 1985. Roundup at 0.75 lb ai/acre and Canopy at 3.0 lb ai/acre were sprayed in 1986 and 1987 immediately after planting. An application of Basagran at 0.75 ai/acre was made OT in early season to control escaped broadleaf weeds. An application of Poast was made OT in early and in midseason at the rate of 0.3 and 0.2 lb ai/a, respectively to control johnsongrass. Soil samples for nematodes were taken in early August each year. Plots were harvested with a plot combine.

Results and Discussion

Cyst nematode counts were the highest in continuous soybean plots but non-existent in the alternate year rotation at the end of the study. This indicates that alternate year crop rotation with soybeans and grain sorghum, and switching from susceptible to resistant soybean varieties, may be beneficial in no-till farming to control SCN (Table 5). The continuous grain sorghum plots became so heavily infested with rhizome johnsongrass after the second year that visual observation indicated this was an unacceptable practice. In this study, when grain sorghum was grown for more than 2 consecutive years following soybeans, the grain sorghum became severely infested with johnsongrass and yields were greatly reduced (Table 6).

There did not appear to be any yield advantage for soybeans following grain sorghum in a 1, 2, or 3-year rotation system (Table 7). Even though SCN count increased in continuous soybeans the cyst nematodes never reached a level whereby yield was reduced. Grain sorghum, however, did benefit from rotation because the rhizome johnsongrass pest problem was kept under control in alternate years.

Grain sorghum yields were highest the first year following soybeans in a rotation and then dropped the second year due to competition of johnsongrass.

Table 5. Effects of crop rotations on the populations of three types of soil nematodes from no-tilled planting.

Treatment	1987 crop[1]	Nematodes found (no./pt of soil) Cyst[2]	Lesion	Stunt
Continuous GS	GS	0	325	0
Continuous SB	SB	143	171	31
I-year rotations	GS	0	170	16
1-year rotations	SB	0	46	309
2-year rotations	GS	0	279	341
2-year rotations	SB	15	93	109
3-year rotations	GS	0	46	46
3-vear rotations	SB	0	186	16

'Grain sorghum and soybeans are represented by GS and SB, respectively.
2Each number is a composite of the number of cyst nematodes in the free larvae hatched, and cyst stages.

Table 6. Annual yields for grain sorghum and number of johnsongrass culms per 15 ft of row when grown in a rotational system with soybeans from no-till planting.

Rotational system	Grain vield (JG culms/l5 ft) 1985	1986	1987
	Ib/a		
Continuous GS	2,383 (22)	136 (195)	235 (197)
GS following SB previous year	2,717 (18)	1,494 (52)	1,051 (166)
GS following SB, 1984, 1985		1,354 (40)	305 (234)
GS following SB, 1984, 1985, 1986			1,150 (132)
LSD (0.05)	ns (ns)	614 (86)	ns (94)
C.V. (%)	48 (119)	36 (53)	84 (32)

GS = Grain sorghum; SB = Soybeans; JG = Johnsongrass.

Table 7. Annual yield for soybeans grown in a rotational system with grain sorghum from no-till planting.

Rotational system	Grain vield 1985	1986	1987
	bu/a		
Continuous SB	31	20	12
SB following GS previous year	29	20	10
SB following GS, 1984, 1985		20	13
SB following GS, 1984, 1985, 1986			12
LSD (0.05)	ns	ns	ns
C.V. (%)	27	12	22

SB = Soybeans; GS = Grain sorghum

Conclusion

Grain sorghum yields were severely reduced after 2 consecutive years due to rhizome johnsongrass. Soybean yields using no-till practices were not increased by rotation with grain sorghum using no-till practices over the continuous no-tilled soybeans. Soybean cyst nematodes increased in the continuous no-till soybean plots, but not to a level to cause yield reduction. Plots with alternate year rotation of no-till soybeans and no-till grain sorghum were free of cyst nematodes at the end of this study.

Soybean Response to Reduced Tillage Systems on Selected Soil Resource Areas

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Introduction

It is estimated that soybeans are grown on approximately 1.25 million acres of Mississippi land where erosion potential exists using current tillage practices. Most of this erodible acreage is in central and northern Mississippi. New tillage implements such as the Paraplow® and Ro-till® have recently been introduced as reduced tillage implements. The Paraplow looks similar to a moldboard plow but differs in that the plow-shank only lifts the soil up as the shank passes through the soil profile, causing very little surface disturbance. The Ro-till is equipped with trash whippers, an in-row subsoil shank, plus two adjustable fluted coulters and a rolling basket per shank. The coulters are adjustable, and move soil over the subsoil slit as the shank moves through the soil profile. The rolling basket trails the coulters and firms the seedbed. This implement is used as a one-pass seedbed preparation system.

Soybean response to tillage systems varies widely. In the Midwest (4, 8, and 10),soybean yields are often not affected by tillage systems ranging from complete residue incorporation to no-till. Others (2 and 7) have reported that reduced tillage systems produced soybean stands, weed control, and yields comparable to those from conventional tillage. Some reported research (3 and 11) indicated no-till systems produced higher yields than a conventional tillage system. Most soybean tillage research in Mississippi has indicated a significant yield increase to tillage (1, 5, 6, and 12). A primary concern with tillage methods is their effect on soil erosion.

Studies with monocrop soybeans have confirmed a much higher soil loss with conventional tillage than with reduced tillage and no tillage. Soil loss studies on a loess soil with a 5 percent slope indicated that conventional tillage resulted in a soil loss of 8.70 tons/acre compared to 3.6 tons/acre from a reduced tillage system and 0.62 tons/acre for no-till system (6). In another study on a Blackland Prairie clay soil in Mississippi, the average soil loss from conventional tillage was 3.97 tons/acre compared to 2.90 tons/acre lost from no-till (5). In a rainfall simulator study in Mississippi on a Leeper silty clay with 0.2 percent slope, the average soil loss from one storm (2.5 inches/hour) with conventional tillage was 1.5 tons/acre compared to 0.18 ton/acre for minimum tillage (9).

This study was conducted to evaluate reduced tillage systems for soybean production that have potential to reduce soil loss. The objective was to evaluate across three major soil resource areas: (1) soybean growth and yield response to selected reduced tillage systems and depth, and (2) soybean growth and yield response to depth of P and K fertilizer placement with the Ro-till reduced tillage system.

Materials and Methods

Field plots were established for the duration of the project (1985-87) on a Catalpa silty clay at the MAFES Northeast Branch Experiment Station, Verona, MS; on a Providence silt loam at the Pontotoc Branch Experiment Station, Pontotoc, MS; and on a Loring silt loam at the Brown Loam Branch Experiment Station, Raymond, MS. The studies at each location were conducted in a randomized complete block design with four replications.

Conventional tillage, consisted of chiseling 6-8 inches deep + disking and paraplowing to depths of 4-6, 6-8, and 12-14 inches in the spring of each year. Tillage dates for Verona, Pontotoc, and Raymond are given in Tables 2, 3, and 4, respectively. Ro-till tillage treatment, at depths of 7-8, 11-12, and 14-15 inches, was done at the time of planting at all three locations. Soybeans were planted as a separate operation following the Ro-till implement. Prior to tillage in the spring of each year, dry fertilizer (0-17-34 analysis) was applied to all plots at 45 and 90 lb/acre of P_2O_5 and K_20, respectively, except in the Ro-till fertilizer placement treatment plots. The fertilizer in the Ro-till fertilizer placement plots was applied as a liquid suspension of K_2HP0_4 and KCI, equivalent to dry fertilizer P and K rates of 45 and 90 Ib/acre P_2O_5 and K_20, respectively. The liquid fertilizer suspension was injected to the depth of Ro-till subsoil tillage as indicated in Tables 2, 3, and 4.

Roundup@ at 1.0 lb ai/acre + X-77® surfactant at 0.5% v/v was applied as a burndown herbicide application to no-till, Paraplow, and Ro-till treatments 7 to 14 days prior to planting. The conventional tillage and Paraplow plots were smoothed with a do-all (an implement equipped with a rolling cutter bar and section harrow) prior to planting soybeans. Soybean planting dates (Table 2, 3, and 4) for 1985-87 ranged from May 31 to June 5 at both Northeast and Pontotoc

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locations and from June 5 to June 26 at the Brown Loam Station.

Centennial soybean was planted at all locations with a John Deere Max-Emerge no-till planter equipped with ripple coulters. Seeding rate was 7 seeds/linear foot of row in 30-inch rows.

Weed control management during the growing season utilized all postemergence herbicides for both Pontotoc and Raymond, and preemergence herbicides plus a post-directed spray for the Northeast Branch Experiment Station (Table 1). Plots were not cultivated during the growing season at any of the locations.

Soybean plant population data were taken about 6 weeks after planting at all three locations. Plants were counted in six randomly selected 3-foot sections of the center two rows of each plot.

Ten randomly selected mature soybean plants in the center two rows of a four-row plot were measured from the soil line to the uppermost node to determine plant height. The two center rows of each plot were harvested with a small plot combine for seed yield. The seed was weighed, then moisture was determined with a Dickey John GACII® grain analysis computer and recorded. Yield data were calculated and adjusted to 13 percent moisture. Mean separation was determined using the least significant difference (LSD) method, at the 0.05 probability level for all data.

Results and Discussion

Soybean growth and yield response to reduced tillage systems varied with year, soil resource area, and rainfall amount and distribution during the soybean growing season.

Northeast Experiment Station

Northeast Branch rainfall distribution during the soybean growing season of May through September ranged from 34 percent above normal in 1985 to about normal in 1986 and 1987. Soybean average yield ranged from 41 bu/acre in 1985 to 29 bu/acre in 1987. Stand density ranged from about 40,000 plants/acre in 1987 to 78,500 in 1986. Stand densities in the Ro-till treatments were generally lower than in the Paraplow, no-till, and conventional tillage treatments in 1985 and 1987 but not in 1986 (Table 2). The seedbed prepared by the Ro-till at planting was cloddy and rough on the surface. Sometimes the killed ,vegetation did not flow through the implement in the tillage operation, causing soil blockage.

In 1985, both Ro-till 7 to 8 and 11 to 12-inch depths with fertilizer surface-incorporated produced lower yield than conventional chisel + disk and Paraplow 6 to 8-inch depth. The Paraplow (6 to 8-inch depth) treatment, no-till, and conventional chisel + disk treatments produced the highest yields and were not different. Depth of tillage for both the Paraplow and Ro-till treatments, and fertilizer placement in the Ro-till treatment had no significant effect on yield.

Stand densities in 1986 (Table 2) were higher than those in 1985 in all tillage treatments. Plant height at maturity was less and soybean yields averaged about 10 bu/acre less than in 1985. This was possibly due to extreme dry weather in July, when rainfall was 4.2 inches below normal. Soybeans showed no response to tillage treatments. Tillage depths with Ro-till and Paraplow had no significant effect on yield.

In 1987, soybean yield ranged from 22 bu/acre for Ro-till (11 to 12-inch depth) to 38 bu/acre for the conventional chisel + disk. Both Paraplow (6 to 8-inch depth) and chisel + disk produced significantly higher yield than no-till and Ro-till (11 to 12-inch depth). In comparison to fertilizer surface applied and incorporated with the Ro-till, fertilizer P and K injected to depth of tillage with a Ro-till had no effect on yield in any of the 3 years.

Pontotoc Experiment Station

Rainfall during the July-September soybean growing season was about normal in 1985, 52 percent below normal in 1986, and 30 percent below normal for 1987. Soybean stand densities averaged 74,500 in 1985, 47,800 in 1986, and 37,700 plants/acre in 1987. Two years, 1985 and 1987, plant densities

Table 1. Herbicides and time of application for weed control in reduced tillage system studies at three MS locations, 1985-87.

Time of application*	Location: Verona Herbicide	lb ai/a	Location: Pontotoc-Raymond Herbicide	lb ai/a
Burndown	Roundup + X-77	1.0 + 0.5%	Roundup + X-77	1.0 + 0.5%
PRE-E	Dual + Scepter	2.00 + 0.125		-
POT	—	–	Poast + Blazer + Crop Oil	0.02 + 0.38 + 1 qt
P-Dir	Sencor + 2.4-DB	0.25 + 0.20		-

*Time of application code: Burndown was applied 7-14 days before planting; PRE-E = preemergence application made following soybean planting; POT = postemergence over-top application as tank mixtures, twice during soybean growing season; and P-Dir = post-directed application to soybeans 8-12 inches tall as a broadcast application.

were affected by tillage systems; in 1985 all paraplow treatments had significantly lower plant densities than both Ro-till 11 to 12-inch depth treatments (Table 3). The Paraplow 4 to 6-inch depth had the lowest plant density and was significantly lower than both Ro-till 11 to 12, and 14 to 15-inch depths fertilizer surface-incorporated; in 1987, however, the

Table 2. Effect of reduced tillage systems and fertilizer placement on soybean plant population, height at maturity and yield on a Catalpa silty clay soil in 1985-87 at the Northeast Experiment Station.

	Reduced tillage treatment	Tillage depth (in)	Fertilizer placement depth (in)	Tillage date	Plants/acre x 1,000	Plant/height (in)	Yield hu/acre
				1985			
1.	Chisel + Disk	6-8	Inc.	4/10	88.9	38	46
2.	No-till	—	Surf.	—	47.9	32	44
3.	Paraplow	4-6	Inc.	4/10	72.6	36	42
4.	Paraplow	6-8	Inc.	4/10	83.1	37	45
5.	Paraplow	12-14	Inc.	4/10	63.5	36	43
6.	Ro-till	7-8	Inc.	5/31	48.7	30	35
7.	Ro-till	11-12	Inc.	5131	46.1	31	38
8.	Ro-till	14-15	Inc.	5/31	63.9	33	41
9.	Ro-till	7-8	7-8	5/31	53.0	31	40
10.	Ro-till	11-12	11-12	5/31	53.7	30	42
11.	Ro-till	14-15	14-15	5/31	46.1	32	41
	LSD (0.05)				1.0	3	6
				1986			
1.	Chisel + Disk	6-8	Inc.	4/04	65.9	23	29
2.	No-till	—	Surf.	—	76.8	23	29
3.	Paraplow	4-6	Inc	4/04	44.1	22	30
4.	Paraplow	6-8	Inc	4/04	58.3	23	32
5.	Paraplow	12-14	Inc.	4/04	80.4	25	34
6.	Ro-till	7-8	Inc.	6/03	76.4	23	32
7.	Ro-till	11-12	Inc.	6/03	98.9	25	33
8.	Ro-till	14-15	Inc.	6/03	94.9	26	33
9.	Ro-till	7-8	7-8	6/03	84.6	25	31
10.	Ro-till	11-12	11-12	6/03	90.5	26	31
11.	Ro-till	14-15	14-15	6/03	92.9	27	34
	LSD (0.05)				33.3	4	N.S.
				1987			
1.	Chisel + Disk	6-8	Inc.	4/13	44.0	29	38
2.	No-till	—	Surf.	—	44.0	25	27
3.	Paraplow	4-6	Inc.	4/15	51.1	27	37
4.	Paraplow	6-8	Inc.	4/15	53.2	30	35
5.	Paraplow	12-14	Inc.	4/15	47.0	31	37
6.	Ro-till	7-8	Inc.	6/02	36.8	23	22
7.	Ro-till	11-12	Inc.	6/02	31.7	25	22
8.	Ro-till	14-15	Inc.	6/02	28.1	23	26
9.	Ro-till	7-8	7-8	6/02	29.0	24	20
10.	Ro-till	11-12	11-12	6/02	31.0	24	25
11.	Ro-till	14-15	14-15	6/02	33.7	27	25
	LSD (0.05)				6.5	6	7

chisel + disk treatment had a population significantly lower than the Ro-till 11 to 12-inch depth, with injected fertilizer. The Ro-till 7 to 8-inch depth, injected fertilizer treatment had the lowest plant density and was significantly lower than both Ro-till 11 to 12 and 14 to 15-inch depths with injected fertilizer treatments, no-till, and Paraplow 4 to 6 and 6 to 8-inch depth treatments.

