The University of Georgia
College of Agriculture
Experiment Stations

Special
Publication No.5

PROCEEDINGS OF THE FIRST ANNUAL SOUTHEASTERN NO-TILL SYSTEMS CONFERENCE

November 29, 1978 Georgia Experiment Station
Experiment, Georgia 30212

Edited by J. T. Touchton and D. G. Cummins

CONTENTS

Sponsored by the Department of Agronomy
University of Georgia College of Agriculture
Experiment Stations, Georgia Station, Experiment, Georgia
O. E. Anderson, *Head*
In cooperation with Departments of Agronomy of Colleges of Agriculture
in Alabama, Florida, Kentucky, North Carolina,
South Carolina, and Tenncssee and thc Soil
Conservation Service, U.S. Department of Agriculture

PREFACE

J. T. TOUCHTON AND G. CUMMINS

No-tillage crop production has received much attention throughout the Southeast during the past few years. Possible advantages of no-tillage farming compared to conventional-tillage farming often cited include: improved erosion control, improved moisture conservation, fewer man-hours required to produce a crop, less time loss between harvesting and planting crops, and energy conservation. These advantages often lead to higher crop yield, improved double-cropping systems, utilization of land once considered unsuitable for row crop production and higher net returns per unit of land area.

Past research on no-tillage farming leaves many questions unanswered. Somc of the most common questions asked about no-tillage systems include 1) what is the impact of no-tillage farming on the environment, 2) what type of mulches should be used and what are their values, 3) is soil compaction a problem in these systems, 4) is in-row subsoiling beneficial, 5) are insects more of a problem than in conventional-tillage systems, 6) what is the inpact of continuous no-tillage on weed populations, and 7) what are the best methods of weed control?

The increased farmer interest in no-tillage cropping systems common to the southeastern states, and the importance of no-tillage farming to agriculture, have created a need for a joint southeastern conference. The objective of this conference is to promote no-tillage systems by providing a means of comunication between research, extension, conservation, and industry personnel, and farmers from Alabama, Georgia, Florida, Kentucky, North Carolina, South Carolina, and Tennessee. The conference will be rotated annually among the seven states involved. Information presented will be of a practical, non-technical nature that should be of value to farmers utilizing no-tillage management systems.

Trade names and company names are included in this publication for the benefit of the reader and do not infer any endorsement or preferential treatment of the product listed by the University of Georgia.

J. T. Touchton is Assistant Professor, Soil Fertility, and D. G. Cummins is Professor, Crop Management, Department. of Agronomy, University of Georgia, Georgia Station, Experiment, Georgia.

NO-TILLAGE, PAST AND PRESENT

S. H. PHILLIPS

INTRODUCTION

No-tillage may be defined as the introduction of seed into untilled soil by opening a narrow slot$, trench or band of sufficient width and depth to obtain seed coverage and soil contact. This system of planting eliminates plowing, discing, harrowing and other conventional methods of seedbed preparation.

Cultivation of row crops is eliminated with the use of herbicides to control unwanted plants or to restrict growth and competition of desirable plants in pasture renovation during the establishment period of the newly seeded crop.

Several terms are commonly used to describe this planting technique: zero till, no-till, zero tillage, direct seeding, direct drilling, sod planting, mulch tillage, stubble planting, ecological systems, and many others. These usually encompass the same basic principles referred to in this publication as no-tillage. Other innovations included in the no-tillage systems include aerial seeding and incorporating seed into fertilizer for broadcast distribution as the fertilizer is applied.

NO-TILLAGE DEVELOPMENT AND ADOPTION

Centuries elapsed between the use of crude, wooden tillage implements and Thomas Jefferson's development of a mathematical formula for the mold-board plow. Charles Newbold, in 1796, received a patent for a cast iron plow and in the early 1830's a steel mold-board plow was introduced. Continued refinement of primary and secondary tillage implements evolved to highly sophisticated, large units which annually disturb the equivalent amount of soil that would be required to build a super highway from New York to California.

Attention turned to no-tillage in the late 1940's with the introduction of plant growth regulators developed during World War 11. Klingman, at North Carolina, reported no-tillage work. Barron, Davidson and Fitzgerald, in 1951, reported successful application of no-tillage techniques. Sprague, in the 1960's, reported pasture renovation using chemicals as a substitute for tillage. Porter, New Zealand, reported on strawberry production followed by Hood and Jeater at Jealott's Hill on small grain. Scharbau of West Germany, in 1968, reported on rape and small grain no-tillage. Hence, worldwide interest in no-tillage and research to provide

---

S. H. Phillips is Assistant Director of Extension for Agriculture, University of Kentucky, Lexington, Kentucky.

the theory for application was well underway.

Refinement of the system can be traced to McKibben, Illinois; Shear and Moschler, Virginia; Triplett and VanDoren, Ohio; Freeman, Kentucky; Lewis and Worsham, North Carolina; and many others in the midwest and southeast.

Speight, North Carolina, reported on double cropping using winter small grains and soybeans using the no-tillage approach.

It would be remiss not to give full credit to innovative farmers for application and further sophistication of the systems and adoption on a commercial scale.

Other crops which have been grown using no-tillage include horticultural crops, tobacco, cotton, grain sorghum, sweet sorghum, sugar cane, sugar beets, popcorn and sweet corn. With continued research it is probable that all crops can be grown using no-tillage methods. Only economics or a lack of imagination will prevent a wide adaptation of this method to all major cultivated species.

It is paradoxical that no-tillage combines the use of modern chemicals with the oldest method of introducing seed into soil, similar to that used by the American Indian in planting maize seed with minimum soil disturbance using crude hand tools.

The no-tillage system was not a sudden development during the 1950-60's, but is a product of continual change in production technology and methods. Researchers and farmers were moving toward less soil preparation, and many concepts were considered.

Wheel track planting is a method where soil is turned or plowed, followed with the planter aligned to plant directly behind and in the tractor tire track. The tire action firmed the soil and eliminated the need for discing and other soil preparation. At the same time a major equipment manufacturer was developing a “plow-plant” system. This system, like wheel track planting, involved plowing of the land and planting without additional seedbed preparation. Farmers did not accept these systems because of a major timing conflict resulting from plowing being delayed until the planting period. Weather risk and peak labor requirements negated the benefits gained by these systems. It should be noted that these systems were part of the technical evolution that made no-tillage more acceptable to producers when the concept was introduced.

The acceptance and adoption of no-tillage by farmers in Kentucky and the southeast in the late 1960’s was influenced by four major factors. If all four factors had not been present, large scale commercial use of no-tillage systems would have been delayed. These four factors were:

1. Late, wet springs which delayed corn and soybean growers planting beyond normal planting dates;

2. Extremely limited available farm labor supply;

3. Introduction of a commercially available no-tillage planter;

4. Labeling and availability of a contact herbicide, Paraquat, which made no-tillage crop production more consistent and successful with the improved control of competing vegetation.

No-tillage evolved into many unforeseen systems. What started as corn grown into killed sod moved into various crops grown in all types of residues and rotations. Perhaps the greatest development will be the multi-cropping systems using no-tillage methods. Double cropped small grains and soybeans, previously practiced only in the south, moved north into Kentucky, Ohio, Indiana and Illinois, and west to Iowa and Nebraska, with the advent of no-till systems.

An agronomic evaluation of no-tillage by researchers, Extension specialists and farmers would list the following major advantages and disadvantages:

Advantages -

Reduction of soil erosion. Wind and water erosion potential dictates land use. Lloyd, Ohio, shows soil erosion can be reduced from 242,000 kg/ha under conventional tillage, to 330 kg/ha under no-tillage on sloping land with high intensity rainfall.

Increased land use. Class II and III land can be used as intensively as Class I land because of reduced water erosion. Individual farmers can increase row crop acreage on land subject to erosion without soil degradation.

Energy conservation. Energy requirements in the production of corn and soybeans can be reduced from 50-75% as compared with conventional planting (Griffith, Purdue).

Less soil compaction. Fewer trips over field and reduction of soil preparation lessen the risk of soil compaction.

Improved timing of crop establishment and planting. Crops may be planted and harvested under a wider range of soil moisture conditions with no-tillage than with conventional methods.

Reduction in irrigation water usage. From 1" to 2" less irrigation water per hectare is required with no-tillage due to reduced evaporation associated with the system. This is an important factor from an economic standpoint and in areas with a depleting soil water supply (Wiese, Texas).

Reduced machinery investment. The need for high horsepower tractors is eliminated with no-tillage; much of that power is required for plowing and discing.

Improved moisture regime. No-tillage generally increases water infiltration rate and reduces erosion. Approximately 20% more soil moisture is available for crop use under no-tillage planting which is sufficient to reduce plant stress during short drought periods.

Disadvantages - -

Soil temperature. Soil temperature tends to run 2-3° lower in no-tillage which is a disadvantage in northern areas because it delays spring planting. Soils have less day-to-night temperature fluctuation under no-tillage, but late spring freezes will injure no-tillage crops to a greater extent than conventional crops due to mulch cover and reduced soil radiation.

Insect activity. Insect numbers and crop damage can be higher than in conventional tillage, and the need for insecticides is greater.

Higher producer-managerial level required. More management ability is needed or must be developed in the no-tillage system than with conventional methods. There are fewer alternatives to correct errors than in conventional systems.