Soybean yields were higher in 1985 than both 1986 and

Table 3. Effect of reduced tillage systems and fertilizer placement on soybean plant population, height at maturity, and yield on a Providence silt loam soil in 1985-87 at the Pontotoc Ridge-Flatwoods Experiment Station.

	Reduced tillage treatment	Tillage depth (in)	Fertilizer placement depth (in)	Tillage date	Plants/acre x 1,000	Plant/height (in)	Yield bu/acre
				1985			
1.	Chisel + Disk	6-8	Inc.	4112	71.5	35	43
2.	No-till	—	surf.	—	75.5	33	43
3.	Paraplow	4-6	Inc.	4112	67.5	33	40
4.	Paraplow	6-8	Inc.	4112	66.4	34	42
5.	Paraplow	12-14	Inc.	4112	69.0	35	41
6.	Ro-till	7-8	Inc.	6104	68.2	36	46
7.	Ro-till	11-12	Inc.	6104	84.9	35	50
8.	Ro-till	14-15	Inc.	6104	80.6	37	45
9.	Ro-till	7-8	7-8	6104	76.2	34	48
10.	Ro-till	11-12	11-12	6104	83.9	38	46
11.	Ro-till	14-15	14-15	6104	75.9	36	42
	LSD (0.05)				13.0	N.S.	7
				1986			
1.	Chisel + Disk	6-8	Inc.	4103	48.1	31	28
2.	No-till	—	Surf.	—	53.2	32	28
3.	Paraplow	4-6	Inc.	4103	42.5	29	26
4.	Paraplow	6-8	Inc.	4103	47.1	34	27
5.	Paraplow	12-14	Inc.	4103	50.5	33	31
6.	Ro-till	7-8	Inc.	6104	46.7	32	26
7.	Ro-till	11-12	Inc.	6104	48.5	33	34
8.	Ro-till	14-15	Inc.	6104	44.3	34	31
9.	Ro-till	7-8	7-8	6104	51.9	33	27
10.	Ro-till	11-12	11-12	6104	45.9	35	27
11.	Ro-till	14-15	14-15	6/04	46.3	35	25
	LSD (0.05)				N.S.	5	8
				1987			
1.	Chisel + Disk	6-8	Inc.	4122	25.7	27	28
2.	No-till	—	Surf.	—	34.4	27	28
3.	Paraplow	4-6	Inc.	4122	36.8	25	27
4.	Paraplow	6-8	Inc.	4/22	34.1	28	30
5.	Paraplow	12-14	Inc.	4/22	31.2	28	34
6.	Ro-till	7-8	Inc.	6/04	33.9	27	25
7.	Ro-till	11-12	Inc.	6/04	30.5	29	32
8.	Ro-till	14-15	Inc.	6/04	33.0	25	34
9.	Ro-till	7-8	7-8	6/04	21.8	23	26
10.	Ro-till	11-12	11-12	6/04	44.2	26	25
11.	Rotill	14-15	14-15	6/04	34.4	27	28
	LSD (0.05)				12.0	N.S.	8

1987. The Ro-till (11 to 12-inch depth) fertilizer surface-incorporated, Paraplow (6 to 8-inch depth), no-till, and chisel + disk treatment yields were not different any year. In contrast to the poor seedbed preparation by the Ro-till on the silty clay soil at the Northeast Branch Station, the Ro-till prepared a smooth, and firm seedbed in a one-pass operation all 3 years.

Although not significant, the shallow depths of tillage with

Table 4. Effect of reduced tillage systems and fertilizer placement on soybean plant population, height at maturity, and yield on a Loring silt loam soil in 1985-87 at the Brown Loam Experiment Station.

	Reduced tillage treatment	Tillage depth (in)	Fertilizer placement depth (in)	Tillage date	Plants/acre x 1,000	Plantlheight (in)	Yield bu/acre
				1985			
1.	Chisel + Disk	6-8	Inc.	4/24	66.2	21	30
2.	No-till	—	Surf.	—	69.7	21	30
3.	Paraplow	4-6	Inc.	4124	66.2	23	29
4.	Paraplow	6-8	Inc.	4/24	64.5	24	32
5.	Paraplow	12-14	Inc.	4124	61.0	22	29
6.	Ro-till	7-8	Inc.	6126	66.2	20	25
7.	Ro-till	11-12	Inc.	6126	76.1	20	26
8.	Ro-till	14-15	Inc.	6/26	57.6	20	22
9.	Ro-till	7-8	7-8	6126	83.6	20	32
10.	Ro-till	11-12	11-12	6/26	76.7	21	25
11.	Ro-till	14-15	14-15	6/26	81.9	20	23
	LSD (0.05)				N.S.	2	6
				1986			
1.	Chisel + Disk	6-8	Inc.	4124	89.9	31	35
2.	No-till	—	Surf.	—	43.9	23	13
3.	Paraplow	4-6	Inc.	4124	58.8	27	27
4.	Paraplow	6-8	Inc.	4124	47.9	26	19
5.	Paraplow	12-14	Inc.	4/24	51.7	25	22
6.	Ro-till	7-8	Inc.	6/16	85.9	31	39
7.	Ro-till	11-12	Inc.	6/16	75.0	33	41
8.	Ro-till	14-15	Inc.	6/16	74.0	30	30
9.	Ro-till	7-8	7-8	6/16	83.4	33	33
10.	Ro-till	11-12	11-12	6116	80.3	30	31
11.	Ro-till	14-15	14-15	6/16	66.9	29	28
	LSD (0.05)				22.4	4	7
				1987			
1.	Chisel + Disk	6-8	Inc.	4/29	149	43	34
2.	No-till	—	Surf.	—	118	43	35
3.	Paraplow	4-6	Inc.	4/29	126	43	36
4.	Paraplow	6-8	Inc.	4/29	I40	45	38
5.	Paraplow	12-14	Inc.	4129	126	45	36
6.	Ro-till	7-8	Inc.	6/05	126	43	35
7.	Ro-till	11-12	Inc.	6/05	144	43	38
8.	Ro-till	14-15	Inc.	6/05	142	40	35
9.	Ro-till	7-8	7-8	6/05	I27	42	35
10.	Ro-till	11-12	11-12	6/05	134	43	36
11.	Ro-till	14-15	14-15	6/05	146	41	34
	LSD (0.05)				N.S.	N.S.	N.S.

the Paraplow and Ro-till generally produced lower yields all 3 years. The Ro-till 11 to 12-inch depth fertilizer surface-incorporated treatment produced higher yield than the 7 to 8-inch depth all 3 years and had higher yield than the 14 to 15-inch depth 2 of 3 years. The Paraplow deepest depth of 12 to 14 inches produced higher yield than the shallower depths 2 of 3 years. Fertilizer P and K applied surface-broadcast and incorporated with a one-pass operation of the Ro-till, and P and Kapplied at the depth of Ro-till tillage indicated no yield difference in any year of the study.

Brown Loam Experiment Station

Rainfall during the June to September growing season was about normal in 1985, 18 percent below normal in 1986, and 29 percent above normal in 1987. In 2 (1985 and 1987) of 3 years plant densities were not significantly affected by tillage system (Table 4). In 1986, however, no-till and both Paraplow 6 to 8 and 11 to 12-inch depths had lower plant densities than chisel + disk and all Ro-till treatments.

The low yields in 1985 were probably the result of the late planting date of June 26. Both Ro-till 14 to 15-inch depth treatments produced lower yields than all Paraplow treatments, no-till, and chisel + disk. There was no significant yield response to tillage depth with either Paraplow or Ro-till. The Ro-till 7 to 8-inch depth with injected fertilizer was the only treatment which produced higher yield than fertilizer surface-incorporated with the Ro-till at the 7 to 8-inch tillage depth.

In 1986, the. no-till and Paraplow 6 to 8 and 12 to 14-inch depth treatments had significantly lower plant densities and lower yields than chisel + disk and all Ro-till fertilizer surface-incorporated treatments. The Ro-till 11 to 12-inch depth with fertilizer surface-incorporated produced more beans than no-till and all Paraplow treatments and Ro-till 14 to 15-inch depth. Fertilizer (P and K) injected at both 7 to 8 and 11 to 12-inch subsoiling depths with the Ro-till produced lower yield than where it had been surface-applied and incorporated with the Ro-till at the same tillage depth. The shallow tillage depth for Paraplow produced higher yield than the deepest tillage.

Plant densities and yields in 1987 were not affected by tillage systems (Table 4). Rainfall was 29 percent above normal and yields averaged 36 bu/acre. Tillage depth with both Paraplow and Ro-till had no effect on yield.

Summary

Soybean growth and yield response to reduced tillage systems from 1985-1987 on three soil resource areas indicated a tillage system xlocation xyear interaction. Depth of tillage with both the Paraplow and Ro-till generally produced no significant difference in yield.

Dry fertilizer P and K, that was surface-broadcast and incorporated with one pass of the Ro-till produced yields equal or greater than fertilizer P and K injected as a liquid suspension to the depth of tillage with the Ro-till at all locations and years.

No-till produced yield equal to the chisel + disk 2 of 3 years at both Verona and Raymond, and all 3 years at Pontotoc. Ro-till although not always significant, produced higher yield than chisel + disk and no-till 2 of 3 years at Raymond and all 3 years at Pontotoc. However, at Verona on a silty clay, Ro-till produced lower yield than chisel + disk 2 of 3 years. Paraplow produced yield equal to chisel + disk all 3 years at Verona and Pontotoc, and 2 of 3 years at Raymond.

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Yields of Soybean Cultivars with High Cyst Nematode Levels as Affected by Tillage, Crop Rotation, and Cultivar

J. H. Edwards, D. L. Thurlow, and J. T. Eason[1]

Abstract

Strip-tillage (in-row chiseling), no-tillage, and conventional tillage (turnplow) systems have been evaluated for 7 years in Alabama with cropping sequences of continuous corn *(Zea mays* L.), continuous soybeans *(Glycine max* [L.] Merr.), and corn-wheat *(Triricum aestivum* sp.)-soybeans. Soybean yields for 1981 to 1984 were highly correlated with soybean cyst nematode *(Heterodera glycine* Ichinohe) (SCN) population; they were 39 percent higher with strip and no-tillage than with conventional tillage, and were 28 percent higher when rotated with corn. In 1985, strip-tillage treatments were split to include a SCN-resistant soybean cultivar, and in 1987 all tillage treatments were split to include the SCN-resistant cultivar. Soybeans yields in all tillage treatments were increased by use of a SCN-resistant cultivar, however, when crop rotation was considered, soybean yields were increased by 30 to 46 percent when compared to Essex soybean yields.

Introduction

In the first 4 years of a conservation tillage study conducted on a Hartsells fine sandy loam (tine-loamy, siliceous, thermic, Typic Hapludults) soil, conservation tillage resulted in 16 to 39 percent higher soybean yields than conventional tillage in 3 of 4 years. By the fourth year of the experiment (1983), soybean yields with conventional tillage were reduced to 690 kg ha^{-1} compared to 1,660 and 1,930 kg ha^{-1} with strip and no tillage.

A significant tillage x rotation interaction occurred in 1981, 1982, and 1983, and was probably caused by a buildup of soybean cyst nematode population. These SCN populations increased faster with conventional than with strip or no-tillage treatments. The SCN populations in 1984 were highest in all tillage systems with continuous soybeans and were lowest with no tillage when soybeans were rotated with corn. In 1985 and 1986, all strip-tillage soybeans were split so that Forrest, a SCN race three-resistant cultivar, could be compared with Essex, a non-resistant race three SCN cultivar. All tillage treatments were split to compare soybean yields in 1985 and 1986 with respect to corn-soybean rotation. The objective of this study was to follow the soybean cyst nematode population as influenced by crop rotation, conservation tillage, and soybean cultivars.

Materials and Methods

Strip-tillage treatments 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-soybeans; and corn-wheat-soybeans. 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 in the Appalachian Plateau area of the state. The experimental design was a split plot in a randomized complete block with four replications. The corn treatment was planted in six 90-cm rows 16 m long. Essex soybeans have been used since the experiment was started in 1980. In 1984, the soybean treatments were split to include a soybean cyst nematode resistant cultivar Forrest.

Soil samples were collected in March, July, and August for nematode analysis. These samples were taken 12 to 14 cm deep under the rows of each plot. The July and August samples were taken 58 and 59 days after planting full-season and doublecropped soybeans. The full-season soybeans were planted in late May and doublecropped soybeans were planted in late June after wheat was harvested for grain. All plots were uniformly fertilized according to Auburn University soil test recommendations.

Results and Discussion

Rotating Essex soybeans with corn resulted in higher yields each year (1981-1987) than continuous soybeans (Figure 1). The 7-year average yields were 1,900 and 2,430 kg/ha for

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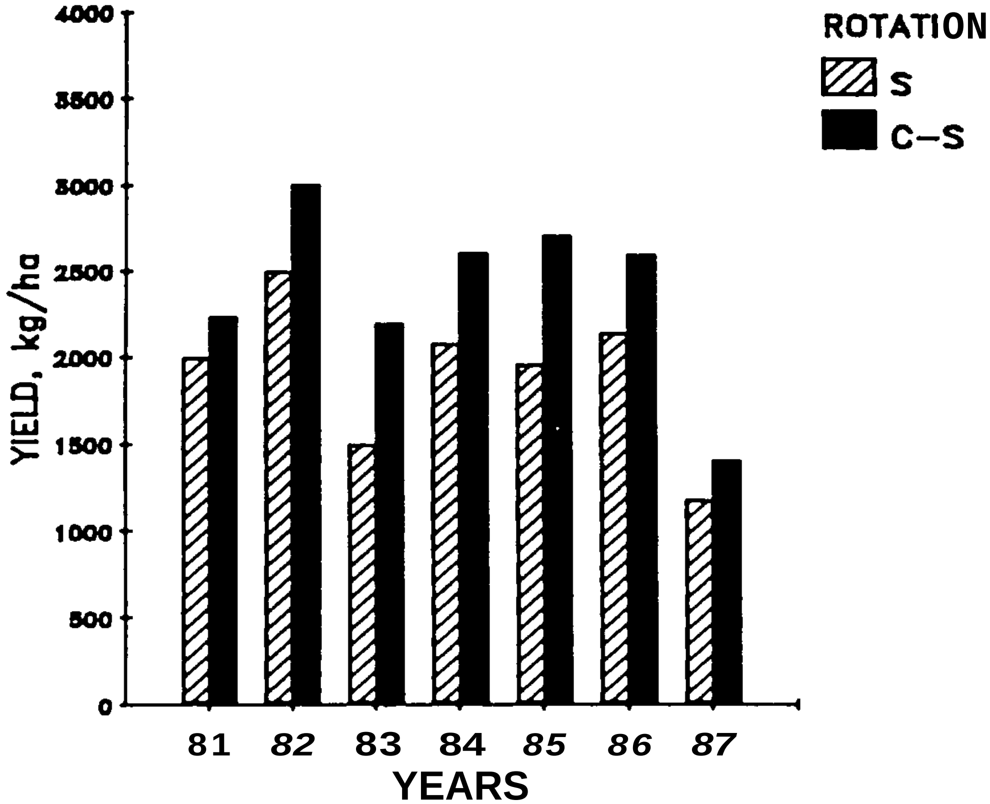

Figure 1. Seven-year average Essex soybean yields for continuous soybean and corn-soybean rotation (S = soybeans; C = corn).

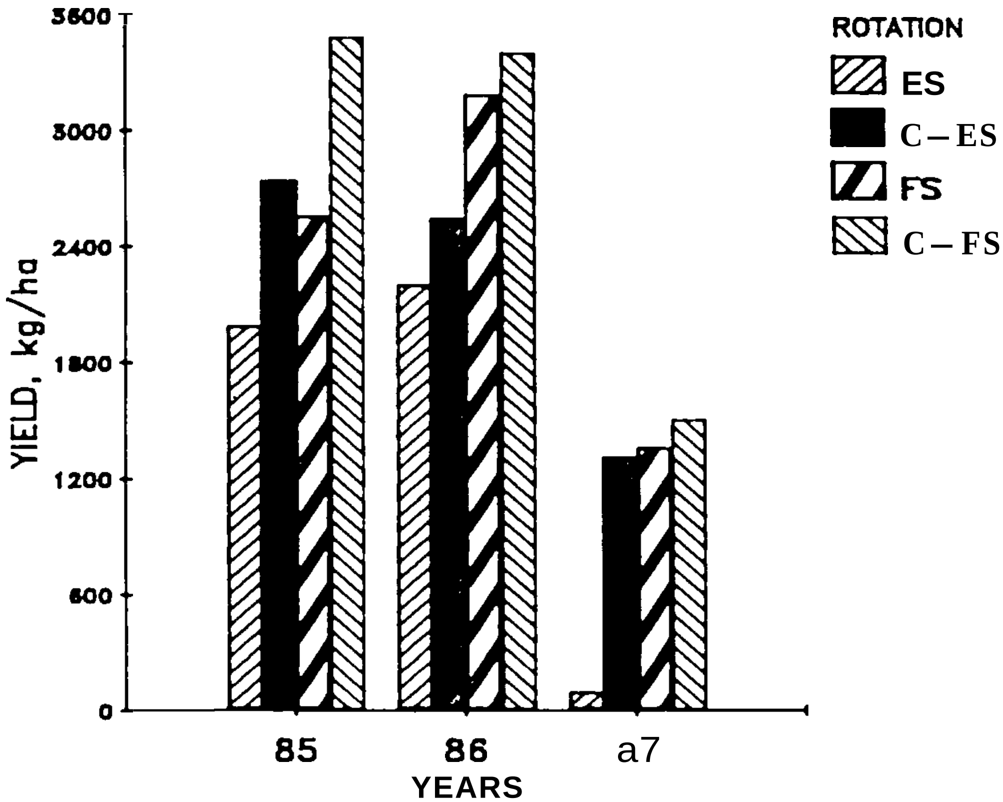

Figure 2. Three-year average Essex and Forrest soybean yields as influenced by continuous soybean and corn-soybean rotation (S = soybean; C = corn; E = Essex; F = Forrest).

continuous soybeans and soybeans grown in rotation with corn, respectively.

Within the strip-tillage system, average yields of Essex soybeans were lower the last 3 years than the first 4 years, but were higher the last 3 years than the first 4 years when SCN-resistant cultivar Forrest was planted (Table 1). The highest yields for the 3 years were obtained when a SCN-resistant soybean cultivar was rotated with corn and full-season soybeans were grown (Figure 2).

The drop in yields of Essex soybean between the first 4 years and last 3 years (Table 2) was influenced by tillage systems. The loss was smaller for no-tillage (8%) than conventional (19%) or strip-tillage (22%). However, the SCN populations were higher with no-tillage than with conventional tillage. This rate of yield loss with time could be due to the SCN populations building up very rapidly in the early stages of the tests under the conventional tillage, with these yields dropping during the second and third years.

The number of SCN counts 60 days after planting with conventional tillage declined with time (Table 3). However, yields of Essex soybeans continue to be lowest with conventional tillage, indicating that other factors may be reducing the SCN populations at a lower levels during the early years of the tests. The Essex yields are continuing to drop with low SCN populations.

Table 1. Influence of crop rotation on average soybean yields for Essex and Forrest with strip tillage.

Crop rotation	Soybean yield under strip tillage: Essex 4-yr avg 1981-84	Essex 3-yr avg 1985-87	Forrest 3-yr avg 1985-87
	kg ha^{-1}		
Continuous soybeans	2,034	1,720	2,410
Soybeans-corn	2,625	2,160	2,810
C-W-S*	2,445	1.680	2,450

*Corn-wheat for grain-soybeans.

Table 2. Influence of conservation tillage systems on average sovbean yields for Essex and Forrest.

Crop rotation	Soybean yields as affected by tillage: Essex 4-yr avg 1981-84	Essex 3-yr avg 1985-87	Forrest 3-yr avg 1985-87
	kg ha^{-1}		
Conventional	2,090	1,700	
Strip tillage	2,370	1,850	2,550
No tillage	2,400	2,200	

Table 3. Soybean cyst nematode counts found in 1985 through 1987 at Crossville, AL, with different tillage and crop rotation svstems.

Tillage systems	Soybean cyst nematode count/100 cc soil Sampled in July (60 days after planting): 1984 Essex	1985 Essex	1985 Forrest	1986 Essex	1986 Forrest	1987 Essex	1987 Forrest
			Corn-Soybean				
Conventional	712	260		161		134	19
Strip tillage	632	612	36	538	48	362	12
No-tillage	216	149		399		171	13
			Continuous Soybeans				
Conventional	586	303		126		91	21
Strip tillage	779	627	133	238	23	510	52
No-tillage	797	426		310		264	128

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Influence of Tillage and Lime on Nutrition of Soybeans Doublecropped with Wheat

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Introduction

No-till is a viable option for doublecropping soybeans after wheat. However, the value of occasional tillage for the incorporation of fertilizer and lime remains unclear. The objectives of this study were to compare the nutritional status and yield of soybean in a no-till system, where all fertilizer and lime were surface applied, with those of soybeans grown following three alternative tillage techniques. The present paper discusses the relationship between selected soil chemical properties, soybean leaflet nutrient concentrations, and soybean yield.

Materials and Methods

Four tillage systems were evaluated on an Olivier silt loam (Aquic Fragiudalf, fine-silty, mixed, thermic) on the same plots in Baton Rouge, LA from 1980 through 1987. The tillage systems studied were: no-till, disk only, moldboard plow plus disk, and subsoil plus disk (Table 1). Fertilizer was broadcast at 20-60-60 (N-P_2O_5-K_2O) lb/acre prior to seedbed smoothing and before soybean planting each year and again at the same rate prior to disking or no-till planting of wheat. Wheat was topdressed with 80 to 100 Ib N/acre each February. In June 1984, tillage plots were split with and without an application of 2 tons of dolomitic limestone/acre. No treatment was cultivated in any year. Thus, the no-till treatment received no pre- or post-plant tillage and all fertilizer and lime were surface applied by broadcasting.

Tillage was performed or glyphosate was applied at 1 Ib a.i./acre (on no-till plots) in late May after combining wheat and spreading straw, and Centennial soybean seed treated with Vitavax-MR® was planted at 50 Ib/acre in early June of each year. Weeds were controlled with a preemergence application of 3 lb a.i. alachlor/acre plus 6 oz a.i. metribuzin/acre. In 1986 and 1987, 7 oz metribuzin + chlorimuron ethyl (10 oz Canopy) per acre plus alachlor were applied. If needed, hand weeding or post-directed, over-the-top, and spot-treatment herbicide applications were used to achieve excellent weed control.

Soil samples were obtained each year in late February or early March and analyzed by the Louisiana Soil Testing Laboratory (Brupbacher et al., 1968). Elemental composition of the most recently expanded central trifoliolate leaflets (excluding petiol) at the R1 growth stage was determined during 1986. DRIS (diagnosis and recommendation integrated system) indices were determined for N, P, K, Ca, and Mg using the norms published by Hallmark (1987). DRIS indices identify nutritional imbalances by comparing element ratios to their ratios in high-yielding populations (Sumner, 1979).

Results

Soybean Yield

From 1980 through 1983, tillage system caused no significant differences in soybean yield (data not presented). Similarly, during 1984 and 1985, neither tillage system nor lime application altered soybean yield and all treatments averaged between 35 and 41 bu/acre (Table 2). During 1986 and 1987, however, lime significantly increased soybean yield. This increase in yield was accompanied by a later date of soybean leaf drop in limed plots.

In 1986, a significant interaction was obtained between tillage system and lime application; lime increased yields of no-till and moldboard treatments, but did not increase yields

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Table 1. Management practices of tillage systems evaluated for wheat-soybean doublecropping, 1980-1987. Olivier silt loam, Baton Rouge, LA.

Tillage system	Management for soybeans	Management for wheat
No-till	Spray, fertilize, plant*	Spray, fertilize, drill
Disk only	Disk, fertilize, disk, plant	Disk, fertilize, do-all, drill
Moldboard	Plow, fertilize, disk, plant	Disk, fertilize, do-all, drill
Subsoil and disk	In-row subsoil, disk', fertilize, disk, plant*	Disk, fertilize, do-all, drill

*30-inch row spacing

of disk only or subsoil plus disk treatments. Although lime increased seeds per plant and weight per seed of all treatments, limed plots of the disked and subsoil plus disk treatments had fewer plants per foot of row, and plants were shorter throughout the growing season. Such symptoms were not observed in any tillage-lime treatment in 1987, and lime significantly increased average soybean yield over all tillage treatments (Table 2). Yield increases in 1987 associated with lime resulted from an increase in stand density of no-till soybeans while increases, in both seed weight and number, were responsible for higher yields in other tillage systems.

Soil Chemical Analysis

As expected, application of lime after wheat harvest in 1984 increased soil pH and Ca levels of samples obtained in March 1986. Tillage influenced the distribution of P, pH, and Ca with depth in the soil (Table 3). In the disked and subsoil plus disk treatments, lime increased soil pH from 5.2 to 6.4 and increased Ca levels to above 1,000 ppm throughout the 0 to 3-inch soil depth. In contrast, in the no-till treatment, lime increased pH in the top inch from 4.8 to 6.2 and raised Ca above 1,000 ppm; but pH remained less than 5.8 and Ca less than 1,000 ppm at depths below the top inch. In the moldboard treatment, pH values of 6.0 and Ca values around 970 were uniform throughout the 0 to 6-inch soil depth. Phosphorus concentrations were most stratified in the no-till plots and most uniform in the moldboard treatment.

Soybean Leaflet Analysis

Leaflet analyses (Table 4) did not reveal any nutrient deficiencies that could explain the stunting of disk only and subsoil plus disk soybean plants in 1986. DRIS indices indicated

Table 2. Yield of Centennial soybean doublecropped after wheat as influenced by tillage system and lime application, Baton Rouge, LA.

Year	**Lime**	**No-till**	**Disk onlv**	**Moldboard and disk**	**Subsoil and disk**	**LSD* *(0.05)***
				bu/acre --------------		
1984	Lime	38	40	40	36	ns, ns
	No lime		36	35	35	ns, ns
1985	Lime	37	39	38	35	ns, ns
	No lime	41	39	39	39	ns, ns
1986	Lime	36	31	35	28	ns, 4
	No lime	31	31	24	28	8, 9
1987	Lime	43	42	43	44	ns, 2
	No lime	39	41	40	42	4. 5

*LSD values to separate specific means are listed in following order: tillage system means, lime treatment means, lime treatment within tillage, lime treatment between tillage systems. ns = not significantly different.

Table 3. Soil pH, Ca, and P values from soil tests conducted during March of 1986 as influenced by tillage every spring and a lime application made during May 1984, Baton Rouge, LA.

Depth (inches)	**No-till**		**Disk only**		**Moldboard and disk**		**Subsoil and disk**	
	Lime	**No lime**	**Lime**	**No lime**	**Lime**	**No lime**	**Lime**	**No lime**
				pH				
0-1	6.2	4.8	6.4	5.2	5.9	5.2	6.5	5.2
1-3	5.7	5.1	6.4	5.2	6.0	5.3	6.4	5.2
3-6	5.5	5.6	6.0	5.5	6.0	5.2	6.1	5.4
6-9	5.5	5.3	5.4	5.4	5.5	5.2	5.5	5.3
				Ca ppm)				
0-1	1,194	680	1,110	715	978	735	1.040	709
1-3	837	605	1,090	720	950	761	1,024	701
3-6	833	775	902	788	970	752	922	802
6-9	930	836	883	853	901	864	930	804
				P (ppm)				
0-1	162	163	110	107	69	79	78	74
1-3	82	71	95	103	71	69	77	73
3-6	20	23	31	30	41	42	34	35
6-9	10	15	12	14	21	21	13	15

N and Ca were the most limiting nutrients for all tillage systems in 1986 (Table 5). Phosphorus was not limiting in any tillage system, but this element was significantly higher in the no-till treatment than in other tillage systems (Table 4).

Discussion

The positive response of soybeans to lime resulted even though the seed was treated with molybdenum at planting each year. This response to lime is in accordance with the soil test interpretations given by Peevy (1972) that Ca levels below 1,000 ppm are considered low for Mississippi terrace soils with CEC of approximately 8 meq/100g. In contrast, soil test values for all other macro-nutrients were in the medium to high ranges given by Peevy (1972). Why the response of soybeans to lime was delayed until the third growing season after application, regardless of tillage, remains unclear.

The positive response of soybeans to lime and the interpretation of soil test results by Peevy are both consistent with the DRIS diagnosis that Ca and N were the most limiting elements. The Ca imbalance may act directly on the physiology of the soybean plant, or it may affect the associated rhizobia. The earlier leaf senescence in unlimed plots is consistent with the interpretation that the response of soybeans to lime is mediated through an increased plant-N status.

The stunting of soybean plants observed in 1986 on disked only and subsoil plus disk treatments, which was due to shortened internode lengths, is consistent with the activity of the herbicide chlorimuron ethyl. This herbicide is known to have greater activity in higher pH environments. Conditions were quite wet after planting in 1986. The combination of wet weather and soil pH above 6.4 in the top 3 inches may have been critical in the expression of herbicide injury. Depth of incorporation of lime may need to be considered when making herbicide recommendations, and detailed soil pH determinations may be warranted under some circumstances. Further research is needed.

A thorough economic analysis is needed before a recommendation among the various tillage systems can be made. Weed control was more difficult in the no-till treatments. However, planting of the no-till treatments frequently was delayed until weather and equipment availability allowed tillage operations on other treatments to be completed. Adopting a common planting date in this study allowed a fairer comparison of soybean growth as influenced by the physical environments created by tillage, but eliminated the timeliness advantage of no-till planting.

Table 4. Element concentrations of soybean leaflets at the R1 growth stage as influenced by tillage and lime application, Baton Rouge. LA. 1986.

Element	No-till		Disk only		Moldboard and disk		Subsoil and disk	
	Lime	No lime	Lime	No lime	Lime	No lime	Lime	No lime
	(%)							
N	5.4	5.3	5.2	4.9	5.2	4.9	5.3	5.0
P	0.63	0.62	0.59	0.60	0.60	0.56	0.58	0.59
K	2.43	2.28	2.37	2.33	2.26	2.28	2.36	2.34
Ca	0.80	0.70	0.86	0.74	0.80	0.76	0.86	0.84
Mg	0.49	0.46	0.48	0.47	0.48	0.48	0.50	0.50
S	0.37	0.35	0.38	0.35	0.35	0.33	0.36	0.36
	(ppm)							
Fe	94	88	106	88	98	83	116	92
Mn	101	272	91	158	99	198	88	149
Zn	65	67	66	68	64	67	62	69
Cu	14	14	13	14	14	14	13	14
B	42	48	41	50	42	52	40	50

Table 5. DRIS indices of soybean leaflets sampled at the R1 growth stage as influenced by tillage and lime application, Baton Rouge, LA, 1986.