GROTJTH AND POTENTIAL OF NO-TILLAGE

The rapid growth of no-tillage from research plots and a few rows for observation on farms to present acreage was not expected. Farmers tried a few acres and gradually changed to total no-tillage. Others started using no-tillage in double cropping while growing a large part of row crop acreage in conventional tillage. Producers in the middle Atlantic states and the upper southeast now grow 20-30% of all corn acreage no-tillage, and 30-50% of soybeans no-tillage.

It is improbable that no-tillage or any single system of production will be used by growers to the exclusion of all other methods. A conservative estimate is that 60-80% of crop acreage will be planted no-tillage within the next 25 years. The ability to control emerging perennial weed problems, regulation and availability of chemicals, changing economics of crop production, increasing environmental concern for sediment control, cost and availability of energy and world need for food and fiber will dictate the percentage of crops grown no-tillage and the rate of change from traditional methods.

No-tillage is off the drawing boards and is a highly desirable method of crop production with a predictable, steady growth in acreage and numbers of producers world-wide.

Wide interest and adoption of no-tillage has been recorded world-wide, and the potential growth and use of no-tillage is unlimited. It should be recognized that the no-tillage system as it is known today is less than

20 years old, while conventional systems are at least 200 years old. It is impossible to forecast the changes and opportunities that will develop with this important concept of crop production.

No-tillage has application for both the large commercial operator and the small subsistence farmer in developing countries. A farmer without equipment can grow only the acres he has the energy to till, but with no-tillage more food can be produced. R. Lal, International Institute for Tropical Agriculture, 1975, reports similar data on no-tillage maize and grain legumes on tropical soils in Ibadan, Nigeria, and sees widespread adoption in the shifting agricultural systems of West Africa.

Argentine reports from J. Cazenave and others, 1977, support growth potential for South America in no-tillage crop production systems involving maize, soybeans, sunflower and wheat.

No-tillage crop production will be limited only by the imagination of researchers such as those of you in attendance at this conference.

CLEAN WATER IN AGRICULTURE

DWIGHT M. TREADWAY

It is a pleasure to be on your program today. First, let me describe the organization I work for--the Soil Conservation Service. The SCS is part of the U.S. Department of Agriculture. We are a technical agency made up of such disciplines as biologists, engineers, soil scientists, soil conservationists, economists, foresters, and agronomists. Our assistance is provided through local soil and water conservation districts and includes (1) providing technical assistance to help landowners plan and carry out conservation practices on their land, (2) preparing soil surveys and making interpretations, (3) helping units of government solve flood problems, provide municipal and industrial water supply, and provide water-oriented recreational activities, and (4) helping units of government and individuals make sound land use decisions.

Next, I will talk about soil conservation, and this is really the heart of my presentation. I don't plan for us to look back into the dust bowl thirties nor to dwell on the severe erosion that was occurring in the thirties and before. We know about those days, but we must not forget those hard. lessons that those before us learned.

My objective today is to build a discussion on old lessons--the need for sound conservation in a tine when we must produce not only to make a living, but also to truly feed the world.. From this comes two things--first, food production and second, the resultant environmental quality standards for a better life of which clean water is one.

The main work of the Soil Conservation Service and soil conservation districts for the wast 40 years has been to deal with soil erosion to protect the land's ability to produce food and fiber. We and conservation districts are justly proud of what we have helped Georgia's landowners do in conservation. We call our basic program of conservation operations "CO." In this program we provide help to landowners to carry out conservation practices on their land. Our soil survey program, the watershed program, and the resource conservation and development program have all been successful. We can point to many success stories.

In spite of this, today three-fourths of the cropland in Georgia does not have adequate conservation treatment and a large portion of urban and other land uses do not have adequate conservation treatment.

Although these figures are for Georgia, the same story also applies to our neighboring states, and throughout all of the South. Erosion is still in the range of ten to fifteen tons per acre per year from untreated cropland. This is two or three times the minimum necessary to maintain sustained production.

Dwight M. Treadway is State Conservationist, Soil Conservation Service, Athens, Georgia.

Technical assistance to land users through soil conservation districts has done much toward the job of controlling erosion. Last year, the Soil Conservation Service delivered over 90,000 services to landowners in Georgia. The other states around us did the same.

In the last five or six years, the American farmer began to compete in the export market more than ever before. This may prove to be a great thing for agriculture. Exports are not only valuable to the farmer, but they are also equally valuable to the entire economy. Exports create jobs and they also buy things such as oil from the world market that our dollars cannot buy. Therefore, for the past few years agriculture was in a no-program, farm-program situation. The green light was on--plant all you wanted. The new USDA grain reserve program changes this somewhat so there will likely be a dampening effect on total production.

This increase in production and in cropland use came about as a result of decisions made at the national level.

On the other hand, in 1972 Congress said that by 1983 all of the streams and waters in the nation would be fishable and swimmable. The question becomes then, "How do we do both?" How do we increase food supply and at the same time improve water quality?

Nearly half of the 1,000,000 acres of new land that went into crop production in Georgia during the past four or five years has been subject to excessive soil erosion.

In Georgia, we now have 7,000,000 acres of cropland. Only half of it is on prime land. The remainder is subject to severe erosion.

But, we have the potential of adding an additional 7,000,000 acres of cropland without creating serious problems. This can be done by using prime lands now is pasture, woodland, or other uses. The same kind of thing could be done in neighboring states.

Another significant happening in the South is the increased use of irrigation. We are approaching the 800,000-acre-range of irrigation on cropland in Georgia. This is creating a new demand for waterways, terraces, and other erosion control practices.

Up to this point, we have talked about increasing exports in order to balance payments to the extent possible so that we can buy foreign oil. We have discussed the increased use of cropland in the South as a result of that. We have also set the stage for the Federal Water Pollution Act setting forth a national objective that by 1983 we will have fishable and swimmable waters.

Our question now is how well are we doing and how well have we done in the past in terms of protecting our soil resource in order to meet these two apparent conflicting objectives.

In 1976, we helped landowners apply conservation practices on 118,000 acres of cropland out of something like 3,000,000 acres of land needing conservation practices. In 1977, we helped landowners apply conservation practices on 290,000 acres of cropland. This year, we will pass the 600,000 mark. How did we do this? A lot of it came from the use of no-till farming

My message to you today is this. In this time of land use changes and demands for greater food production, we must speed up our application of conservation and improved water quality practices. If we depend on terraces, contour stripcropping, or other traditional practices, we will never get the job done.

The bright star in our program today is no-till farming. No-till offers the best ray of hope that we have for meeting the demands of soil erosion control on farms in the South and still reach the goals of increased food production and improved water quality. We in the Soil Conservation Service are going all out to advocate the use of no-till. There is no other choice.

Sure, we recognize there are still problems, but it is the only tool we have at present for controlling soil erosion on a large area in a relatively short time. So, we ask your help--we ask for your skills, your knowledge, your ideas, your technical competence, your patience, and your understanding. It is the best erosion control tool that has come along lately, and we must use it.

We think no-till has a great future in Georgia and in the South. Research conducted by the University of Georgia and the Southern Piedmont Research Center has been expanded during the past year. We are looking forward to results from this work as well as research from adjoining states. We have good conservation farmers throughout the South who value their topsoil and are interested in keeping it at home.

We are grateful to the people in agriculture, industry, research, and extension for joining together to make this meeting possible. Most of all, we appreciate you fanners and all others who took time to attend this conference.

I hope this meeting will answer many of our questions and move no-till farming a step closer to becoming a science.

With all of us working together we can make no-till become an outstanding success in the South.

MULTIPLE CROPPING - VALUE OF MULCH

RAYMOND N. GALLAHER

INTRODUCTION

Multicropping (growing two or more crops per year on the same land area) has greatest advantage in the tropics and sub-tropics where 12 month growing seasons are not unusual. Since Florida and much of the southeastern U.S. lies in or close to this region, properly managed multicropping systems could result in increased food production by taking advantage of the long growing season. Farmers in Taiwan, for example, successfully use multicropping and routinely grow as many as 5 or more crops per year on the same land. This success by the Taiwan farmers is due in part to the utilization of a year-round favorable growing season and to the use of new technology, including short season crop varieties, ingenious systems for overlapping planting and harvest dates, and proper use of fertilizer and pesticides.

The acreage under multicropping has increased rapidly during recent years in the U.S., the largest agronomic multicropping system being small grain succeeded by soybeans. Climatic conditions in the southeast are such that multicropping should be exploited to the utmost to help meet the demand for agricultural products. Food and fiber production must increase to satisfy the needs of a rapidly growing population in the southeast and to help meet the needs created from national and world competition. Producers in the southeast must make better utilization of their farmland on a year-round production basis to offset increased cost and inflation from land prices, taxes, labor, machinery, interest, irrigation systems and other forms of overhead.

Many multicropping farmers are increasing their chances for success by utilizing no-tillage (the opening of a slot in the soil only sufficiently deep and wide to properly deposit and cover the seed) or no-tillage plus subsoiling, to plant one or more crops in their multicropping system. Multicropping no-tillage farming requires a high level of management that most producers have not experienced. No-tillage has numerous advantages over conventional tillage planting management. No-tillage reduces erosion (18). No-tillage conserves soil moisture when plantings are into a chemically controlled mulch crop and indications are that a more vigorous root system develops to aid in withstanding drought stress (11). No-tillage results in timely planting of crops in succession without delays experienced in conventional seedbed preparation (13). No-tillage reduces the number of farming operations, thus in many cases reducing production cost and conservation of fuel (22). No-tillage results in greater or equal yield of crops (10, 12, 19). No-tillage reduces problems with Lesser Corn Stalk *Borer,* one of the most dreaded insects in the southeast *(2,3).* No-tillage in

---

Raymond N. Gallaher is Associate Professor of Agronomy, Coordinator of Multiple Cropping Research and Director, Agronomy Research Support Laboratory, Department of Agronomy, Wallace Building, University of Florida, Gainesville, Florida, 32611.

conjunction with a good mulch crop can reduce weed problems when compared equally with conventional tillage (12). No-tillage farming has disadvantages as well as the previously mentioned advantages. The disadvantages can be summed up in the fact that this type of farming requires an innovative, highly skilled, and informed farmer who, to be successful, wants to make it work.

Many producers are utilizing no-tillage planters to grow crops in crop residues, mulch crops or sod crops in succession multicropping systems. Because of new no-tillage and no-tillage plus subsoiling equipment and chemical weed control, producers can utilize crop residues, mulch crops and sods to great advantage as mulch for succeeding crops instead of burning or otherwise destroying them as in past management. Mulch materials include anything left on or applied to the soil surface around plants or in which crops are planted into to conserve moisture, moderate soil temperature, control weeds, prevent erosion and to increase crop or plant production capacity. The mulch material may be organic, such as compost, bark, leaves, grass clippings, crop residues, dormant or killed sods, and killed winter cover crops such as small grains and legumes; or it may be inert, such as sand, gravel, pebbles, tinfoil or polyethylene film.

Probably the most important factor to farmers is the fact that properly utilized mulch can result in significant increases in yield of crops (11, 14, 23, 24). The major contributing factors to yield response from use of a mulch is a result of the conservation of soil water (6, 11, 14, 20, 23, 24), from reduced water runoff (1, 4, 14, 16, 24) and increased water infiltration (9, 15, 16). Mulch material prevents loss of water from the soil by evaporation. Soil moisture moves by capillary action to the surface and evaporates if not covered by a mulch. Mulching will prevent crusting of the soil surface, thus improving absorption and percolation of water into the soil and at the same time, eliminating erosion. Soil itself, fertilizers and other chemicals applied to the soil are major contributing sources to agricultural pollution. Losses of soil and chemicals by both water and wind erosion can be reduced to near zero by utilizing mulches in crop production (1, 4, 9, 15, 16, 23). Maintenance of a more uniform soil temperature can be obtained by using mulches in crop production (6, 20, 23). The mulch acts as an insulator that keeps the soil warm during cool periods and cool under intense sunlight. Organic mulches can improve soil structure and tilth. As the mulch decays, the material works down into the topsoil. Decaying mulch can serve as a source of increased cation exchange sites to hold more plant nutrients as well as the addition of nutrients to the soil. Mulch from legumes can furnish substantial quantities of nitrogen (N) and other nutrients to the succeeding crop (17). Good mulches have ‘controlled or reduced weeds (5, 12, 21), increased plant nutrient
the need for tillage operations and thereby reduced soil compaction (7), increased soil aggregation, organic matter and soil N (4), and improved crop stands and reduced production costs (5).

When no-tillage and mulch management are properly incorporated in various multiple cropping systems, advantages of each can assist modern day farmers to be better producers of food and fiber. The objective of this paper is to discuss some examples of mulch management associated with multiple cropping. It will be impossible to cover all aspects of the subject or to cite every research reference on the subject.

SMALL GRAIN RESIDUE FOR A MULCH

Small grain followed by soybeans is the agronomic multicropping system most widely grown in the southeast U.S., and probably in the world About half of small grain plants is crop residue that can be used for a mulch in no-tillage planting of summer annuals. Wheat straw residue averages about 90, 0.67, 0.07, 0.97, and 0.17% dry matter, N, phosphorus (P), potassium (K) and calcium (Ca), respectively (8). A 40 bu/A wheat crop will leave a residue of about 4,080 lb/A containing about 27, 6 and 47 lb/A of N, P_20 and K_20, respectively. Soil erosion can be reduced to a minimum with about 1,700 lb/A of wheat residue on a sandy or sandy loam soil and about 750 lb/A is needed on a clay loam (8).

Interrill erosion can be reduced by 40% with 450 lb/A wheat straw and about 80% by 1,800 lb/A as compared to no mulch (15). Erosion was near zero at higher mulch rates. Water runoff was slightly reduced at the 1,800 lb/A rate. Another study found that 2,000 lb/A of wheat straw decreased soil loss to only 18% but that 4,000 lb/A reduced erosion to less than 5% of the control (16). Runoff velocity reduction by the mulch was the major contributing factor to reduce erosion.

Summary of 3 to 4 years and 4 locations in Georgia of wheat-soybean double cropping yield is found in Tables 1 and 2. Note that system 4, no-tillage of soybeans into wheat straw, is the system in which mulch is utilized. Soybean yield for treatment 4 is equal to soybeans in all other systems including monocropped full season soybeans, treatment 3.

Table 2 shows fertility response of wheat soybean double cropping at the same soil site for 3 years. Effective use of preemergence and post-emergence herbicides, narrow rows, timeliness of harvesting of wheat and planting of soybeans into the wheat straw has essential to obtain these yields.

WINTER ANNUAL CROPS FOR A MULCH

These multicropping systems include growing of wheat, rye, oats, barley, ryegrass, vetch, lupin and clovers that are chemically killed and converted to a mulch crop at or before planting of the succeeding crop. In some instances a small grain and legume mixture is grown as the mulch crop. No-tillage corn planted into Harry vetch and crimson clover mixtures produced grain yields comparable to those obtained by the application of 100 lb/A N in a University of Delaware study (17). Approximately one-third of the total N from mulch covers was released to the corn in a single season, with about 90% of this derived from cover crop top growth. Mulch covers were less reflective than the bare soil surface, resulting in mulch surface temperatures up to 10 C higher than those with unprotected soil surfaces. Temperatures immediately below the mulch covers were more than 10 C lower than those of the surface of unprotected soil.

Ten years of research at Clemson University has shown that vetch and rye mulch averaged 3.11 inches less water runoff per year, 2.38 tons/A less soil erosion loss per year and that yield was equal or greater than plowed unmulched corn (4). This study showed that the degree of soil aggregation increased after 10 years in mulched treatments but was reduced significant y in the plowed check treatment. Mulched treatment of vetch and rye inc eased soil organic matter from 1.5 to 2.6%, and soil N from 0.047 o 0.069% after 10 years of continuous corn, while the plowed check remained at 1.2% organic matter and 0.036% N.

In a Georgia study, no-tillage of corn and soybeans showed that using the rye crop for a mulch as opposed to removal for hay resulted in 52 bu/A more corn and 13 bu/A more soybeans (11). This was a 46% increase for corn and 30% increase for soybeans. Conservation and better utilization of moisture was the major attributing factor to better yield from the rye mulch torn and soybeans. Similar studies in Florida of no-tillage plus subsoiling into rye mulch versus conventional tillage resulted in significantly greater soybean and grain sorghum yields, taller plants, greater crop populations and fewer weeds (12).

Tables 3-5 give yield data from the University of Florida on growth of crops planted in winter annuals grown for a mulch. These data illustrate many of the benefits of no-tillage and a mulch as discussed in the introduction. No-tillage plus subsoiling resulted in higher yield than regular no-tillage for corn, grain sorghum and sunflowers (Table 3). In a similar study corn yield was 133 bu/A from no-tillage plus subsoil in rye for mulch and 114 bu/A for conventional tillage plus subsoil.

Harry vetch provided almost all the N required for corn and grain sorghum Table 4), and no-tillage of these crops into the vetch gave higher yield than conventional tillage. Data in Table 5 illustrates the difference in N requirements of grain sorghum depending on the mulch or green manure crop preceeding the grain sorghum.

SOD CROPS FOR A MULCH

Sod crops of perennial grasses, such as orchardgrass, bluegrass, fescue, bermudagrass and bahiagrass have been used as mulch crops for no-tillage corn more than any other summer annual. More problems have been encountered from the warm season sod crops than cool season. In general corn production has been good in these sod crops if the sod is killed effectively with herbicides so that the sod crop does not compete with corn for water and fertilizer. Properly managed sods can be beneficial as a mulch for growing no-tillage corn.

A Virginia study (14) showed that mulched treatments, whether of undisturbed killed orchardgrass sod on no-tillage plots or of wheat straw on conventional plots, gave the lowest values for water runoff and highest values for soil water content and yield of corn. Soil water conserved by the mulches increased corn yield by 39 bu/A. Another Virginia study produced an average of 103 bu/A corn on no-tillage in orchardgrass versus 80 bu/A from conventional tillage (23). The higher yield with 23 bu/A more corn from no-tillage versus conventional was attributed to less water runoff, less evaporation, and negligible erosion. This resulted in more efficient use of water for crop production. Kentucky researchers have shown that killed bluegrass sods have higher soil water content and lower soil temperatures in no-tillage corn studies (6). In an Ohio study, tall fescue killed and used for a mulch in no-tillage corn management produced 3 times as great a yield effect for corn as conventional tillage treatments (24).

In a Georgia study, the author found that no-tillage of corn in a field of about 50% fescue and 50% bermudagrass averaged 10 bu/A less than conventional tillage treatments. Conventional tillage corn ranged from 128 to 154 bu/A with an average of 143 bu/A and no-tillage into the sod ranged from 121 to 138 bu/A with an average of 133 bu/A. Incomplete control of the bermudagrass resulted in competition of the sod with the no-tillage corn.