DRIS index	No-till		Disk only		Moldboard and disk		Subsoil and disk	
	Lime	No lime	Lime	No lime	Lime	No lime	Lime	No lime
N	—0.6	—0.4	—0.8	—0.9	—0.7	—1.0	—0.6	—1.0
P	3.3	3.4	2.6	3.1	3.2	2.7	2.8	3.0
K	0.2	0.1	0.1	0.2	—0.1	0.1	0.1	0.1
Ca	—2.3	—2.9	—1.7	—2.4	—2.2	—2.2	—1.9	—2.0
Mg	1.1	1.1	1.1	1.2	1.1	1.4	1.3	1.3
Dry matter	—1.7	-1.3	—1.5	—1.3	-1.5	—1.2	—1.6	-1.5

Conclusion

Incorporation of fertilizer and lime with tillage did not increase the yield nor improve the nutritional status of soybeans compared with continuous no-till planting. After 8 years of continuous no-till, soybean yields were equal and leaflet P concentrations were higher in no-till than in other treatments. Ca and N were the most limiting elements with all tillage systems, but response to lime was as great for no-till as for any tillage system. Neither deep tillage (moldboard or subsoiling) nor shallow mixing were needed on this soil in order to maintain soybean productivity when weeds were controlled by other means.

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Soybean-Wheat Doublecropping Systems for the Loessial Terrace Soils of Northeast Louisiana

R. L. Hutchinson, T. R. Sharpe, and T. P. Talbot[1]

Soybean-wheat doublecropping offers the farmer a means of producing two crops per year on the same unit of land. In many instances, net yearly income can be increased significantly and seasonal cash flow can be improved. However, yields of doublecrop soybeans on the droughty silt loam soils of the Macon Ridge in northeast Louisiana are generally too low to offset production costs where conventional dryland production practices are used.

Inadequate rainfall for soybean stand establishment is often a problem when wheat residue is burned and the soil is tilled to prepare a seedbed for soybeans. A delay in soybean planting due to inadequate moisture for stand establishment will generally result in reduced soybean yields since yields usually decline drastically when planting is delayed past mid-June. In addition, inadequate rainfall during the vegetative and reproductive growth stages of doublecrop soybeans often limits vegetative growth and yields on these soils. On the other hand, if the wheat straw is not burned and tillage is eliminated, soil moisture is often adequate for soybean planting immediately following wheat harvest.

A 5-year study was conducted at the Macon Ridge Branch of the Northeast Research Station, Winnsboro, from 1982 through 1986, to determine the effects of burning wheat residue, spring tillage, and irrigation on productivity of doublecrop soybeans. All treatments were maintained in the same plots each year so that long-term effects of these practices on soybean productivity and soil properties could be evaluated. A split-plot experimental design with a factorial arrangement of wheat residue-tillage combinations with four replications was used.Main plots were irrigated versus non-irrigated regimes and subplots were burning-tillage combinations. Plots were 60 feet in length and 24 feet wide.

Coker 762 wheat was drill seeded in a prepared seedbed each fall after all plots had been double-disked and smoothed with a row conditioner. Wheat was harvested from mid-May through early June with a combine equipped with a straw chopper-spreader, which spread the straw uniformly across each plot. Cutting height for the wheat was approximately 10 inches. Wheat yields from 1982 to 1985 ranged from 34 to 50 bushels per acre with an average of 45 bushels per acre. No wheat was harvested in 1986 because a hail storm completely destroyed the wheat after heading.

After wheat harvest each year, the appropriate plots were burned and tilled. Tillage consisted of double-disking and smoothing to prepare a seedbed for planting soybeans. The entire test area was then planted with a no-till planter equipped with ripple coulters and double-disk seed furrow openers on a 20-inch spacing. A seeding rate of five seeds per linear foot of row was used each year and dates of planting ranged from late-May through mid-June. Weeds were controlled effectively in all plots with a combination of burndown, preemergence, and postemergence over-the-top herbicides.

Water was applied to irrigated treatments on an as-needed basis with a lateral-move overhead sprinkler system. Soil moisture status was determined by tensiometer and neutron probe readings. Total amounts of water applied to the irrigated soybeans were 7.0 inches in 1982, 11.0 inches in 1983, 7.5 inches in 1984, 5.8 inches in 1985, and 11.3 inches in 1986. Most of this water was applied from mid-July through late-September. However, in 1984, 1985, and 1986, irrigation (1.5 to 2.3 inches) was needed during the early-June through early July period.

Yields

Yields of tilled and non-tilled soybeans were similar each year of the study (Table 1). However, in 1986, the non-tilled plots slightly, but significantly, outyielded the tilled plots by about 2 bushels per acre. The 5-year average yields for tilled and non-tilled plots were 30.4 and 30.8 bushels per acre, respectively. No significant interactions were noted involving tillage and burning or tillage and irrigation.

Irrigation increased yields significantly 4 out of 5 years (Table 2). In 1985, a numerical increase of 4 bushels per acre

Table 1. Effect of spring tillage on yield of doublecrop Centennial sovbeans grown on a Gigger silt loam soil: 1982-1986.

Tillage treatment	1982	1983	1984	1985	1986	5-year average
	Yields, bushels per acre'					
Tilled	34.1	28.7	33.4	24.9	31.1	30.4
No Till	34.3	30.2	33.1	26.3	32.9	30.8
Significance	N.S.	N.S.	N.S.	N.S.	*	N.S.

'Yields are averaged across burned vs. non-burned and irrigated vs. non-irrigated conditions.

'5tatistically significant at the 0.05 level of probability.

N.S. Not statistically significant at the 0.05 level of probability.

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was observed with irrigation. However, this yield increase was not statistically significant. Several weeks of rainy weather delayed harvest and caused severe yield and quality losses in 1985. It is likely that these conditions cancelled much of the actual yield increase obtained with irrigation. The largest yield increase with irrigation, 20.3 bushels per acre, was observed in the extremely dry year of 1983. Yield increases of about 10 to 12 bushels per acre were noted in 1982, 1984, and 1986.

Burning significantly reduced yields each year except in 1983. Yield reductions from burning averaged across irrigation and tillage regimes ranged from less than 1 bushel per acre in 1983 to 7.7 bushels per acre in 1985.

In addition, significant irrigation x burning interactions were noted in 1982 and 1985. Under irrigated conditions in 1982, yields of burned and non-burned plots were similar, but under dryland conditions burning reduced yields by more than 7 bushels per acre or about 22 percent. Similar results were obtained in 1985 when burning reduced yields by 4.5 bushels per acre under irrigated conditions compared with 10.7 bushels per acre under non-irrigated conditions.

The consistent yield advantages observed when the wheat residue was not burned were likely a result of the favorable effect of crop residue on soil water conservation. Several studies have demonstrated that the presence of crop residue on or near the soil surface aids in decreasing soil temperatures and reducing the rate of evaporative water loss from the soil surface. Neutron probe and tensiometer data from these studies (data not shown) have consistently shown more favorable soil moisture status in non-burned plots compared with burned plots.

Table 2. Effects of burning wheat residue and irrigation on yield of doublecrop Centennial soyeans averaged over tilled and non-tilled conditions: 1982-1986.

Burn Regime	Irrigation regime: Irrigated	Non-irrigated	Mean
	bushels/acre		
1982			
Burn	39.8	25.5	32.6 a
No Burn	39.1	32.6	35.8 b
Mean	39.4 a	29.1 b	
LSD (0.05) Burn x Irrigation interaction = 3.4			
1983			
Bum	39.8	19.8	29.8 a
No Bum	39.4	19.0	29.2 a
Mean	39.6 a	19.3 b	
LSD (0.05) Bum x Irrigation interaction = N.S.			
1984			
Burn	36.5	25.5	31.0 a
No Bum	39.6	31.5	35.5 b
Mean	38.1 a	28.4 b	
LSD (0.05) Bum x Irrigation interaction = N.S.			
1985			
Bum	24.0	16.9	20.4 a
No Bum	28.5	27 6	28.1 b
Mean	26.2 a	22.2 a	
LSD (0.05) Bum x Irrigation interaction = 2.1			
1986			
Bum	37.4	24.I	30.8 a
No Bum	38.6	28.1	33.4 b
Mean	38.0 a	26.1 h	
LSD (0.05) Bum x Irrigation interaction = N.S.			
1982-1986 Average			
Bum	35.5	22.4	28.9 a
No Bum	37.0	27.8	32.4 b
Mean	36.2 a	25.1 b	
LSD (0.05) Bum x Irrigation interaction = 1.0			

'Values within columns or rows and within the same year followed by a common letter are not significantly different at the 0.05 level of probability according to the F test.

Organic Matter

Small increases in soil organic matter content can contribute greatly to the water infiltration rate and moisture holding capacity of soil. Analyses of soil samples taken from this study in 1983, 1985, and 1986 indicated that soil organic matter content has declined gradually with time (Table 3). However, data from 1985 and 1986 indicate that organic matter content of non-burned plots was significantly higher than in burned plots. Irrigation and tillage had no significant effect on soil organic matter content.

Plant Growth

The number of days required from planting to canopy closure is an indirect measure of early vegetative growth. Early canopy closure is associated with rapid vegetative growth, an important consideration from a weed control standpoint. Once the canopy is completely closed, the crop

Table 3. Effects of irrigation, burning wheat residue and spring tillage on soil organic matter content of a Gigger silt loam soil.

Treatment	Percent organic matter *0-6* inch depth: 1983	1985	1986
Irrigated	1.30	1.17	1.01
Non-Irrigated	1.17	1.11	0.99
Significance	N.S.	N.S.	N.S.
Bum	1.22	1.07	0.96
No Burn	1.25	1.21	1.04
Significance	N.S.	*	*
Till	1.27	1.14	1.02
No Till	1.20	1.14	0.99
Significance	N.S.	N.S.	N.S.
Irrigation x Burn	N.S.	N.S.	N.S.
Irrigation x Till	N.S.	N.S.	N.S.
Bum x Till	N.S.	N.S.	N.S.
Irrigation x Burn x Till	N.S.	N.S.	N.S.

N.S. = Not significant at the 0.05 level of probability
*Significant at the 0.05 level of probability.

Table 4. Effects of irrigation, burning and tillage on number of days from planting to canopy closure of doublecrop Centennial soybeans, 1982-1986.

Treatment	Days from planting to canopy closure				
	1982	1983	1984	1985	1986
Irr-Burn-Till	48	64	52	59	47
Irr-Burn-No Till	49	64	55	69	41
Irr-No Burn-Till	50	66	54	51	38
Irr-No Burn-No Till	51	66	53	53	38
Non Irr-Burn-Till	47	—	53	—	—
Non Irr-Bum-No Till	48	—	56	—	—
Non Irr-No Burn-Till	51	—	55	59	48
Non Irr-No Burn-No Till	51	—	55	55	45

should be virtually safe from late emerging weeds. In 1982, the first year of the study, rainfall was near optimum during the vegetative growth period and irrigation had no effect on the number of days from planting to canopy closure (Table 4). However, burned plots reached full canopy closure 3 to 4 days earlier than non-burned plots.

In 1983, a very dry year, none of the non-irrigated treatments reached full canopy closure due to poor growing conditions from late June through blooming. Under irrigated conditions the burned treatments reached canopy closure 2 days earlier than the non-burned treatments. In 1984, irrigation and burning had little effect on canopy closure.

In the last 2 years of the study (1985 and 1986), both irrigated and the non-burned conditions resulted in earlier canopy closure. Under non-irrigated conditions the burned treatments never reached full canopy closure due to inadequate rainfall in late June and early July.

These data suggest that the effects of burning versus not burning of wheat residue are cumulative and that several years may be required before the benefits of leaving the wheat residue unburned are fully realized. Tillage generally had little effect on canopy closure. However, under irrigated conditions slightly earlier canopy closure was noted in tilled plots than in non-tilled plots. Under non-irrigated conditions, tillage tended to slightly delay canopy closure in the later years of the study. This may have been a result of soil moisture losses associated with the tillage operations.

Summary

Irrigation was very useful in increasing soybean yields and minimizing yield variations caused by inadequate rainfall. Yield response to irrigation varied considerably from one year to the next and was often influenced by burning regimes. Irrigation increased soybean yields by an average of 13.1 and 9.2 bushels per acre under burned and non-burned conditions, respectively.

Burning of wheat residue generally reduced yields more under non-irrigated conditions than under irrigated conditions. Under non-irrigated conditions, the average yield reduction from burning was 5.4 bushels per acre compared with 1.5 bushels under irrigated conditions.

Tillage generally had no significant effect on yields under irrigated or non-irrigated conditions.

Irrigation generally resulted in earlier and more complete canopy closure. In the early years of the study, soybeans in burned plots tended to reach canopy closure earlier than those in non-burned plots. However, in later years earlier canopy closure was noted in non-burned plots. This is an extremely important consideration since earlier canopy closure may eliminate the need for one or more expensive herbicide applications.

At the conclusion of the study, soil organic matter content was found to be 8-12 percent higher in non-burned plots than in the burned plots. Soil moisture status was usually more favorable in non-burned plots than in burned plots.

These data indicate that alternate systems for producing doublecrop soybeans, including no-till planting in wheat residue, may improve yields and profit potential for soybean growers in northeast Louisiana. Growers should, however, carefully consider production costs for each system since equipment, labor, and herbicide costs could vary considerably.

Net Returns for Soybean Reduced Tillage Systems on Three Land Resource Areas

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Introduction

Soybeans are grown on approximately 1.25 million acres in Mississippi where erosion potential exists when current tillage practices are used. Most of this erodible acreage is in central and northern Mississippi. New tillage implements such as the Paraplow® and Ro-till® have recently been introduced in Mississippi as reduced tillage implements. The Paraplow looks similar to a moldboard plow but differs in that the plow-shank only lifts the soil as the shank passes through the soil profile, causing very little surface disturbance. The Ro-till is equipped with trash whippers (disks that remove surface residue from the row), in-row subsoil shanks, two adjustable fluted coulters per shank, and one rolling basket per shank. The coulters are adjustable and move soil over the subsoil slit as the shanks move through the soil profile. The rolling baskets trail the coulters and firm the seedbed. This implement is used as a one-pass seedbed preparation system.

Reducing the amount of tillage in crop production systems is receiving national attention. Literature indicates that soybean response to tillage systems varies widely. In the Midwest (4, 10, and 11), soybean yields are often not affected by tillage systems ranging from complete residue incorporation to no-till. Others reported (9 and 2) that reduced tillage systems produced soybean stands, weed control, and yields comparable to the conventional tillage system. Some research reports (13 and 3) indicate no-till systems produced higher yields than conventional tillage system. Most soybean research in Mississippi, however, has indicated a significant yield increase attributed to tillage (1, 5, 8, and 14).

Economics of reduced tillage systems play a role in the adoption of these systems by producers. No information is available in the literature on the economic comparisons of Paraplow and Ro-till reduced tillage systems. Most comparisons have been made with conventional and no-till systems. On a Blackland Prairie soil (5), conventional tillage and no-till monocrop soybean systems produced net returns of \$53 and \$24/acre, respectively. On a clay soil in the Mississippi Delta, conventional and stale seedbed systems for soybeans under non-irrigated plantings showed no significant difference in net returns (6). These comparisons have not included new reduced tillage implements such as the Ro-till and Paraplow.

This study was an economic analysis of 3 years (1985-87) of field data evaluating reduced tillage implements for soybean production on three land resource areas. The objective was to estimate short-term net returns to land and management with soybean conservation tillage systems on three land resource areas.

Materials and Methods

Field plots were established for the duration of the project (1985-87) on a Catalpa silty clay at the Northeast Branch Experiment Station, Verona, MS; on a Providence silt loam at the Pontotoc Branch Experiment Station, Pontotoc, MS; and on a Loring silt loam at the Brown Loam Branch Experiment Station, Raymond, MS. The studies at each location were conducted as a randomized complete block with four replications.