Grain sorghum tended to yield about the same for no-tillage versus conventional tillage in a bahiagrass sod (Table 5). Bahiagrass was effectively controlled by preapplication of Roundup and post direct application of Paraquat in this study.

SUMMARY

Crop residues, mulch crops, and sod crops can be utilized in numerous multiple cropping systems. Effective management of mulches requires knowledge of how to farm by the no-tillage method and how to effectively utilize contact herbicides such as Paraquat and Roundup to kill and/or convert crop residues, mulch crops and sod crops into a mulch. Properly managed mulches in multicropping no-tillage farming are valuable because of reduced erosion and pollution, moisture conservation, lower soil temperatures in warm weather, higher soil temperatures in cold weather, being a source of soil organic matter and plant nutrients, reduced weed growth, reduced Lesser Corn Stalk Borer infestation, improved chemical and physical soil properties, improvement in timeliness for planting of crops, fewer tillage operations, and improved crop yield.

REFERENCES

1. Ackerman, F. G. 1944. Stubble-mulching and subsurface tillage. Soils and Fertilizers. 7(2):215-216.
2. All, J. N. and R. N. Gallaher. 1976. Insect infestation in no-tillage corn cropping systems. Georgia Agr. Res. 17(4):17-19.
3. All, J. N. and R. N. Gallaher. 1977. Detrimental impact of no-tillage corn cropping systems involving insecticides, hybrids and irrigation on lesser corn stalk borer (Elasmopalus lignosellus) infestations. J. Econ. Entomol. 70(3):361-365.
4. Beale, O. W., G. B. Nutt and T. C. Peele. 1955. The effects of mulch tillage on runoff, erosion, soil properties, and crop yields. Soil Sci. Soc. Amer. Proc. 19:244-247.
5. Bickers, Jack. 1961. Big year ahead for mulch planting. Farm J. 85: 33,34,39.
6. Blevins, R. L. and Doyle Cook. 1970. No-tillage its influence on soil moisture and soil temperature. Univ. of Kentucky, Coll. of Agric., Agr. Exp. Sta., Lexington. Progress Report 187.

7. Eagles, Dow and T. C. Maurer. 1963. Mulch planting pays dividends in the southeast. Crops and Soils. 15:7-9.

8. Fenster, C. R., R. H. Follett and E. J. Williamson. 1978. Best use of cr-op residues. Crops and Soils. 30(9):10-13.

9. Force, D. W. 1960. Anchored mulches will control wind erosion. Crops and Soils. 13:23.

10. Gallaher, R. N., L. R. Nelson and R. R. Bruce. 1976. Double cropping wheat and sorghum forage. Georgia Agr. Res. 17(4):9-12.

11. Gallaher, R. N. 1977. Soil moisture and yield of crops when no-till planted in rye. Soil Sci. Soc. Amer. J. 41:145-147.

12. Gallaher, R. N. 1978. Benefits of killed rye for a mulch in no-tillage cropping systems. Southern Weed Sci. Soc. Proc. 31:127-133.

13. Hoeft, R. G., et. al., 1975. Double cropping in Illinois. Univ. of Illinois at Urbana-Champaign, Cooperative Extension Service. Circular 1106.

14. Jones, J. N., Jr., J. E. Moody and J. H. Lillard. 969. Effects of tillage, no-tillage, and mulch on soil water and plant growth. Agron. J. 61:719-721.

15. Lattanzi, A. R., L. D. Meyer and M. F. Baumgardner. 1974. Influences of mulch rate and slope steepness on interrill erosion. Soil Sci. Soc. Amer. Proc. 38:946-950.

16. Mever, L. D., W. H. Wischmeier and G. R. Foster. 1970. Mulch rates required for erosion control on steep slopes. Soil Sci. SOC. Amer. Proc. 34:928-931.

17. Mitchell, W. H. and M. R. Teel. 1977. Winter-annual cover crops for no-tillage corn production. Agron. J. 66:569-573.

18. Moldenhauer, W. C. and M. Amemiya. 1969. Tillage practices for controlling cropland erosion. J. Soil and Water Conser. 24(1):19-21.

19. Nelson,L. R., R. N. Gallaher and R. R. Bruce. 1975. Corn forage yields in double-cropping systems. Georgia Agr. Res. 17(2):26-30.

20. Onderdonk, J. J. and J. W. Ketcheson. 1973. Effect of stover mulch on soil temperature, corn root weight, and phosphorus fertilizer uptake. Soil Sci. Soc. Amer. Proc. 37:904-906.

21. Peters, R. A. 1970. Corn without tillage, when, where, and how to use the no-till system. Agway Cooperator. May issue, pp. 12-14.

22. Phillips, S. H. and H. M. Young, Jr. 1973. No-Tillage Farming. Reiman Associates, Inc., 733 North Van Buren Street, Milwaukee, Wisconsin. 53202.

23. Shanholtz, V. O. and J. H. Lillard. 1969. Tillage system effects on water use efficiency. J. Soil and Water Conser. 24(5):186-189.

24. Van Doren, D. M., Jr. and G. B. Triplett, Jr. 1973. Mulch and tillage relationships on corn culture. Soil Sci. Soc. Amer. Proc. 37:766-769.

TABLE 1. AVERAGE OF THREE OR FOUR YEARS AND THREE LOCATIONS (CALHOUN, GRIFFIN AND PLAINS, GA.) OF DOUBLE CROP WHEAT-SOYBEANS.

SOYBEANS			AVERAGE YIELD	
System Following	Planted	Tillage	Wheat	Soybeans
			ton DM/A	bu/A
1. Wheat forage	early	no	3.0	32
2. Wheat forage	early	yes	3.0	28
3. No-crop	early	yes	-	31
4, Wheat grain	late	no	45.0	31
5. Wheat grain	late	yes	45.0	31

TABLE 2. THREE YEAR AVERAGE YIELD OF WHEAT-SOYBEAN MULTICROPPING FROM FERTILIZATION ON A CECIL SCL AT GRIFFIN, GA.

Treatment	Tillage		Annual Fertility		Yield		
	Wheat	Soybeans	Wheat	Soybeans	Wheat	Soybeans	Total
			N-P-K			bu/A	
1	yes	no	0-0-0	0-0-0	15 d	16 d	31 d
2	yes	no	67-0-0	0-0-0	39 c	29 c	68 c
3	yes	no	67-65-125	0-0-0	43 a	36 b	79 b
4	yes	no	67-130-250	0-0-0	50 a	39 a	89 a

TABLE 3. CORN, GRAIN SORGHUM, AND SUNFLOWERS PLANTED NO-TILLAGE INTO RYE FOR A MULCH IN 1978 AT WILLISTON, FLORIDA.

Crop	Variety	No-Tillage	No-Tillage plus subsoil	Difference	% Increase
Corn	Funks G4507	89 bu/A	100 bu/A	11 bu/A	12
Sorghum	Grower ML135	46 bu/A	72 bu/A	26 bu/A	57
Sorghum	Dekalb BR54	27 bu/A	69 bu/A	42 bu/A	156
Sunflower	Sungrow 380*	358 #/A	914 #/A	556 #/A	156

* Sunflower data was in cooperation with Or. Brian A. Bailey.

TABLE 4. GRAIN AND FORAGE YIELD FOLLOWING HARRY VETCH KILLED FOR A MULCH (M) OR USED AS A GREEN MANURE (GM). AVERAGE OF 1977 and 1978 AT THE UNIVERSITY OF FLORIDA.

Tillage	Nitrogen #/A 0	75	150	average
	Dekalb BR54 Grain Sorghum bu/A			
no (M)	62	71	72	68
yes (GM)	49	53	57	53
X̄	56	62	65	
	Dekalb BR54 Grain Sorghum ton dry matter/A			
no (M)	4.45	4.97	4.97	4.80
yes (GM)	3.52	3.86	4.03	3.80
X̄	3.99	4.42	4.50	
	Dekalb XL75A Corn ton dry matter/A			
no (M)	3.65	3.85	4.05	3.85
yes (GM)	2.53	2.65	2.63	2.60
X̄	3.09	3.25	3.34	

TABLE 5. YIELD OF DEKALB BR54 GRAIN SORGHUM PLANTED INTO VARIOUS CROPS THAT ARE USED FOR A MULCH (NO-TILLAGE PLUS SUBSOIL) OR GREEN MANURE IN 1978 AT THE UNIVERSITY OF FLORIDA. (MULCH, M. GREEN MANURE, GM.)

Tillage	Nitrogen #/A 0	25	50	100	200	X̄
			bu/A			
	cover crop--Pensicold bahiagrass					
no (M)	18	32	53	59	73	47
yes (GM)	19	32	66	67	67	50
X̄	19	32	60	63	70	
	cover crop--Wrens Abruzzi Rye					
no (M)	18	46	70	83	85	60
yes (GM)	20	46	57	81	74	56
X̄	19	46	64	82	80	
	cover crop--Frost Lupin					
no (M)	42	62	72	72	70	64
yes (GM)	65	77	86	70	69	73
X̄	54	70	79	71	70	
	cover crop--none, winter fallow					
no	18	50	65	79	86	60
yes	35	58	68	86	86	67
X̄	27	54	67	83	86	

INSECT RELATIONSHIPS IN NO-TILLAGE CROPPING

J. N. ALL

Insect relationships in several types of no-tillage (NT) cropping systems have been studied in Georgia for the past 5 years. UGA and USDA-SEA agronomists and plant pathologists have been involved in this research and their cooperation is acknowledged. Cultural practices such as various planting dates, irrigation, subsoiling, pesticides (including herbicides, insecticides, and nematocides), fertilization, etc. were studied in NT systems to determine their influence on insect populations. These were primarily noncontinuous types of NT systems, and a tillage operation usually occurred every 1-2 years during a multicrop sequence. Usually the NT system was compared directly to a conventional tillage (CT) program that differed only in the tillage operation. Research also has been conducted to determine the causes responsible for the phenomena observed in NT.

We found that various insects are enhanced, deterred, or not affected in NT ecosystems. Over the last 2 years, infestations of the Southern corn billbug, Spenophorus callosus (Oliver), have been much higher in NT than CT in early season plantings of corn, Zea mays L. Practices such as irrigation and subsoiling did not influence infestations in the NT and CT plots, but selected insecticides reduced damage in both tillage systems. However, no insecticide treatment reduced infestations below economic thresholds in NT. It is known that these types of severe infestations often occur in fields having nutgrass, Cyperus rotundus L. (this was present in our tests) and other weeds, thus growers should be concerned about billbug infestations in these type areas when using NT.

Anotner problem in NT corn is the insect transmitted virus diseases maize chlorotic dwarf (MCD) and maize dwarf mosaic (MDM). Epiphytotics of either disease often are associated with johnsongrass, Sorghum halepense (L.)(Pers.), since the virus overwinters in rhizomes of the weed. Even when johnsongrass is in low levels the diseases can be severe in NT fields because johnsongrass seedlings are often present at the time NT corn is planted. In NT many contact herbicides do not suppress johnsongrass seedlings as well as planting time tillage operations and inoculum is available in NT for vector transmission even as corn is germinating. We have found that suppression of johnsongrass with certain systemic herbicides decreases the diseases in NT. Also systemic insecticides carbofuran and aldicarb control leafhopper vectors of MCD and reduce virus transmission in NT. Use of disease resistant hybrids is another method that can be used to suppress virus damage. However, integrated use of all these techniques has proven the best procedure for managing virus diseases in NT and can result in substantial yield increases.

J. N. All is Associate Professor of Entomology, Department of Entomology, University of Georgia, Athens, Georgia.

We are concerned about increased damage in NT by certain stored grain insects, especially in corn planted in the stubble of small grains. Sampling indicates that field infestations of sap beetles (Nitidulidae), maize weevil complex (Sitophilus spp), and grain beetles (Tenebrionidae) occur in unharvested small grains (NT residue) and these populations move into corn prior to harvest. Other insects that have higher infestations in NT include spittlebugs, Prosapia spp, (nymphal feeding on brace roots) and the ring-legged earwig, Euborellia annulipes (Lucas), (in harvest stage ears of corn), but damage appears negligible.

One of our most interesting findings is that infestations of lesser cornstalk borer, Elasmopalpus lignosellus (Zeller) are consistently reduced in NT. This has been observed in corn, sorghum, and soybeans by us and others. Research suggests that this occurs primarily from diverse behavior of larvae in NT as compared to CT rather than a detrimental effect on its biology. Several types of experiments all indicate that larvae are facultative pests in NT. They feed on the residues of former crops and don't attack corn unless it is encountered in their migrations. Thus, NT crop residues act as a diluting system for lesser cornstalk borer populations by providing an abundance of an alternate food source on which larvae can survive. In CT fields no feeding material other than corn is available and larvae must find and attack the seedlings or they will perish.

Fall armyworm, Spodoptera frugiperda (J. E. Smith), infestations of late planted corn and sorghum are reduced in NT as compared to CT. This occurs only for a short period when seedlings have not yet grown above the NT residues. Research indicates that two factors are involved (1) reduced oviposition by fall armyworm moths in NT and (2) increased predation of young fall armyworm larvae in NT. However, the infestations greatly increase as seedlings grow above NT residues and damage ultimately becomes nearly as great as in CT when fall armyworm populations are high.

This short lag in population buildup by fall armyworm in NT corn/sorghum may have practical importance for controlling infestations. We currently are investigating insecticide strategies that utilize reduced spray schedules and rates in NT in order to de elop more economically efficient management systems for fall armyworm in late planted crops.

Most insects that attack older corn have similar populations in NT as in CT. This includes stalk borers European corn borer, Ostrinia nubilalis (Hubner), and the Southwestern corn borer, Diatraea grandiosella (Dyar). We have noted no significant differences between NT and CT in the number plants attacked or lodging by either insect in several tests conducted over the past 4 years. Ear damage by the corn earworm, Heliothis zea (Boddie), fall armyworm, and European corn borer in NT has also been similar to CT.

We have been studying the influence of NT on beneficial insect populations including predators such as ground beetles (Carabidae), tiger beetles (Cincindelidae), and others. These biological control agents are important regulators of pest insects and our sampling indicates that their populations often are several fold higher in NT than CT. A major objective of most pest management systems in agriculture is to develop ways to enhance activities of biological control agents and our results indicate that NT promotes development of favorable environments for many predatory insects.

Observations indicate that higher predator populations in NT reduce fall armyworm levels on young corn and we are currently investigating this on other pests also.

Our research to date emphasizes the fact that insect relationships in NT cropping systems often differ from CT and that each species must be studied individually in order to develop a collective conclusion on overall pest potential in NT. In general, noncontinuous NT systems that have some form of tillage operation within a 1 or 2 year cropping sequence do not appear to develop greater insect infestations than CT systems planted at the same time. However, our research indicates that insect pest management will be a primary concern in multicrop NT systems where crops are planted later than normal.

Pest management in NT must be based on sound knowledge of pest bionomics in NT ecosystems. Direct control methods should be used only when necessary and be precluded by use of cropping practices in NT that, if are not detrimental to pests, are at least not conducive to population buildups. Use of NT practices that enhance biological control factors should be encouraged. When direct suppression of pests is necessary, the control strategies should be founded on an understanding of (1) effective techniques for pest suppression and their costs, (2) rapid sampling procedures that accurately define current pest levels, (3) damage potential and economic impact of specified pest levels, and (4) impact of pest control methods on biological control agents and other factors in NT ecosystems. With this knowledge, action thresholds can be defined for specified pest populations and the most effective and efficient control methodology recommended.

CONSERVATION TILLAGE SYSTEMS AND THEIR CONTROL OF WATER EROSION IN THE SOUTHERN PIEDMONT[1]

G. W. Langdale, A. P. Barnett, and J. E. Box, Jr.[2]

INTRODUCTION

Soil erosion has been considered a serious hazard to row crop production on sloping cultivated Piedmont lands since the early 1930's. Soil erosion induced by conventional tillage causes soil management problems. In the 1940's Adams (1) observed yield reduction of 34 to 40% for row crops (cotton and corn) on Southern Piedmont soils (Capability Class IV land) where the top 15 cm (6 inches) had been eroded by water. Langdale et al. (5) recently observed a similar 40% corn yield reduction, even though modern fertilizers, herbicides, and improved varieties have increased corn yields more than 100% in the past 30 years.

Sediment from soil erosion has recently been identified as our most serious pollutant (8), and it serves as a carrier of agrichemicals. In the Southern Piedmont the source of most farm-transported sediment is conventionally tilled, row cropped land (3). Barnett and Hendrickson (2) demonstrated the hazards of continuous tilling cotton for 20 years. Their annual soil losses from runoff plots ranged from 11 to 119 metric tons/ha (5 to 53 tons/acre) on Capability Class III land. They concluded that summer thunderstorms account for 25% of the annual rainfall and cause 56% of the annual runoff as well as 86% of the annual soil loss. Willis and Evans (13) estimated a current monetary value of $59.00/ha ($24.00/acre) for the major nutrients (N, P, and K) contained in the generally accepted natural soil loss of 11.2 metric tons/ha/yr (5.0 tons/acre/yr).

This paper describes the effects of recent conservation tillage procedures on runoff and sediment transport from rainfall simulator plots and small upland watersheds at the Southern Piedmont Conservation Research Center. Both plots and watersheds were located primarily on eroded Cecil sandy loam soil *(Typic Hapludults)* with slopes ranging from 3 to 7% (9). Tillage and cropping sequences used on these research sites are given in Table 1. Summer annuals, either soybeans *(Glycine max* L. Merr.) or grain sorghum *(Sorghum vulgare* Pers.) followed small grain-barley *(Hordeum vulgare* L.) or rye *(Secale cereale* L.), which provided a mulch upon harvest.

---

[1] Contribution from Southern Piedmont Conservation Research Center, Watkinsville, GA 30677, Agricultural Research, Science and Education Administration, U. S. Department of Agriculture, in cooperation with the University of Georgia Experiment Station.

[2] Soil Scientist, Agricultural Engineer, and Soil Scientist, respectively, U. S. Department of Agriculture, Watkinsville, GA 30677.

Table 1. Tillage treatments, cropping sequence, slope, ana crop row orientation on rainfall simulator plots and watersheds.