Tillage dates for conventional tillage, chisel (6-8 inches deep) + disk, and Paraplow tillage treatment depths of 4-6, 6-8, and 12-14 inches at all locations ranged from April 4 to April 30 for all 3 years. Ro-till tillage treatment depths of 7-8, 11-12, and 14-15 inches were done at the time of planting at all three locations. Soybeans were planted as a separate operation following the use of the Ro-till. Prior to tillage in the spring of each year, dry fertilizer (0-17-34) at 45 and 90 lb/acre of P_20_5 and K_20, respectively, was applied to all plots except the Ro-till fertilizer placement treatment plots. The fertilizer in the Ro-till fertilizer placement plots was applied as a liquid suspension of K_2HPO_4 and KCl, equivalent to the dry fertilizer rates. The liquid fertilizer suspension was injected to the depths (7-8, 11-12, and 14-15 inches) of Ro-till tillage treatments. Roundup@ + X-77® surfactant at 1.0 lb ai/acre + 0.5 percent viv was applied as a burndown herbicide application to no-till, all Paraplow, and Ro-till treatments 7-14 days prior to planting. The conventional tillage and Paraplow plots were smoothed with a do-all (an implement equipped with a rolling cutter bar and section harrow) prior to planting soybeans. Soybean planting dates for 1985-87 ranged from May 31 to June 5 at both Northeast and Pontotoc locations and from June 5 to June 26 at the Brown Loam Station. Centennial soybeans were planted at all locations with

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a John Deere Max-Emerge® no-till planter equipped with ripple coulters. Seeding rate was 7 seeds per linear foot of 30-inch row.

Weed control during the soybean growing season was with postmergence herbicides at Pontotoc and Raymond, and preemergence herbicides plus a post-directed spray at Verona. (Table 1). None of the plots at any locations were cultivated during the soybean growing season. All materials used and operations performed on each treatment were recorded for each location. The two center rows of each plot were harvested with a small plot combine for seed yield. The seed was weighed and seed moisture was determined with a Dickey John GAC II® grain analysis computer and recorded. Yield data were calculated and adjusted to 13 percent moisture and averaged over 3 years of the study.

Economic Analysis

The economic analysis was based on short-term returns to land and management. The total expenses did not include a charge for land, management, and general farm overhead. A dollar value was not included in the economic comparisons for the long-term effect of these tillage systems on soil erosion and soybean yield.

Soybean budgets were developed for each tillage system at the three locations using an economic computer budget generator (12). Net returns were based on 3-year average yield obtained from field studies (1985-87) at all locations (Table 4). Rates of application for all variable inputs were those described in the materials and methods section. The soybean price used in the budgets was $5.32/bu, the statewide average price received by farmers in Mississippi during 1985-86 (7). Costs of variable inputs and machinery were based on 1986 prices paid by Mississippi farmers. In constructing the budgets, performance rates on all field operations were based on 8-row equipment with associated power units. Primary tillage implement widths were 16-foot wide chisel plow, 10-foot wide Ro-till, and 5-foot wide Paraplow. The hourly wage rate was $4.50/hour. Interest on operating capital was computed at 10 percent annual percentage rate.

Results and Discussion

Fixed Costs

Fixed costs for these systems ranged from about $19 to $25/acre (Table 2). Due to fewer implements needed, the no-till production system fixed costs at all locations were about $4 to $7/acre less than chisel + disk, Paraplow, and Ro-till. Fixed costs for Paraplow and Ro-till implements were about the same as the chisel + disk system.

Direct Costs

Direct costs (Table 3) ranged from $97 to $140/acre and were higher for both Pontotoc and Raymond than Verona. The higher costs at both Pontotoc and Raymond were associated with the postemergence herbicide system for weed

Table 1. Herbicides and time of application for weed control in reduced tillage system studies at three locations, 1985-87.

Time of Application*	Location: Verona Herbicide	lb ai/a	Pnntotoc-Raymond Herbicide	lb ai/a
Burndown	Roundup +	1.0 +	Roundup +	1.0 +
	x-77	0.5%	x-77	0.5%
PRE-E	Dual +	2.00 +	—	
	Scepter	0.125	—	
POT		—	Poast +	0.20 +
			Blazer +	0.38 +
			Crop Oil	I qt
P-Dir	Sencor +	0.25 +	—	—
	2.4-DB	0.20	—	—

*Time of application code: Burndown was applied 7 to 14 days before planting; PRE-E = preemergence application made following soybean planting; POT = postemergence over-top application as tank mixtures, twice during soybean growing season; and P-Dir = post-directed application to soybeans 8 to 12 inches tall as a broadcast application.

Table 2. Estimated 1987 fixed costs for reduced tillage systems on three soil resource areas.

Reduced tillage treatment	Tillage depth (in)	Location: Verona	Pontotoc	Raymond
		------------	$/acre	-------------
Chisel + Disk	6-8	24.67	24.37	24.37
No-till	—	19.00	19.32	19.32
Paraplow	4-6	24.50	24.38	24.38
Paraplow	6-8	25.32	25 20	25.20
Paraplow	12-14	26.20	26 09	26.09
Ro-till	7-8	23.98	23.59	23.59
Ro-till	11-12	24.58	24.12	24. I2
Ro-till	14-15	25.37	24.72	25.72
Ro-till	7-8*	23.63	23.06	23.06
Ro-till	11-12*	24.35	23.77	23.77
Ro-till	14-15*	25.30	24.49	24.49

*Depth of fertilizer placement and tillage

Table 3. Estimated 1987 direct costs for reduced tillage systems on three soil resource areas.

Reduced tillage treatment	Tillage depth (in)	Location: Verona	Pontotoc	Ravmond
		———	$/acre	----------------
Chisel + Disk	6-8	96.99	116.37	116.37
No-till	—	110.22	131.17	130.05
Paraplow	4-6	117.99	137.58	137.58
Paraplow	6-8	118.97	138.70	138.22
Paraplow	12-14	120.11	140.03	139.07
Ro-till	7-8	115.55	135.94	136.10
Ro-till	11-12	116.39	137.75	137.11
Ro-till	14-15	117.63	138.13	136.85
Ro-till	7-8*	113.95	134.60	134.44
Ro-till	11-12*	115.20	135.19	134.87
Ro-till	14-15*	116.23	135.79	135.15

*Depth of fertilizer placement and tillage.

control. The preemergence herbicide followed by a post-directed spray application at Verona was less costly than the all-postemergence system at Pontotoc and Raymond. Due to the burndown herbicide application, no-till, Ro-till, and Paraplow direct costs were higher than those for chisel + disk at all locations. No-till, however, had a lower direct cost than Paraplow and Ro-till. These higher direct costs were related to additional labor and fuel involved in the tillage operation for the Paraplow and Ro-till. Direct costs for Paraplow were slightly higher than Ro-till due to the use of a do-all prior to planting

Table 4. Estimated total expenses, gross income and net returns for reduced tillage systems on three soil resource areas, 1987.

Reduced tillage treatment		Depth (in)	3-yr av yield Bu/a	Gross income $/a	Total expenses[1] $/a	Net returns $/a
			Verona			
1.	Chisel + Disk	6-8	38	202.03	121.66	80.37
2.	No-till	–	33	175.45	129.22	46.23
3.	Paraplow	4-6	36	191.40	142.49	48.91
4.	Paraplow	6-8	37	196.72	144.29	52.43
5.	Paraplow	12-14	38	202.03	146.31	55.72
6.	Ro-till	7-8	30	159.50	139.53	19.97
7.	Ro-till	11-12	31	164.82	140.97	23.85
8.	Ro-till	14-15	33	175.45	143.00	32.45
9.	Ro-till	7-8*	30	159.50	137.58	21.92
10.	Ro-till	11-12*	33	175.45	139.55	35.90
11.	Ro-till	14-15*	33	175.45	141.53	33.92
		avg	34	179.80	138.74	41.06
			Pontotoc			
1.	Chisel + Disk	6-8	33	175.45	140.74	34.71
2.	No-till	–	33	175.45	150.49	24.96
3.	Paraplow	4-6	31	164.82	161.96	2.86
4.	Paraplow	6-8	33	175.45	163.90	11.55
5.	Paraplow	12-14	35	186.08	166.12	19.96
6.	Ro-till	7-8	32	170.13	159.46	10.67
7.	Ro-till	11-12	39	207.35	161.87	45.48
8.	Ro-till	14-15	37	196.72	162.85	33.87
9.	Ro-till	7-8*	34	180.77	157.66	23.11
10.	Ro-till	11-12*	33	175.45	158.96	16.49
11.	Ro-till	14-15*	32	170.13	160.28	9.85
		avg	34	179.80	158.57	21.23
			Raymond			
1.	Chisel + Disk	6-8	33	175.45	140.74	34.71
2.	No-till	–	26	138.23	149.37	-11.14
3.	Paraplow	4-6	31	164.82	161.96	2.86
4.	Paraplow	6-8	30	159.50	163.92	-3.92
5.	Paraplow	12-14	29	154.18	165.16	-10.98
6.	Ro-till	7-8	33	175.45	159.62	15.83
7.	Ro-till	11-12	35	186.08	161.23	24.85
8.	Ro-till	14-15	29	154.18	161.57	-7.39
9.	Ro-till	7-8*	33	175.45	157.80	17.95
10.	Ro-till	11-12*	31	164.82	158.64	6.18
11.	Ro-till	14-15*	28	148.87	159.64	-10.77
		avg	31	163.37	158.12	5.28

[1]Total expenses did not include a charge for land, management, and general overhead

*Depth of fertilizer placement.

Net Returns

Three-year soybean yields, averaged over tillage systems (Table 4), were 34 bu/acre for both Pontotoc and Verona, and 31 bu/acre for Raymond. Gross returns, averaged over tillage systems, were $179.80/acre for both Pontotoc and Verona, and $163.37/acre for Raymond. Net returns, averaged over tillage systems, were $41.06, $21.23, and $5.28/acre for Verona, Pontotoc, and Raymond, respectively. The higher net return to land, management, and general farm overhead at Verona than Pontotoc was due to lower direct costs for weed control. Lower net returns at Raymond than Pontotoc were due to lower yield.

At Verona, the chisel + disk treatment had the lowest total expenses, produced the highest gross income, and had the highest net return of $80.37/acre. The Paraplow 12 to 14-inch depth produced the same gross income as chisel + disk, but had $25/acre more total expenses than chisel + disk, and resulted in net returns of $55.72/acre. The Ro-till 11 to 12-inch depth surface-incorporated fertilizer, produced 7 bu/acre less than Paraplow and chisel + disk, had total expenses of $140.97/acre, and showed a net return of $23.85/acre. The deepest depth of Ro-till (fertilizer surface-incorporated) and Paraplow produced about $12/acre and $7/acre more than the shallowest depths, respectively. Fertilizer placed to the depth of Ro-till tillage generally showed slightly higher net return than surface broadcast and incorporated with Ro-till.

At the Pontotoc Flatwoods soil resource area, total expenses ranged From $140.74/acre for chisel + disk to $166.12/acre for the Paraplow 12 to 14-inch depth. The Ro-till (fertilizer surface-incorporated) 11 to 12-inch depth produced the highest gross income of $207.35/acre. Both chisel + disk and no-till produced gross incomes of $175,45/acre. Net returns for no-till and chisel + disk were $24.96/acre and $34.71/acre, respectively. Net return for the Ro-till 11 to 12-inch depth surface-incorporated Fertilizer was $45.48/acre, or about $10/acre and $20/acre more than chisel + disk and no-till, respectively. Deeper tillage depths with the Paraplow showed highcr net returns. The 12 to 14-inch depth produced a return of $19.96/acre in comparison to $11.55/acre and $2.86/acre for 7 to 8 and 4 to 6-inch depths, respectively.

Fertilizer injected to the depth of Ro-till tillage generally showed lower net return than fertilizer surface-incorporated with the Ro-till. However, the Ro-till 7 to 8-inch injected fertilizer depth was the only treatment that showed higher net return than fertilizer applied surface broadcast and incorporated with the Ro-till.

At the Brown Loam Station, the Ro-till 11 to 12-inch depth produced the highest 3-year average yield of 35 bu/acre, but showed net returns of $24.85/acre, about $10/acre less return than chisel + disk net return of $34.71/acre. The no-till and both Paraplow tillage depths (6-8 and 12-14 in) produced negative returns of $11.14, $3.92, and $10.98/acre, respectively.

Fertilizer injected to depth of tillage with the Ro-till generaly produced lower net returns than surface applied and incorporated with Ro-till. However, the Ro-till 7 to 8-inch depth was the only Ro-till tillage depth which produced higher net return for injected fertilizer than surface-incorporated fertilizer.

Summary

Economic analyses were based on short-term returns to land and management. Total expenses did not include a charge for land, management, and general farmoverhead. No constraints were placed on farm size for the complement of reduced tillage systems used in this study.

Soybean reduced tillage systems that were evaluated indicated no-till had a lower fixed cost than all other reduced tillage systems at all locations. Fixed costs for Paraplow and Ro-till were about $l/acre more than chisel + disk. The chisel + disk system had lower direct and total expenses than no-till, Paraplow, and Ro-till at all locations. The direct costs of about $20/acre less at Verona than at both Pontotoc and Raymond was related to the different herbicides used for weed control. Pontotoc and Verona, averaged over reduced tillage systems, produced the same gross income — about $16/acre more than at Raymond. Net returns, however, were about $20/acre more at Verona than Pontotoc due to lower herbicide expenses. The Raymond location had the lowest yield average and net returns averaged about $5/acre.

Economic analysis indicated that the chisel + disk system produced the highest net return of all tillage treatments at both the Brown Loam and Northeast Stations. On the Flatwoods soil at the Pontotoc Station, the Ro-till 11 to 12-inch depth with surface-incorporated fertilizer produced the highest net returns of all treatments. Fertilizer placement depth effect on net returns interacted with location and depth. All Ro-till injected fertilizer treatments at Verona produced higher net return than surface applied fertilizer incorporated with the Ro-till. However, at both Pontotoc and Raymond, the Ro-till7 to 8-inch depth was the only treatment showing higher returns for injected fertilizer than surface-incorporated.

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Influence of Tillage Systems on Wheat Yields and the Need for In-row Subsoiling for Doublecropped Soybeans

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Introduction

Many of the sandy Coastal Plain soils are highly compactible, and contain root restricting tillage pans 8 to 12 inches below the soil surface. These relatively thin (1 to 2 inches thick) pans are created primarily by tillage implements and machinery traffic. If they are not fractured at planting, crop yields can be severely reduced, especially in dry years.

In areas where root restricting tillage pans are common, in-row subsoilers are used at planting. The subsoilers, which are generally attached to the planting unit, fracture the tillage pan directly under the row, and permit root growth into the subsoil area. In untilled soils, they also fracture and loosen a 6- to 12-inch strip of surface soil. Data reported by Whiteley and Dexter (1982) suggest the possibility that positive yield responses to in-row subsoilers are due as much from fracturing the surface soil as from fracturing the tillage pan.

Although these subsoilers are needed in soils with tillage pans, they create such problems as slow planting speeds, high horsepower requirements, and high initial investments. In addition, soils and or conditions in which in-row subsoilers are needed have not been well defined. These problems are some of the primary reasons for slow adoption of conservation tillage in sandy Coastal Plain soils.

For successful wheat and soybean doublecropping systems, soybeans have to be planted immediately after wheat harvest. Each one-day delay in planting soybeans after wheat harvest can reduce soybean yield an average of 0.3 bu/acre (Thurlow, 1986). To avoid delays caused by tillage, no-tillage production is frequently used. Data from a previous study (Touchton and Johnson, 1982) indicate that yield of no-tillage wheat can be reduced 8 bu/acre unless deep tillage (chisel or moldboard plowing) is used prior to planting soybeans or in-row subsoiling is used at soybean planting. Other studies have indicated that some form of deep tillage is needed prior to planting wheat (Hargrove and Hardcastle, 1984; Karlan and Gooden, 1987).

The interval between harvesting and planting is not as critical for soybean harvest and wheat planting as it is for wheat harvest and soybean planting. Thus, for soils where some tillage is needed, it would be more opportune to till prior to planting wheat instead of after wheat harvest. Since there is no fallow period between wheat harvest and planting of doublecropped soybeans, wheat root growth promoted by tillage may prevent soil recompaction and form macropores that would eliminate the need for in-row subsoiling for soybeans. The objectives of field studies reported here were to determine tillage effects on wheat yield, and if tillage prior to planting wheat would eliminate the need for in-row subsoiling at soybean planting.

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Materials and Methods

Field studies were conducted for 3 years on seven soils within three geographic regions of Alabama. The first five soils listed in Table 1 are in the Coastal Plains, the Sumpter soil is in the Black Belt, and the Decatur soil is in the Tennessee Valley. Except for the Lucedale soil, the Coastal Plain soils contained defined tillage pans 5 to 9 inches below the soil surface. On these soils, yield responses to in-row sub-

Table 1. Wheat grain yields (3-year average) as affected by tillage prior to planting wheat.

Tillage	Soil						
	Dothan	Malbis	Benndale	Lucedale	Bama	Sumter	Decatur
				bu/acre			
None	32	36	19	43	26	31	32
Disk	40	42	21	51	37	40	42
Chisel	45	43	35	52	45	40	45
Turn	52	48	36	50	45	39	48
LSD **(0.10)**	4	3	3	3	4	3	2

soiling at soybean planting are not uncommon. The Sumter and Decatur soils generally do not contain root-restricting tillage pans, and yield responses to in-row subsoiling on these soils are not common.

Treatments consisted of six tillage systems prior to planting wheat and two at soybean planting. Tillage treatments prior to planting wheat were (1) no-tillage, (2) disk only, (3) chisel-disk, (4) turn-disk, (5) chisel-level, and (6) turn-level. The leveling implements for treatments 5 and 6 consisted of a drag bar at three locations and a roterra at three locations. The disk-only treatment consisted of one pass with an offset disk. Depth of disking was 3 to 5 inches. Shank spacing on the chisel plows was 15 inches for each of the dual tool bars. The shanks on the front and back tool bars were offset so that actual distance between chisel points was 7½ inches. Actual depth of chiseling ranged between 6 and 9 inches. Turning depth with the moldboard plow for treatments 4 and 6 was 8 to 10 inches.

Soybeans were planted into wheat stubble with (except on the Sumter and Decatur soils) and without in-row subsoiling. Depth of subsoiling was 10 to 12 inches. Each year, wheat was planted in November and soybeans were planted in late May or early June. Wheat was drilled in 6⅔-inch row widths, and soybeans were planted in 36-inch row widths the first year and 24- to 30-inch row widths in subsequent years when the in-row subsoiler was used. When the subsoiler was not used, row widths were 18 to 24 inches depending on location. Seeding rates were 60 and 90 lb/acre for soybean and wheat, respectively.

Results and Discussion

Soil leveling methods (disking, dragging, roterring) after deep tillage had no effects on wheat or subsequent no-tillage soybean yields. Therefore, data presented for the chisel and turn plow treatments are averaged over leveling methods.

Although differences between years occurred and interactions between years and tillage treatments existed, the effects of tillage were consistent enough that conclusions drawn from 3-year averages did not result in substantially different conclusions than using any one year of data. No treatment resulted in higher wheat (Table 1) or soybean yields (Table 2) than moldboard plowing, and for comparison purposes, the moldboard plow is used as the standard treatment.

Wheat grain yields

No-tillage resulted in lower yields than any other treatment (Table 1). When averaged across soils, no-tillage resulted in 23, 30, and 31 percent lower wheat grain yields than disking, chiseling, and turning, respectively.

On the Lucedale and Sumter soils, disking only resulted in yields equal to moldboard plowing. On the Benndale, Lucedale, Bama, Sumter, and Decatur soils, chiseling resulted in yields equal to moldboard plowing. The increase in yields as the amount of surface soil tilled increased indicates that yield-restricting surface soil compaction existed on all soils. Those showing the greatest yield response to the amount of surface soil tilled (disking vs. chiseling or turning) were the Dothan, Benndale, and Bama soils. Since incremental increases in yields decreased as the amount and depth of surface soil tilled increased (yields averaged 31, 40, 44, and 45 bu/acre for no till, disk, chisel, and turn, respectively), it appears that surface soil compaction is a yield restricting factor with no-tillage wheat.

On coarse, loamy soils with well-developed tillage pans, such as those that exist in the Dothan and Benndale soils, depth of tillage can have a large influence on plant growth and yields. The tillage pan depth on the Dothan and Benndale soils was 8 to 9 and 5 to 6 inches, respectively. The moldboard plow (10-inch depth) penetrated the tillage pan on both soils, but the chisel plow did not penetrate the deep pan in the Dothan soil. Failure to penetrate the tillage pan in the Dothan soil may be the reason chisel plowing resulted in lower yields than the moldboard plow on the Dothan, but not the closely related Benndale soil. This response indicates that the disruption of tillage pans is also important for wheat production.

Yield difference between no tillage and the absolute highest yielding deep tillage treatment was greater the second than first year except on the Lucedale and Sumter soils. The difference continued to increase the third year on the Dothan, Malbis, and Bama soils, which indicates that the adverse effect of continuous no-tillage on wheat-grain yield can increase with time on some soils.

Table 2. Yield of no-till soybeans (3-year average) as affected by in-row subsoiling at planting and tillage prior to planting wheat.

Wheat tillage	Soil and Subsoiling[1]											
	Dothan		Malhis		Benndale		Lucedale		Bama			
	ss	NS	ss	NS	ss	NS	ss	NS	ss	NS	Sumter	Decatur
	bu/acre											
None	43	40	52	49	46	30	32	35	31	28	35	33
Disk	45	40	49	47	49	36	31	36	29	24	30	30
Chisel	46	44	49	49	48	43	38	35	31	21	33	31
Turn	43	44	50	52	49	45	31	36	30	28	31	28
LSD *(0.10)*	3		ns		5		ns		ns		ns	ns

[1]SS is in-row subsoiling and NS is no subsoiling. Subsoiling was not a treatment variable on the Sumter and Decatur soils

In-row subsoiling at soybean planting resulted in an early-season visual growth response for wheat planted without tillage and with disk tillage. The wheat for 4 to 6 inches on each side of the old subsoil track grew faster and had a darker green color than wheat in the old row middles. This early season growth difference resulted in higher grain yields in one year on the Dothan (6 bu/acre) and Benndale (8 bu/acre) soils. Improved wheat yields from in-row subsoiling for soybeans, however, did not result in yields equal to those obtained with deep tillage (chisel or turn) prior to planting wheat at any location.

Soybean yield

Tillage prior to planting wheat did not have an effect on soybean yields except on the Dothan and Benndale soils (Table 2). Within years, the response to tillage occurred in 2 of the 3 years on the Dothan soil and each year on the Benndale soil. At the five locations where in-row subsoiling was a treatment, it improved yields only on the Dothan and Benndale soils. These were the same soils in which tillage prior to planting wheat influenced soybean yields. On all soils, however, in-row subsoiling resulted in more rapid early season growth and larger plants at maturity than when in-row subsoilers were not used (data not shown).

In-row subsoiling improved yields only when deep tillage was not used prior to planting wheat, which indicates that deep tillage prior to planting wheat can eliminate the need for expensive in-row subsoilers for no-tillage soybeans when soybeans are planted in relatively narrow rows (18 to 24 inches). If wider rows (30 to 36 inches) had been used, however, the increased plant growth from in-row subsoiling probably would have resulted in yield increases over smaller plants in non-subsoiled rows.

Summary and Conclusions

As expected, method of leveling the soil after deep tillage had no effect on yields. Therefore, when leveling is needed, a drag bar attached to the tillage implement would be more economical than a separate leveling operation.

When yields of both crops are considered, the highest yielding system would be no-tillage soybeans with deep tillage prior to planting wheat on soils with physical characteristics similar to either the Dothan, Malbis, Benndale, Bama, or Decatur soils. On soils with physical characteristics similar to the Lucedale or Sumter soils, diskng prior to planting wheat would be the most economical tillage system. However, it is not easy to separate the Lucedale from the Dothan, Malbis, or Bama soils on the basis of soil characteristics.

If the presence of a root-restricting tillage pan cannot be determined, the best option would be to chisel plow prior to planting wheat. On soils with root restricting tillage pans, deep tillage prior to planting wheat can eliminate the need for expensive in-row subsoilers in conservation-tillage soybean production. Although in-row subsoiling at soybean planting can have some residual effect on yield of the subsequent wheat crop, it will not compensate for deep tillage prior to planting wheat. Deep tillage can be accomplished and conservation practices can be maintained by using a chisel plow instead of a moldboard plow prior to planting wheat

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Soybean-Wheat Intercropping Response and Effect on Estimated Net Returns

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Introduction

Relay planting, or relay intercropping, is a cropping system where one crop is planted into another crop before it is harvested. In our intercropping research, soybeans were relay planted into wheat prior to wheat harvest. Our early research with this system involved row spacings of both wheat and soybeans, and soybean planting dates. Wheat row spacings of 7, 15,and 20 inches with soybeans relay planted in 15-, 20-, and 30-inch rows were evaluated. All the wheat-soybean row-spacing combinations caused varying amounts of wheat to be tracked down by both the planter units and tractor wheels. The 20-inch wheat-soybean row-spacing combinations caused the least amount of wheat to be tracked down by the tractor wheels. The 15-inch row combinations had slightly more wheat tracked down by the tractor wheels, but the planter units rubbed against each other. Therefore, a 16-inch row spacing and 24-inch wide skips for tractor wheels were selected. The 16-inch row spacing allowed a 1-inch clearance between planter units.

In simple terms, with the relay planting system we planted a 20-foot swath of wheat in 16-inch rows with 24-inch wide skips (2 skips per 20-ft planter swath) for tractor wheels. At soybean planting, all units were moved over 8 inches and soybeans were planted between the wheat rows in mid to late May. It was observed, however, that 20-inch wide tractor tires tracked down some wheat with a planter rate of travel of 5 mph.

Therefore, a study was conducted to evaluate the effect of tractor wheel track skip width, soybean planting date, and soybean row spacing on wheat and soybean yield. Economic estimates of net return to land, management, and general farm overhead were made using 3-year average yield data of these doublecropping systems.

Materials and Methods

Field studies were conducted at the Northeast Branch Experiment Station, Verona, MS for 3 years, 1984-86, on a Marietta loam, an Ora fine sandy loam, and a Catalpa silty clay, respectively. The four cropping systems used in the study were monocrop wheat, monocrop soybeans, relay planted soybeans in wheat, and soybeans planted in wheat stubble. To better duplicate farm conditions, large field-size plots were used. We felt that if this system was to be accepted and used by producers, the planter rate of travel would have to be higher than the planter rate of travel in most small plot research. The planter rate of travel in this study was approximately 5 mph.

The wheat-soybean relay cropping system followed a previous crop of monocrop soybeans each year. The study area was chiseled, disked, and smoothed with a do-all (implement equipped with vibratine shanks, rolling cutter bar, and section harrow) twice before planting wheat. In the spring of each year, monocrop soybean plots were tilled with a field cultivator once or twice as needed before planting. Prior to chiseling in the fall of each year, phosphorous and potassium as 0-20-20 were applied as dry fertilizer at 300 and 600 lb/acre for the monocrop and doublecrop systems, respectively. All 16-inch row wheat and 16- and 32-inch row soybeans were planted with a 20-foot wide John Deere soybean special planter equipped with ripple coulters, narrow depth bands (2-inch), cast-iron press wheels, and lift assist wheels. The 7-inch wheat rows were planted with a John Deere grain drill. Preplant nitrogen at 30 lb N/acre were applied each fall as ammonium nitrate. In February of each year, 80 lb N/acre were applied surface broadcast as ammonium nitrate.

Wheat was seeded at 45 lb/acre and soybean seeding rates were 5 and 10 seeds per foot of row in 16- and 32-inch rows, respectively. Wheat varieties used were Coker 916 in 1984, and Florida 302 in 1985 and 1986. Centennial was the variety of soybeans planted.

Wheat was planted all 3 years about November 10. Soybeans were relay planted in wheat about May 15 and May 30, and planted in wheat stubble about June 19 and July 4 of each year. Monocrop soybeans were planted each year about May 15.

Skips (2 per 20-foot planter swath) of 24, 28, and 32 inches (Table 1) for tractor wheel tracks were evaluated. In 1984, only 24-inch wheel tracks and 16-inch soybean rows were used. Wheat row spacings were 7 and 16 inches, with 16-inch rows being utilized for the relay planting system. The 7-inch wheat row was a standard for comparison. In all soybean cropping systems and planting dates, soybeans were planted in 16-inch rows in 1984 and in both 16- and 32-inch rows in 1985-86. Removal of every other planter unit gave us the 32-inch row spacing.

Weeds were controlled in both crops at high levels and weed

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Table 1. Row spacing and tractor wheel track combinations used in relay planting systems at the Northeast Mississippi Branch Experiment Station, 1984-86.

Tractor wheel track spacing (in.)		Wheat row spacing (in.)		Soybean row spacing (in.)
24				16
28*	X	16	X	
32*				32*

*Used only in 1985 and 1986.

management systems varied with the cropping systems. A burndown herbicide (paraquat) was applied to all plots where soybeans were planted in wheat stubble. Postemergence herbicides were used according to label rates for soybean weed control on all plots. Soybean herbicides applied were Basagran®, Blazer®, 2,4-DB, and Fusilade®. The combination of herbicides used varied each year depending on the weed problem. Hoelon® was used each year for ryegrass control in the wheat. Dithane M-45® and Benlate® were applied 2 of the 3 years to wheat for disease control but no fungicides were applied to the soybeans.

Table 2. Weed control management systems used for developing economic analysis hndget of four cropping systems, 1984-1986, MAFES Northeast Branch.

Monocrop Soybeans

16-inch rows
1. PPI — Prowl
2. POT — Basagrao + Blazer
3. POT — Blazer + surfactant

32-inch rows
1. PPI — Prowl
2. Early Cult. + POT hand — Basagran + Blazer
3. Late Cult. + PD hand — Sencor + 2.4-DB

Soybean Relay Planted System

16-inch rows
1. E. POT — Fusilade + crop oil
2. E. POT — Basagran + Blazer
3. L. POT Blazer + surfactant

32-inch rows
1. E. POT — Fusilade
2. Cult. + POT hand — Basagran + Blazer
3. Cult. + PD hand — Sencor + 2.4-DB

Soybeans Planted in Wheat Stubble

16-inch rows
1. Burndown application — Paraquat
2. E. POT Fusilade + crop oil
3. E. POT — Basagran + Blazer
4. L. POT — Blazer + surfactant

Wheat

7-inch row
1. POT - 2,4-D

PPI = Preplant incorporated
POT = Postemergence over-top application
Early cult. = Early cultivation
Late cult. = Late cultivation
PD = Post-directed herbicide application
E. POT = Early postemergence over-lop application
L. POT = Late postemergence over-top application

Economic Analysis

Economic estimates of net returns to land, management, and general farm overhead were based on an estimated practical farming situation. The total expenses did not include a charge for land, management, and general farm overhead. For practical economic comparisons, the weed control systems for soybeans relay planted in wheat and monocrop soybeans were modified as indicated in Table 2. The assumption in the analysis for a practical farm situation was that the modified weed control systems provided the same level of weed control and the cropping systems would produce the same yield as those in the research plots. Budgets were developed for each cropping system. Net returns were based on 3-year average yields obtained from the field studies.