Tillage*	Crop Sequence	Slope	Row Orientation
		%	
	Rainfall Simulator Plots		
CT/NT	Comb. Rye/Soybean	6	Contour
CT/NT plus	Grazed + Comb. Rye/Soybean	6	Slope
	Conservation Watershed (Terraced)		
CT/CT	Plowed down Rye/Soybean	1 - 3	Contour
NT/NT	Combined Barley/Grain Sorghum	1 - 3	Contour
	Nonconservation Watershed (Nonterraced)		
CT	Fallow/Soybean	2 - 7	Contour
NT/NT	Comb. Barley/Grain Sorghum	2 - 7	Slope

* CT = conventional till; NT = no-till; NT plus = no-till plus.

Rainfall Simulator Plots

All rainfall simulator tests (7) were performed on 6% slopes with an average K value of 0.25. Simulated rainfall was applied in 12.7-cm increments at a constant rate of 6.4 cm/hour (erosion index, EI, = 174 metric tons-m/ha). Unless otherwise specified, total rye residues averaged approximately 2.5 metric tons/ha with plot lengths of 10.7 m. The standard 6-cm fluted coulter (no-till) and no-till plus (10, 11), as well as conventional tillage treatments, were imposed'on plots. The no-till plus implement utilizes a spring-loaded fluted coulter, a 5.0-cm wide chisel, and a slot filler tine (10, 11). This reduced tillage treatment was in-row chiseled 20 cm deep.

Conservation Watershed

One Southern Piedmont Conservation Research Center watershed is located on 3.0% sloping land with parallel terraces (25.6 m apart) and bisecting grass waterways behind flumes (12). This watershed was 1.26 ha in size and referred to as P-3. Three consecutive years of conventionally-tilled soybeans with fall-planted rye (green manuring) were grown (October 1972 to October 1975) on this watershed (Table 1). Three consecutive years (October 1975 to October 1978) of continuous double crop no-tilling of barley and grain sorghum followed.

Nonconservation Watershed

Another Southern Piedmont Conservation Research Center watershed, P-1, is located on 2.0 to 7.0% sloping land without terraces or grass waterways (6). This 2.71-ha watershed was planted to soybeans using conventional tillage methods for two consecutive years. The watershed was fallowed between November and April each year. Rows were oriented approximately parallel to ground contours. After harvesting the second soybean crop, a 0.28-ha grassed waterway 11 m wide was established before no-till double cropping barley and grain sorghum continuously for two consecutive years. Rows of both of these crops were oriented up- and downhill to permit herbicide application parallel to the grass waterway.

DISCUSSION

Rainfall Simulator Plots

Cumulative runoff response to tillage during low antecedent soil moisture is presented in Fig. 1. Excessive runoff (72%) associated with the tilled-fallow plots shows how vulnerable clean till soil is to natural high-intensity storms (2). With crop residue mulch (standing rye stubble plus combine residues) no-till practices created surface conditions that reduced runoff volume (56%). The combined effect of chiseling 20 cm deep (no-till plus) and a rye residue mulch almost eliminated runoff (5%) when antecedent soil moisture was low. However, runoff data in Fig. 2 and Table 2 suggest that "in-row chiseling" associated with the no-till plus treatment diminishes in importance as soil water, slope length, and soybean canopy increase. Slope length is probably the most important parameter, because the chances are remote for high-intensity rainstorms occurring when antecedent soil moisture is high after soybean canopy development in double crop systems (6). For the no-till plus treatment in-row chiseling did not affect runoff after canopy development under high antecedent soil moisture and rye residues. The interactive effects of rye residue quantity and soybean canopy development did not appear to alter runoff values for no-till treatment (Table 3).

Table 2. Runoff and sediment losses from rainfall simulator plots planted to soybeans with the no-till plus* system and from tilled fallow at low and high antecedent soil moisture.

Slope Length, m	Rye Stubble Low**	Rye Stubble High	3/4 Canopy Low	3/4 Canopy High	Tilled Low	Tilled High
			Runoff, %			
10.7	4.2	36.7	19.2	62.0	71.5	87.5
21.4	12.9	67.4	43.8	80.8	85.0	91.8
			Sediment, metric tons/ha			
10.7	0.05	0.40	0.09	0.22	36.3	39.2
21.4	0.29	0.72	0.11	0.18	50.1	39.4

* The no-till plus treatment utilized a fluted coulter and in-row chiseling (20 cm deep on Cecil scl soil with 6.0% slope.)

** Antecedent soil moisture was considered low during initial rainfall simulator runs, which began at average soil moisture. Antecedent soil moisture was considered high during the second runs made within 24 hours on wet soil.

Table 3. Runoff and sediment losses from low antecedent soil moisture plots planted to soybeans with the no-till system in varying quantities of rye mulch.

Canopy	Rye Residue, metric tons/ha			
	2.46**	3.02	3.58	4.70
	Runoff, %			
Rye Stubble	57.1	57.6	57.6	54.2
Half-Canopy	57.7	58.6	59.7	51.4
Full-Canopy	58.2	52.2	56.6	58.1
	Sediment, metric tons/ha			
Rye Stubble	0.11	0.09	0.07	0.07
Half-Canopy	0.11	0.09	0.09	0.09
Full-Canopy	0.05	0.07	0.05	0.09

* The no-till treatment utilized a 6-cm fluted coulter without additional tillage.

** Standing rye stubble only.

Both of the reduced tillage treatments provided adequate soil erosion control for soybean production on Southern Piedmont soils (Fig. 3, Tables 2 and 3). Rows may even be oriented up- and downhill on slopes of <6% and slope lengths <20 m. Harrold and Edwards (4) effectively controlled soil erosion during a 100-year frequency storm on a 21% sloping watershed with no-till corn. The sediment loss (-40 metric tons/ha) associated with the tilled-fallow treatment in Fig. 3 approximates the average annual sediment values of Southern Piedmont watersheds with similar slopes (6). Since the simulated rainfall represented approximately one-third of the annual rainfall energy, this shows the obvious importance of residue mulches for controlling erosion. Although sediment yield values reported for the no-till treatment are small (Table 3), differences associated with rye residue quantity and soybean canopy are large enough to change C-values (Fig. 4) of the universal soil-loss equation (14).

Conservation Watershed

Hydrologic data representing the conservation watershed are presented in Table 4 and Fig. 5. We concluded that tillage and residue management provided the only real difference in runoff and soil erosion. Although runoff (12%) and soil erosion (2.8 metric tons/ha/yr) were controlled within respectable limits during the tillage period with conservation practices, no-tillage double crop management reduced runoff and erosion slightly more than 50 and 90% respectively. Even on a per unit erosion index (EI), the soil erosion reduction is still near 90%. Average annual rainfall was not highly different (123.3 vs 118.5 cm) between tillage periods. During the no-till period, approximately 80% of the runoff occurred during seasons 3 and 4 (Table 4). This was a period of minimum ground cover at the pre-tiller small grain stage.

Table 4. Hydrologic parameters associated with tillage on a conservation watershed.

Season*	Rainfall	Erosion Index	Runoff Events	Runoff	Sediment
	cm	metric tons-m/ha	no.	cm	metric tons/ha
		Tillage Period			
1 (May-Jul)	33.6	289	4	4.2	2.06
2 (Aug-Oct)	21.7	107	2	1.3	0.25
3 (Nov-Jan)	30.3	142	4	2.8	0.11
4 (Feb-Apr)	37.7	201	5	6.4	0.39
Avg. Annual Mean	123.3	739	15	14.7	2.81
		No-Till Period			
1 (May-Jul)	30.4	122	1	0.5	0.02
2 (Aug-Oct)	30.1	188	3	0.8	0.01
3 (Nov-Jan)	34.0	105	5	3.3	0.11
4 (Feb-Apr)	24.0	62	1	1.7	0.05
Avg. Annual Mean	118.5	477	10	6.3	0.19

Most of the runoff during the tillage period occurred during seasons 1 and 4. However, slightly more than 70% of all soil erosion occurred during season 1 of the tillage period (Table 4). Sediment yield data is expressed on a monthly basis in Fig. 5 to emphasize the erosion hazard during season 1 with conventional tillage practices.

Nonconservation Watershed

Hydrologic data are given in Table 5. Except for extremes during the tillage period, data trends were similar to those of the conservation watershed. During the tillage period, soil erosion was a disaster (22.2 metric tons/ha). Cumulative monthly sediment yields are given in Fig. 6 to show how closely high energy rainfall coincides with single cropped, conventional tilled soybeans. Sixty percent of the annual runoff and 85% of the soil erosion occurred during this season. During the no-tillage period, similar percentages of all runoff and soil erosion occurred in season 4. Flume-measured runoff and sediment were reduced 2.5- and 194-fold by continuous no-tilling. These wide differences clearly suggested that no-till systems may be used in the Southern Piedmont with strategically located grass waterways to minimize runoff and sediment transport on slopes up to 7%. Results during the tillage period on this watershed were analogous to those observed on most current conventionally-tilled farms in the Southern Piedmont.

Table 5. Hydrologic parameters associated with conventional and no-till nonconservation watersheds.