Soybean price used in developing budgets was a 5-year (1981-86) average of $6.21/bu for soybeans and $3.31/bu for wheat received by farmers in Mississippi. Costs of variable inputs and machinery were based on 1986 prices paid by Mississippi farmers. In constructing the budgets, performance rates on all field operations were based on 8-row equipment with associated power units. The hourly wage rate was $4.50/hour. Interest rate on operating capital was computed at 10 percent annual percentage rate

Results and Discussion

Wheat

The first year, 1984, only the 24-inch wheel track spacing was used. The 24-inch wheel tracks with the relay planted treatments produced less yield than the 28- and 32-inch in 1986, but not in 1985 (Table 3). The tractor we used had 20-inch wide tires and the 24-inch wide skip for the tractor wheels allowed only 4 inches for wheel track error in the field planting operation. Wheat yields for the 28- and 32-inch tractor wheel track skips were similar. The wider wheel tracks provided a wider space for tractor wheel track error in doing field operations. Therefore, all data reported are for the 32-inch wide skip (Tables 4 and 5) and averaged over years. Three-year average yields for monocrop wheat planted in the traditional drilled rows (7-inch) averaged 48 buiacre, while the 16-inch wheat rows with soybeans relay planted in mid and late May averaged 44 buiacre (Table 4). This was 92 percent of the 7-inch row monocrop yield. Wheat yields for the two relay planting dates of mid and late May showed little difference between planting dates. Yields for wheat harvested before soybean planting and wheat harvested after soybeans had been relay planted into wheat were very similar. Thus, soybean planting date for a wheat doublecropping system could be extended 2 to 4 weeks using relay planting.

Wheat yields from the late May relay planted soybeans were the same for both soybean row spacings (Table 5).The 16-inch soybean rows had twice as many planter units pass between

Table 3. Effect of relay planting and tractor wheel track width on wheat yield at the Northeast Mississippi Branch Experiment Station, 1984-86.

Systems	Row spacing (in)	Wheel track space (in)	Wheat yield 1984	1985	1986
Monocrop					
Wheat	16	24	53	41	41
Wheat	16	28	—	41	44
Wheat	16	32	—	36	43
Wheat	7	—	53	45	45
Doublecrop					
Relay Planted					
5/14 - 5/15	16	24	50	—	—
5/14 - 5/15	16	28	—	32	44
5/14 - 5/15	16	32	—	40	45
Relay Planted					
5/29 - 6/2	16	24	55	35	42
5/29 - 6/2	16	28	—	38	41
5/29 - 6/2	16	32	—	39	41
Stubble Planted					
7/2 - 7/7	16	24	53	41	41
7/2 7/7	16	28	—	39	45
7/2 7/7	16	32	—	40	41

the wheat rows as the 32-inch soybean rows, but this did not affect wheat yield. Thus, planting between wheat rows in late May had no adverse effect on wheat yield. The mid-May relay planting date for the 16-inch soybean rows produced 5 bu/acre lower wheat yield than the 32-inch soybean rows.

Soybeans

The skip width for the tractor wheel track had no effect on soybean yield. Yield of relay planted soybeans did not differ from monocrop soybeans. Three-year average yield data (Table 4) for 16-inch soybean rows indicated that the relay planting system produced 41 percent (20 bu/acre) more soybeans than those planted in wheat stubble about July 4. Monocrop soybeans in 16-inch rows produced 36 bu/acre. In the relay planting system, 16-inch soybean rows produced 37 and 35 bu/acre for May 15 and May 30 planting dates, respectively. Soybeans planted in wheat stubble about June 19 and July 4 produced 35 bu/acre and 15 bu/acre, respectively. Soybeans planted in wheat stubble about June 19 yielded about as good as monocrop and relay planted beans. The late planting date of about July 4, however, severely reduced yields and indicated no advantage for doublecropping.

Two-year average yields for 16- and 32-inch soybean rows (Table 5), indicated little difference among row spacings. The main advantage for the 32-inch rows is the capability to utilize band application of herbicides and to cultivate. Yields for soybeans planted from May 15 to June 19, regardless of system, ranged from 28 to 35 bu/acre, but declined to 10 bu/acre for the later-than-optimum date (about July 4) for soybeans planted in wheat stubble.

Table 4. Three-year average yields and net returns of four cropping systems at the Northeast Mississippi Branch Experiment Station, 1984-86.

Systems	Row spacing (in)	Net returns ($/acre)*	Avg yield (bu/a)' Wheat	Soybeans
Monocrop				
Soybeans 5/14	16	$ 89	—	36
Wheat	7	$ 18	48	—
Doublecrop				
Relay planted				
5/14 - 5/15	16	$117	42	37
5/29 6/2	16	$117	45	35
Stnhhle planted				
6/17 - 6/21	16	$ 91	41	35
7/2 - 7/7	16	-$ 14	46	15

1 Average includes 24-inch wheel track space data of 1984 and 32-inch wheel track space data of 1985 and 1986.

2 Net returns per acre do not include a charge for land, management, and general farm overhead.

Economic Analysis

Economic estimates for 16-inch soybean rows (Table 4) indicated monocrop soybeans, relay planted soybeans, and soybeans planted in wheat stubble about June 19 produced higher net returns than monocrop wheat and soybeans planted in wheat stubble about July 4. The highest net return, however, was $117/acre for the relay planting system, $28/acre more than monocrop soybeans. The monocrop soybeans and soybeans planted in wheat stubble produced net returns of $89 and $9l/acre, respectively. A negative return of $14/acre was shown for the soybeans planted in wheat stubble about July 4. The relay cropping system has the most potential to increase net returns for producers who plant soybeans in wheat stubble after June 19 in Northeast Mississippi and similar areas.

Two-year average net returns for 16- and 32-inch rows differed among systems and planting dates (Table 5). The monocrop 16-inch soybean rows showed returns of $8/acre more than 32-inch rows. The May 15 relay planting date showed no difference in returns between 16- and 32-inch rows. However, with the May 29 relay planting date, the 32-inch rows showed net returns of $110/acre compared to $87/acre for 16-inch rows.

Conclusion

Monocrop wheat produced **8** percent more than wheat in 16-inch rows. Relay planting soybeans in wheat had no effect on wheat yield. Tractor wheel track skips (2 per 20-foot planter swath) of 28 and 32 inches showed no wheat yield difference but resulted in higher yields than 24-inch skips 1 of 2 years. The 24-inch wide skip was too narrow for planter operating rates of 5 mph and resulted in some of the wheat being tracked down.

Table 5. Two-year average yields and net returns of four cropping systems at the Northeast Mississippi Branch Experiment Station, 1985-86.

Svstems	Row spacing (in)	Net returns ($/acre)[2]	Avg yield (bu/a)' Wheat	Sovbeans
		Monocrop		
Soybeans 5114	16	$ 78	—	34
	32	$ 70		32
Wheat	7			
		Doublecrop		
Relay planted				
5/14 - 5/15	16	$ 79	38	33
	32	$ 79	43	28
5129 612	16	$ 87	40	33
	32	$110	40	35
Stubble planted				
6/17 - 6121	16	$ 78	42	32
712 - 717	16	-$ 48	41	10

[1] Average includes 24-inch wheel track space data of 1984 and 32-inch wheel track space data of 1985 and 1986.

[2] Net returns per acre do not include a charge for land, management, and general farm overhead.

Soybean yield (3-year average 16-inch rows) for the relay cropping systems was equal to monocrop soybeans and 20 bu/acre higher than soybeans planted in wheat stubble about July 4. Two-year average yield for relay planted soybean in 16- and 32-inch rows varied with planting date. Monocrop soybeans showed higher yield average with 16-inch rows.

Economic estimates using 3-year average yield data indicated relay planting soybeans into wheat about May 15-30 produced net returns of $117/acre, $28/acre more than monocrop soybeans, and $26/acre more than soybeans planted in wheat stubble about June 19. Two-year average data comparing 16- and 32-inch soybean rows indicated 32-inch rows produced net returns equal to or greater than 16-inch rows.

Relay planting is a doublecropping system that offers producers an opportunity to take advantage of an additional 1 to 4 weeks for planting soybeans and producing yields equal to monocrop soybeans. The approximately 15 to 25 percent soybean yield reduction for the traditional wheat-soybean doublecropping system is due to later planting. Due to the wider rows, wheat yields in 16-inch rows were reduced by 8 percent. But comparing the price of these two commodities, the trade-off of lower wheat yield for higher soybean yield is economically favorable.

The relay cropping system offers several other advantages. Established skips for tractor wheels keep wheat from being tracked down during the soybean relay planting operation. and provide a permanent wheel track for subsequent field operations. The use of the same planter for planting both crops maximizes utilization of equipment. Additional benefits are reduced tillage and reduced erosion potential. The wheat stubble provides excellent soil erosion protection and, with relay planting, soybean land preparation is eliminated.

Relay planting is not the best choice for all situations nor all producers. Because it is a form of reduced tillage, it requires more intensive management and the use of herbicides for weed control. The greatest potential for this cropping system is on bottomland sites where more stored water is available to adequately supply the two crops, and for growers who experience soybean yield reductions from late dates of planting soybeans into wheat stubble.

Tillage Effects on Nutrient Loadings of Waterways

T.A. Dillaha, S. Mostaghimi, and C.D. Heatwole[1]

Introduction

Conservation tillage is the fastest growing agricultural practice in the history of U.S. agriculture. Conservation tillage increased from 30 million acres in 1972 to approximately 100 million acres or one-third of total U.S. cropland in 1982 (Myers, 1983). Some agricultural leaders project that 50 to 75 percent of U.S. cropland will be farmed with conservation tillage methods by the year 2010 (Crosson, 1981; OTA, 1982).

The use of conservation tillage is increasing because in most cases it is a cost-effective practice which reduces production costs (labor, equipment, and fuel), increases yields, conserves moisture, and maintains the long-term productivity of soils by reducing soil erosion and increasing the organic matter and nutrient content of soils.

Conservation tillage also is being promoted because it is thought to be one of the best available techniques for controlling nonpoint source water pollution from cropland. This paper discusses the environmental consequences of excessive nutrients in surface waters and the effects of conservation tillage on the transport of commercial nitrogen (N) and phosphorus (P) fertilizers to surface waters. Also discussed are fertilizer application techniques that can be used in conjunction with conservation tillage to minimize nutrient losses in surface runoff.

Environmental Consequences of Nutrients

Nitrogen and phosphorus are essential nutrients for aquatic as well as terrestrial vegetation. If present in sufficient quantities, however, N and P can promote eutrophication or premature aging of lakes and estuaries. Accelerated eutrophication causes excessive algae growth, which creates turbid conditions that may eliminate submerged aquatic vegetation and destroy the habitat and food sources of aquatic animals and waterfowl. When the algae die and decay, they may also reduce dissolved oxygen levels and suffocate fish and shellfish. Blooms of toxic algae can also release toxins to water that affect the health of swimmers, and under extreme circumstances, kill cattle and other animals that drink the water. Taste and odor problems caused by eutrophication can also reduce the quality of water for recreation and increase water treatment costs.

Nutrients are transported from cropland to waterways in soluble and sediment-bound forms in surface runoff and in soluble forms in subsurface flow. Nitrate (NO_3-N) is an extremely soluble form of N and is the only nutrient transported principally in subsurface flow. Subsurface transport mechanisms will not be discussed further in this paper. Principal forms of N and P transported in surface runoff include NO_3-N, ammonium (NH_4-N), organic N, orthophosphate (PO_4-P), organic P, and mineral P. All of these nutrient forms exist in both soluble and sediment-bound phases, but all are associated primarily with sediment except NO_3-N. Orthophosphate is also highly soluble but it tends to bind to organic matter and clays.

Soluble inorganic forms of nutrients such as NO_3-N, NH_4-N, and PO_4-P are the nutrients of primary concern with respect to water quality because they are the only forms of N and P which aquatic plants can assimilate directly. Soluble organic N and P are not immediately available to plants but since they can be rapidly metabolized to soluble inorganic forms by bacteria we must be concerned with their presence.

In addition, an equilibrium exists between sediment-bound and soluble nutrients. Consequently, if we decrease the concentrations of soluble nutrients in water, and sediment-bound nutrients are present, the sediment will release soluble nutrients until a new equilibrium is reached. Thus, it is obvious that all forms of N and P are significant with respect to eutrophication but soluble inorganic nutrients are the most important with respect to eutrophication because they are immediately available to plants.

To prevent eutrophication and nuisance algae growth, it has been suggested that concentrations of PO_4-P, NO_3-N, and total N (Nt) in lakes be limited to 0.025, 0.3, and 1-2 mg/L, respectively (Wetzel, 1983). Recommended limiting concentrations for PO_4-P in streams where they enter lakes are 0.05 mg/L and 0.10 mg/L in streams far upstream of lakes (NCAES, 1982).

Nitrate is the only major nutrient for which a health limit has been set. The maximum permissible concentration of nitrate (NO_3-N) in domestic water supplies is 10 mg/L. Nitrate itself is not toxic but it can be reduced to nitrite (NO_2-N) in the gastrointestinal tracts of infants and react with hemoglobin in the bloodstream to impair oxygen transport. This condition is referred to as methemoglobinemia and is most common in agricultural areas where surface and ground waters have been contaminated with N fertilizer (USEPA, 1976).

Cropland, pasture, and range have been identified as significant sources of N and P polluting the nation's water supplies. Cropland, pasture, and range together contribute nearly 6.8 million tons of N and 2.6 million tons of P to U.S. surface waters each year (Bailey and Wadell, 1979). This represents

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approximately 61 and 46%, respectively, of the total amount of N and P delivered to the nation's waters. To control nutrient losses and to protect water supplies, management practices such as conservation tillage, contouring, terraces, and improved fertilizer and pesticide management are being promoted. These practices are particularly needed in the Southern Region (Southern Plains, Delta States, Southeast, and Appalachia) where nonpoint source pollution is the main water quality problem and where cropland is the principal source of nonpoint source pollution (USEPA, 1984). Conservation tillage has great potential for reducing agricultural nonpoint source pollution in the Southern Region because only 23% of the cropland was in conservation tillage in 1987 (Magleby and Schertz, 1988).

Effects of Conservation Tillage on Nutrient Transport

Conservation tillage is defined as any tillage or planting system which leaves at least 30 percent of the soil surface covered with crop residue after planting. Major types of conservation tillage include no-tillage, ridge-till, strip-till, and mulch-till. Conservation tillage affects nutrient transport in surface runoff by increasing crop residue on the soil surface, decreasing soil erosion and surface runoff, and reducing incorporation of fertilizers.

Surface residues associated with conservation tillage reduce soil erosion and transport of sediment-bound nutrients in several ways. First and foremost, crop residue protects the soil from impacting raindrops. If the raindrops do not hit the soil surface directly, soil particles are not separated from the soil mass and erosion is greatly reduced. Baker and Laflen (1983) reported that erosion was approximately halved with every 9 to 16 percent increase in percent residue cover. This means that conservation tillage should reduce erosion by 75 to 90 percent (depending on the amount of surface residue) compared to conventional tillage. Reductions in nutrients transported by sediment are expected to be similar.

Conservation tillage systems also increase infiltration and reduce average annual runoff volumes by about 25 percent compared to conventional tillage (Baker and Johnson, 1983). The reduction in runoff would he expected to reduce the transport of soluble and sediment-hound nutrients. Unfortunately, concentrations of both soluble and insoluble forms of N and P in surface runoff generally increase with conservation tillage and usually offset the reduction in runoff volume. As a consequence of increased infiltration, leaching of soluble nutrients such as N03-N may lead to groundwater contamination.

The most significant factor affecting nutrient transport with conservation tillage involves the placement, timing, and rates of fertilizer applications. The primary goals of conservation tillage are to minimize the disturbance of surface residues and to avoid incorporation of crop residues. From an agronomic and water quality viewpoint, however, we would like to incorporate fertilizers so that they are close to plant roots and away from the soil surface where they are subject to loss via surface runoff and erosion. Unfortunately, these two goals are in conflict because current fertilizer incorporation practices also incorporate residue.