Season	Rainfall	Erosion Index	Runoff Events	Runoff	Sediment
	cm	metric tons-m/ha	no.	cm	metric tons/ha
		Tillage Period			
1 (May-Jul)	38.1	389	10	13.3	22.22
2 (Aug-Oct)	20.2	115	4	2.3	0.86
3 (Nov-Jan)	37.0	115	6	2.0	0.51
4 (Feb-Apr)	32.3	138	6	4.5	2.67
Avg. Annual Mean	127.6	757	26	22.1	26.26
		No-Till Period			
1 (May-Jul)	32.5	262	3	1.5	0.02
2 (Aug-Oct)	20.5	119	2	0.1	0.01
3 (Nov-Jan)	27.3	63	3	0.5	0.01
4 (Feb-Apr)	43.5	172	8	6.6	0.10
Avg. Annual Mean	123.8	616	16	8.7	0.14

CONCLUSIONS

Reduced tillage is essential for effective control of runoff and soil erosion during high energy rainfall probability months (May - July) on >3.0% sloping row crop land in the Southern Piedmont. All of the reduced tillage procedures used adequately controlled soil erosion from rainfall simulator plots and watersheds. The no-till plus treatment reduced runoff to 20% (average for low and high antecedent soil moisture rainfall simulator runs on 10.7-m slope lengths) which is a precedent in conservation tillage. In double cropped-reduced tillage systems, slope length was extremely important, whereas average percent slope and crop canopy or residue quantity were only mildly important in runoff control. If continuous reduced tillage systems are used, crop rows may be oriented up- and downhill with an occasional properly-located grass waterway.

REFERENCES

1. Adams, William E. 1949. Loss of topsoil reduced crop yield. J. Soil and Water Cons. 4:130.

2. Barnett, A. P., and B. H. Hendrickson. 1960. Erosion on Piedmont soils. J. Soil and Water Cons. 26:31-34.

3. Carreker, J. R., S. R. Wilkinson, A. P. Barnett, and J. E. Box, Jr. 1977. Soil and water management systems for sloping lands. U.S. Dep. Agr. ARS-S-160. 76 pp.

4. Harrold, L. L., and W. M. Edwards. 1972. A severe rainstorm test of no-till corn. J. Soil and Water Cons. 27:30.

5. Langdale, G. W., J. E. Box, Jr., R. A. Leonard, A. P. Barnett, and W. G. Fleming. 1979. Corn yield reduction on eroded Southern Piedmont soils. J. Soil and Water Cons. *(In review)*

6. Langdale, G. W., A. P. Barnett, R. A. Leonard, and W. G. Fleming. 1979. Reduction of soil erosion by the no-till system in the Southern Piedmont. Trans. ASAE *(Accepted for publication in early 1979)*

7. Meyer, L. D., and D. L. McCune. 1958. Rainfall simulator for runoff plots. Agr. Eng. 39:644-648.

8. Minimum Tillage. 1975. A preliminary technology assessment. U. S. Dep. Agr. Office of Planning and Evaluation. 34 pp.

9. Perkins, H. F., and F. T. Ritchie, Jr. 1968. Physical features of Georgia. J. Soil and Water Cons. 23:97-100.

10. Pitts, Nadine S. 1978. New design for no-till planter. Soil Cons. (USDA) 43(9) 9-11.

11. Reardon, J. C. 1978. Plant nutrient losses in runoff under simulated rainfall using various ground covers. M.S. Thesis, University of Georgia.

12. Smith, C. N., R. A. Leonard, G. W. Langdale, and G. W. Bailey. 1978. Transport of agricultural chemicals from upland Piedmont watersheds. U.S. Environmental Protection Agency, Athens, GA and U.S. Department of Agriculture, Watkinsville, GA. Final Report on Interagency Agreement No. D6-0381. Pub. No. EPA-600/3-78-056. 364 pp.

13. Willis, W. O., and C. E. Evans. 1977. Our soil is valuable. J. Soil and Water Cons. 32:258-259.

14. Wischmeier, W. H., and D. D. Smith. 1965. Predicting rainfall-erosion losses from cropland east of the Rocky Mountains. Agric. Handbook No. 282, USDA, U.S. Government Printing Office, Washington, DC. 47 pp.

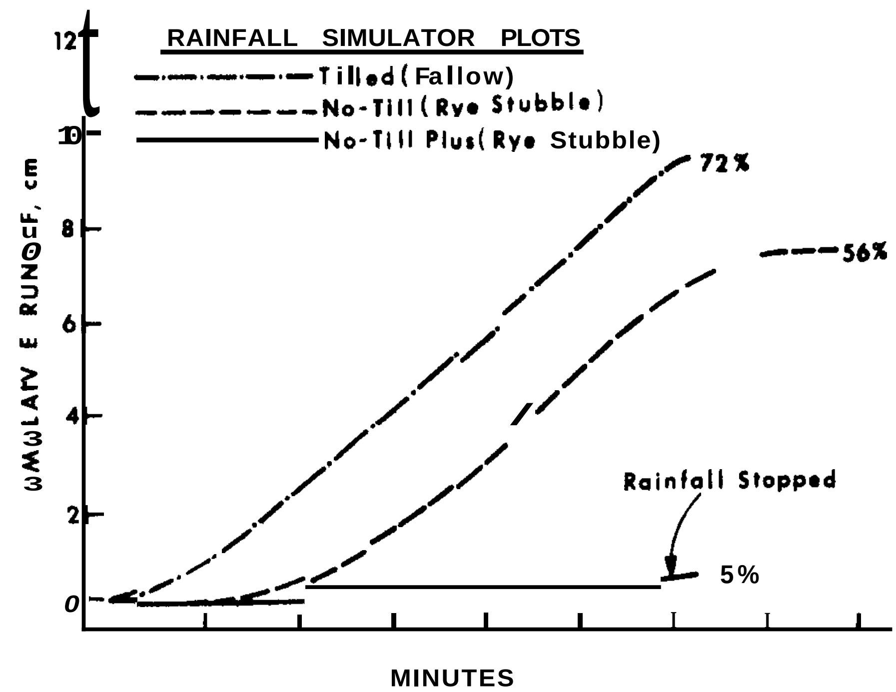

Fig. 1. Simulated runoff response to tillage associated with low antecedent soil moisture.

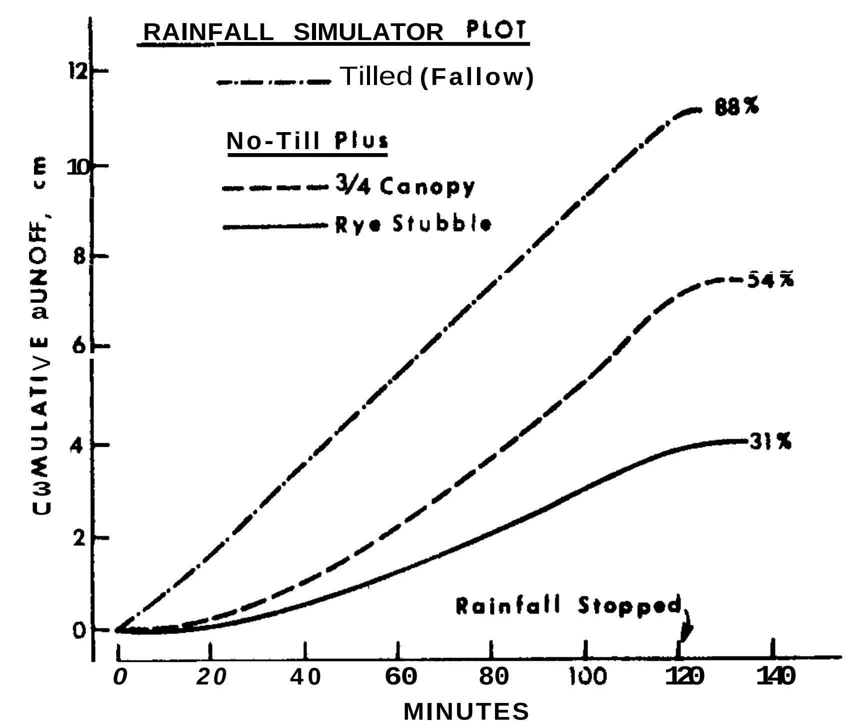

Fig. 2. Simulated runoff response to tillage associated with high antecedent soil moisture.

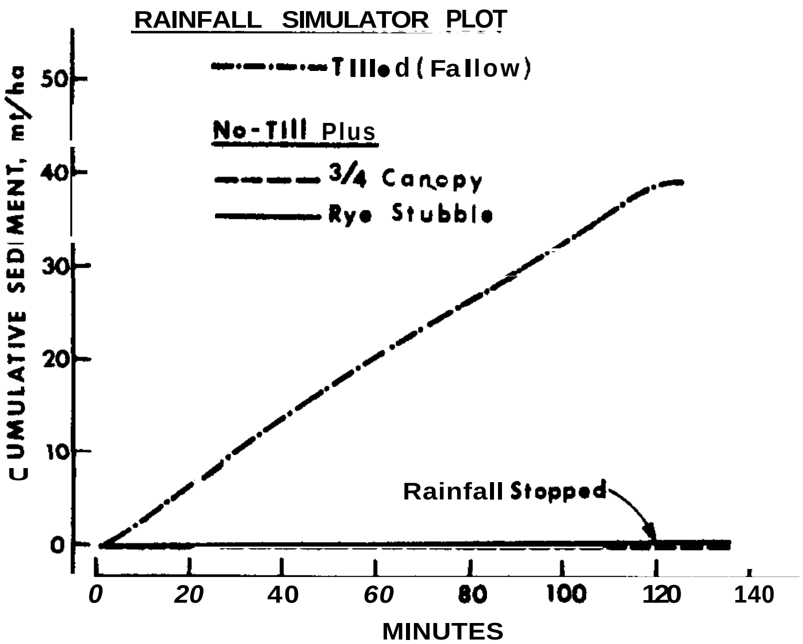

Fig. 3. Simulated soil loss associated with tillage and high antecedent soil moisture.