When fertilizers are broadcast and not incorporated, they concentrate near the soil surface where they are most susceptible to surface loss. In contrast, fertilizers are distributed more or less uniformly throughout the plow layer with conventional tillage. In a 5-year study comparing conventional tillage and no-till corn-soybean rotations, Erbach (1982) found that concentrations of P in the upper 2 inches of the soil profile were 67 percent higher with no-till. Similar results are expected with N except that increased infiltration with conservation tillage will tend to leach NO3-N down into the soil profile.

Concentration of nutrients near the soil surface with conservation tillage has two consequence. First, since the surface soil has higher nutrient levels, the concentration of nutrients in eroded sediment will also he higher. For example, in the corn-soybean rotation study discussed above, sediment associated P loss would decrease with no-till only if the 67 percent increase in soil P concentrations were offset by a 67 percent reduction in soil loss.

The second consequence of reduced incorporation of fertilizers is that concentrations of soluble nutrients in surface runoff are significantly higher with conservation tillage than with conventional tillage because soluble nutrient concentrations in runoff are directly proportional to nutrient levels at the soil surface (Baker and Laflen, 1982). Thus, doubling nutrient concentrations in the soil surface will approximately double soluble nutrient concentrations in runoff. As with sediment-hound nutrients, losses of soluble nutrients with conservation tillage will not decrease relative to conventional tillage unless the increased concentrations are offset by larger reductions in runoff volume.

Surface residues have also been identified as a source of soluble nutrients in surface runoff (Barisas et al., 1978; Smith et al., 1974). These researchers concluded that leaching of soluble nutrients from crop residues was a major cause of higher soluble nutrient losses with no-till.

Fertilizer Management Practices for Conservation Tillage

As discussed above, conservation tillage is unlikely to achieve significant reductions in nutrient delivery to waterways unless nutrient levels in surface soils can he reduced. Surface application of fertilizers is the most popular but most inappropriate method of conservation tillage fertilization. New fertilizer application methods are needed which will incorporate fertilizer into the soil with minimal disturbance of surface residue. Shallow tillage with knives or disks may be acceptable to apply nutrients with corn residue hut a single disking for ammonia application with soybean residue may reduce surface cover excessively (Baker and Laflen, 1983).

A study of hand incorporation P fertilizer found that there were no significant differences in soluble P concentrations in runoff from conventional, no-till, and conservation tillage plots (Mueller et al., 1982). Soluble P losses were found to be reduced in proportion to the runoff volume reductions achieved by the different tillage systems. These results support the hypothesis that subsurface application of fertilizers can reduce the concentrations of nutrients in surface runoff and consequently reduce total nutrient losses relative to conventional tillage. Similar results would be expected for insoluble P and both soluble and insoluble N losses.

Morrison (1986) gives an excellent review of machinery for improved fertilizer application with conservation tillage. Slot injectors for liquid and dry fertilizers are described which greatly increase fertilizer use efficiency and minimize losses in surface runoff. Coulter/nozzle, v-wheel and sweep, and high-pressure nozzle slot injectors are described (Morrison, 1986) along with a spoked-wheel point injector developed by Baker et al. (1985). The effectiveness of alternative fertilizer application knife types are also discussed. Fertilizer injection via injectors on paraplow blades is also a promising technique.

If subsurface application equipment is not available, Morrison (1986) recommended dribble banding of liquid and solid fertilizers as the best available surface fertilizer application practice. Dribble banding of liquid fertilizer should also reduce loss of nutrients in surface runoff because the liquid fertilizer will flow further down into the soil than when it is distributed uniformly over the soil surface.

Summary and Conclusions

Conservation tillage is a promising alternative for agricultural nonpoint source pollution control. Conservation tillage reduces soil erosion by 75 to 90 percent and surface runoff volumes by approximately 25 percent compared to conventional tillage. Since most nutrients in surface runoff are associated with sediment, conservation tillage usually results in a net decrease in nutrient losses.

Currently, most fertilizers are surface broadcast to land in conservation tillage. Surface broadcasting of fertilizers causes nutrients to concentrate at the soil surface where they are most susceptible to loss in surface runoff. This increases concentrations of soluble and sediment associated nutrients in runoff and can result in higher losses of some nutrients than with conventional tillage. To minimize this problem, fertilizer application methods must be developed that apply fertilizers below the soil surface while minimizing disturbance of surface residue.

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Effect of Hairy Vetch, Crimson Clover, and Rye Cover Crops on Yield and Quality of No-Till Flue-Cured Tobacco in North Carolina

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Field experiments were conducted in 1986 and 1987 at two locations in North Carolina to evaluate the feasibilty of hairy vetch *(Vicia villosa* Roth.) and crimson clover *(Trifolium incarnatum* L.) alone, and in a mixture with rye *(Secale cereale* L. cv. 'Abruzzi') as cover crops for no-tillage flue-cured tobacco *(Nicotiana tabacum* L.). Yield of tobacco grown no-tillage in a hairy vetch cover crop averaged 3,332 Ib/acre at one location. In general, yields of tobacco grown no-tillage in cover crops containing hairy vetch or crimson clover were greater or not significantly different from tobacco grown no-tillage in rye. Quality of tobacco grown no-tillage with legume cover crops was comparable to tobacco grown no-tillage with rye or conventionally tilled tobacco. Sugar and total alkaloids were significantly affected by the hairy vetch and crimson clover cover crops, but these changes were within the accepted range for good quality.

Introduction

The production of flue-cured tobacco has traditionally relied on cultivation to control weeds, maintain a row ridge to reduce lodging and drowning, and soften the soil to enhance water penetration and aeration **(3).** This dependence on cultivation has made flue-cured tobacco land highly susceptible to erosion (2).

The advantages of adopting no-tillage practices utilizing cover crops in tobacco are in theory numerous, just as in other agronomic crops. Savings in fuel, labor, and reduced soil erosion, along with increased soil moisture conservation should be realized. Other specific benefits unique to flue-cured tobacco, include the possibility of decreasing blowing sand damage to young tobacco transplants and the potential of increasing quality by reducing the raindrop splash of soil on the downstalk leaves (8). In addition, results of previous research have suggested that cover crop residues in no-tillage tobacco can provide some degree of weed suppression (5).

Further impetus for adopting no-tillage practices is the Food Security Act of 1985, which states that farmers with highly erodible land must implement by 1995 an acceptable soil conservation plan in order to continue receiving federal commodity program benefits (1). This may be of particular concern to tobacco growers in the Piedmont and Mountain regions. Research in no-tillage flue-cured and burley tobacco in North Carolina bas been encouraging, with yield and quality at times comparable to or greater than conventional cultivated tobacco (5, 8). Improvements in planting, fertilization and especially weed control are still needed before no-tillage tobacco is considered a practical alternative.

In recent years, there has been a renewed interest in legume cover crops as a source of nitrogen (4). A legume cover crop in no-tillage tobacco could serve a two-fold purpose, stabilize the soil and possibly contribute enough nitrogen to reduce the inorganic nitrogen input. Nitrogen management in flue-cured tobacco is critical to ensure good yields and quality. Adequate nitrogen must be available for vigorous early season vegetative growth, but nitrogen depletion must eventually occur around 8 to 10 weeks after transplanting or tobacco will be difficult to cure. Organic nitrogen sources have been considered poor choices for flue-cured tobacco because of the lack of control over the amount and time of release of the nitrogen (3).

We conducted field experiments for 2 years to evaluate whether there was any advantage to legume, legume and rye mixture cover crops over rye alone for no-tillage flue-cured tobacco. The effect of fall sown cover crops, hairy vetch and crimson clover alone, and in a mixture with rye, on yield and quality of no-tillage flue-cured tobacco are reported here. Questions concerning nitrogen contribution of the cover crops will be addressed later.

Materials and Methods

Field experiments were conducted in 1986 and 1987 at the Central Crops Research Station near Clayton, NC and the Upper Coastal Plain Research Station near Rocky Mount, NC. Soil at the Clayton, NC location in 1986 and 1987 was a loamy sand (pH 5.2) with 1 percent organic matter (OM). Soil at the Rocky Mount location in 1986 was a sandy loam (pH 6.2) with 1.2 percent OM and in 1987, a loamy sand (pH 5.9) with 0.6 percent OM. In the fall prior to each growing season, fields at each location were disked and bedded. Soil insecticide and/or nematicide was used if needed. Rye, inoculated hairy vetch, and crimson clover were spread with a cyclone seeder and incorporated with a ground-driven roll-

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ing cultivator each fall, leaving beds at an appropriate height for transplanting.

Seeding rates were: rye at 223 lb/acre (4 bu/acre), crimson clover 25 lb/acre, hairy vetch at 30 lb/acre, and the rye plus crimson clover or hairy vetch mixtures at 84 Ib/acre (1.5 bu/acre) for rye and 15 Ib/acre for crimson clover or hairy vetch. For comparison purposes, a conventional culture treatment without a cover crop was included at each location. The experimental design at both locations was a randomized complete block split plot with four replications, with the main plots (four bedded rows by 22.5 feet) consisting of the different cover crop treatments; and the subplot (two bedded rows by 22.5 feet) treatments were nitrogen at sidedressing and no nitrogen at sidedressing.

Paraquat® at 0.56 lb ai/acre plus 0.5 percent (v/v) nonionic surfactant was applied in the middle of April each year to kill the cover crops and any emerged weeds. The conventional culture main plots were rebedded prior to transplanting of tobacco, which occurred 10 to 14 days after paraquat application. Tobacco was transplanted using a minimum tillage model, one-row mechanical transplanter. Immediately after transplanting, diphenamid at 6.0 lb ai/acre was broadcast over the entire experiment. Additional weed control was provided by shielded application of non-selective herbicides and mowing with a gas-powered weed trimmer.

Complete mixed fertilizer (N-P-K) was knifed into the soil as a band to the side of the tobacco plants about one week after transplanting. A sidedress application of N was applied to the appropriate two rows of each main plot about 3 weeks after transplanting. N, P, and K rates were according to recommendations by soil test for conventionally-grown flue-cured tobacco. Two-row subplots were harvested by hand as leaves matured (ie. normal practices used in harvesting). Leaves were cured according to standard flue-cured practices. Yield and grade indices were determined after curing for tobacco harvested from each subplot. The grade index is an indication of quality (6) and is based upon equivalent qualities of tobacco being assigned an equal U.S. Government grade value. A weighted mean of grade value x weight/grade provides an overall index value. The poorest possible grade is assigned a value of 0 and the best possible grade, 100. Leaf chemical analysis for total alkaloids and percent reducing sugars was conducted by the Crop Science Department Tobacco Chemistry Laboratory to determine if treatments affected smoking quality of the leaf.

Data for 2 years at each location were combined, where possible, and subjected to analysis of variance, along with mean comparisons, using the Waller-Duncan t-test (K-ratio = 100; equivalent to 5 percent level of significance).

Results and Discussion

In both years, cover crops were well established at both locations by April. Main plots with hairy vetch alone or in mixture proved difficult to kill, and required more than one application of paraquat. In 1986 at both locations, a significant tobacco stand reduction was observed in the hairy vetch and crimson clover plots (data not presented). Growth of tobacco transplants in these plots lagged behind other transplants in rye, rye-legume mixture, and conventional plots. This reduced vigor in transplants was temporary and did not have any significant effect on yield. Greenhouse experiments suggest that killed legumes and tobacco are compatible (data not presented). It is believed that soil moisture levels were significantly different under the various cover crops and this adversely affected the early growth of the transplants. No significant stand reduction or reduced vigor of tobacco transplants was observed in 1987 at either location for any treatments.

Yield of no-tillage flue-cured tobacco at the Clayton location in both years was excellent and of acceptable to excellent quality. Tobacco grown no-tillage in a hairy vetch cover crop at the Clayton location (Table 1) had the highest yield, based on 2 years' data. Yield of tobacco grown in hairy vetch was significantly higher than any of the other no-tillage cover crop treatments and the conventionally managed (cultivated) tobacco plots (Table 1). There were no significant differences in grade index in 1986 or 1987 at the Clayton location. Grade indices in 1986 ranged from 64 to 69, an indication of excellent quality. Grade indices were lower in 1987, but still acceptable (Table 1.).

Yields were consistently lower both years at the Rocky Mount location, probably more of a reflection of harvest management differences than other factors such as tobacco variety, weed control, soil type, and weather. Water was not limiting at either location in either year, since irrigation was used when needed. Tobacco grown with a crimson clover and hairy vetch cover crop did yield significantly higher than tobacco grown with a rye cover crop (Table 2). Conventional tobacco (cultivated) averaged the highest yield over 2 years, but yield was lower than the Clayton location. Quality as indicated by grade index was poor in 1986 at the Rocky Mount

Table 1. No-tillage flue-cured tobacco yield, grade index, and leaf chemistry as affected by cover crop at Clayton, NC, 1986 and 1987. (Data are means of 2 years unless otherwise indicated.)

Cover Crop			Tobacco[a]			
			Chemistry		Grade Index[b]	
Type	Fall sowing rate (lb/A)[c]	Yield (lb/A)	% Sugar	% TA	1986	1987
Rye	223	2,712c	18.3a	1.6c	64	53
Crimson Clover	25	3,081b	14.8c	2.1a	66	48
Hairy Vetch	30	3,332a	13.4d	2.2a	67	46
Rye+CC[d]	84 + 15	2,781c	19.0a	1.6c	64	51
Rye+HV[d]	84 + 15	2,997b	18.5a	1.7bc	69	51
Conventional (no cover crop, normal tillage)		2,999b	16.1b	1.8b	65	53

[a] Means within a column followed by the same letter are not significantly different as determined by Waller-Duncan I-test (K-ratio = 100).

[b] No significant differences at 5% level.

[c] 223 lb = 4 bu, 84 lb = 1.5 bu.

[d] CC = Crimson Clover, HV = Hairy Vetch.

location and only slightly improved in 1987 (Table 2). There were no significant differences in grade index in 1986 or 1987.

Leaf chemical constituents were affected by cover crop at both locations. Percent reducing sugar was significantly lower and percent total alkaloids (TA) was significantly higher in tobacco grown in the crimson clover and hairy vetch cover crops compared to the other treatments (Tables 1 and 2). These results are expected, since the sugar to total alkaloid ratio is partly dependent on nitrogen levels (3). The legume mulch is responsible for elevated N levels and, therefore, would affect this ratio. Reducing sugar to total alkaloid ratio in tobacco is considered one indicator of proper chemical constituent balance or quality. In general, a ratio of 6:1 to 8:1 is desirable for the highest quality. Sugars should range between 15 to 18 percent, while total alkaloids should range between 2.5 to 3 percent (7). The data collected suggest that the quality of tobacco, grown no-tillage with the legume cover crops, is not adversely affected and is comparable to tobacco grown no-tillage with rye or conventional tillage.

Table 2. No-tillage flue-cured tobacco yield, grade index and leaf chemistry as affected by cover crop at Rocky Mount, NC, 1986 and 1987. (Data are means of 2 years unless otherwise indicated).

Cover crop			Tobacco'			
			Chemistry		Grade index[b]	
Type	Fall sowing rate (lb/A)[c]	Yield (lb/A)	Sugar	%TA	1986	1987
Rye	223	1,812c	18.8a	1.7c	42	41
Crimson Clover	25	2,121b	16.4bc	2.2a	37	53
Hairy Vetch	30	2,141b	15.6c	2.4a	42	49
Rye+CC[d]	84 + 15	1,984bc	18.4ab	1.9bc	38	47
Rye+HV[d]	84 + 15	2,061bc	18.8a	1.8bc	36	42
Conventional (no cover crop, normal tillage)		2,425a	19.4a	2.0b	37	SO

[a] Means within a column followed by the same letter are not significantly different as determined by Waller-Duncan t-test (K-ratio = 100)
[b] No significant differences at 5 percent level.
[c] 223 lb = 4 bu, 84 lb = 1.5 hu.
[d] CC = Crimson Clover, HV = Hairy Vetch.

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