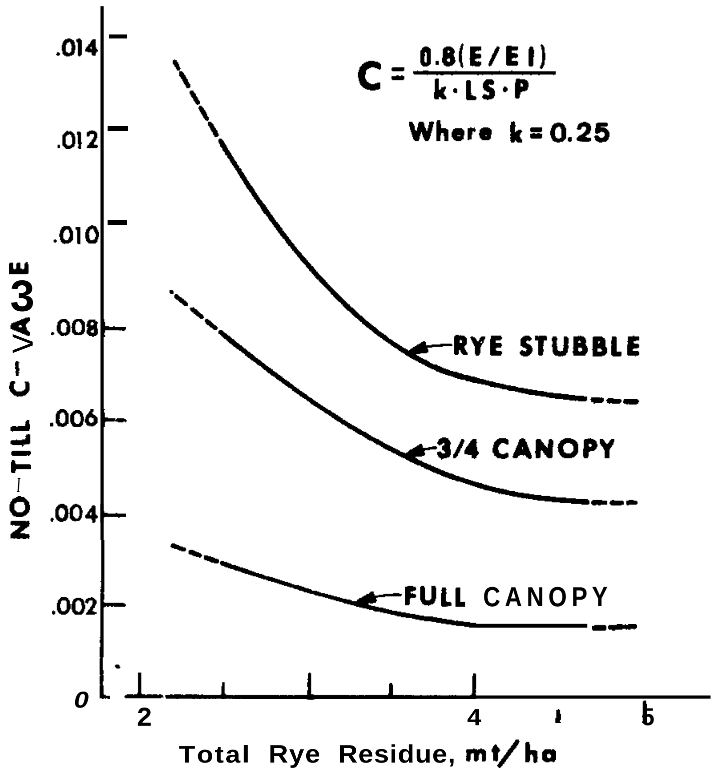

Fig. 4. Cover management factor "C" relation to no-till soybean canopy and rye residue on rainfall simulator plots.

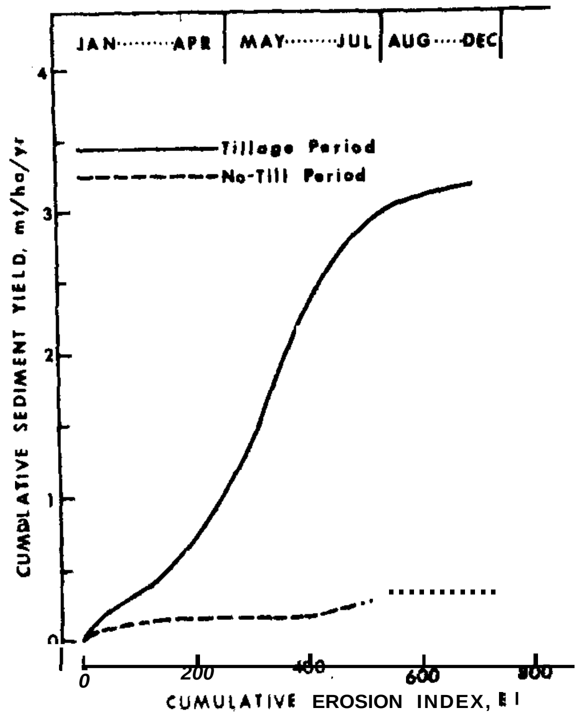

Fig. 5. Average annual cumulative erosion index (EI) relation to average annual cumulative sediment yield on the conservation watershed.

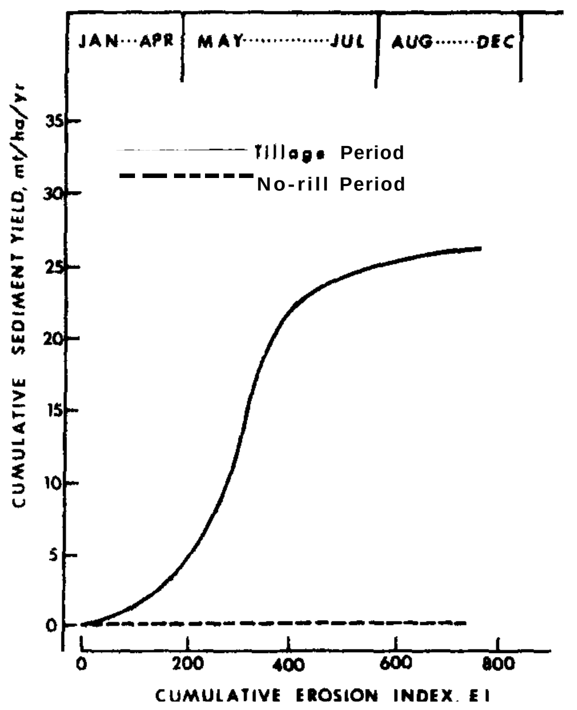

Fig. 6. Average annual cumulative erosion index (EI) relation to average annual cumulative sediment yield on the nonconservation watershed.

PHYSICAL CONDITIONS OF SOIL AFFECTING NO-TILIAGE TECHNIQUES

ALBERT C. TROUSE, JR,[1/]

Fields have been tilled to bury surface debris for many generations, and they have been overworked in order to leave a covering of smooth, pulverized soil. Although these fields may present an attractive appearance, the soil is exposed to the forces of wind and water with potentially devastating effects, To reduce the damage, as well as to keep costs down, fields toddy should be tilled only to reclaim the undesirable features in a soil profile. If soils need tillage, they should he tilled no deeper than necessary for reclamation of all barrirrs to assure deep air, water, and root permeability. Indiscriminant tillage not only wastes fuel, money, and time, but leaves the soil vulnerable to serious recompaction. The first pass of a wheel over well-tilled soil seriously affects root and water permeability so that by the time a field has been trafficked in many locations to apply all needed cultural operations, a great portion of the field has become a poor medium for moisture capture and root development.

Conservation tillage and related practices have been suggested to conserve moisture. and reduce erosion. But farmers will only adopt those conservation methods that allow them to produce a crop profitably. No-tillage farming, which became feasible with the advent of chemicals to control weeds, is one of the principle ways to conserve soil while utilizing the land. More water can be absorbed where the rain drops fall when a mulch is left on the soil surface. This leaves less water to wash rills that join to accumulate erosive volumes of runoff capable of carrying away tons of topsoil. We are now becoming aware of the expensive and wasteful proportion of the applied fertilizers and the amount of protective chemicals that are carried off the farm in this runoff. At the same time, we are more aware of the sediment, plant nutrients, and chemical pesticides carried to our streams and lakes--and the effect they have on the quality of our water.

If no-till farming is a simple and sure answer to soil and water conservation, why has it not become more readily accepted? Initial failures--and there have been many--have discouraged some farmers, but failures do not mean that the system will not work. More often farmers have not sufficiently mastered the new skills and techniques necessary for no-till farming to be successful. Just as farmers have to develop skills using the familiar tools for success with conventional farming, so must they master the new no-till farming tools and techniques,

For no-till farming to be acceptable special chemicals and different implements had to be devised. Some have been available to the American farmer for several decades, and, as interest in no-tillage practices has expanded, better chemicals and improved no-till implements are rapidly

---

1/ Soil Scientist, National Tillage Machinery Laboratory, Agricultural Research, Science and Education Administration, U.S. Department of Agriculture, Auburn, AL

being introduced. However, to keep up with advancements, a determined farmer must make time to acquire special knowledge to know which chemicals and implements are needed for his specific set of conditions, and how and where and when to apply them. And, although farmers skilled in the use of chemicals can control most weeds without tillage, limited shallow cultivations may still be necessary to control certain undesirable plant competition. However, new technology is needed for cultivating no-tillage crops if a residue cover is to remain effective.

Farmers interested in making no-till farming work may have difficulty developing certain needed crop rotations into a no-till system. They may have crop residue problems capable of interfering with planting or of delaying the warming of soil in the spring. Invariably they will encounter obstacles in controlling certain weed species. Resolutions to these problems are needed if farmers are to be successful. They must become pioneers, discovering solutions to their problems just as their predecessors did when they cleared our nation using the only tools and techniques available to them.

Soil surfaces must remain permeable to rains in order to capture and store more moisture for profitahle use. Standing stubble, when killed with chemicals, can conserve moisture, reduce erosion, and increase yields in fallow farmed sections of the country (Good and Smika, 1978). However, in addition to a good surface soil condition, farmers must also recognize the significance of a good roothed. After all, a seedhed is needed for only a few days, whereas a good rootbed is required for the life of the crop. Although good weed control is imperative, no-tillage farming can fail unless proper attention is focused on all conditions of the entire soil profile.

In this paper the physical properties of soil will he discussed as they affect no-tillage farming. Three types of no-tillage farming will be considered to point out their use as related to the soil condition: (A) Standard no-tillage, where a special planter inserts the seed into a sparsely prepared seedbed; (B) No-tillage-plus, where seeds are planted over *an* access way through a soil horizon in poor physical condition; and *(C)* No-tillage--no-trafficfarming, a new concept where all operations, from preplanting through postharvesting, are done on widely separated wheelways.

No-tillage-plus cannot, in the strictest sense, be called "no-tillage farming." To the purist, however, even the standard no-till planter is accused of "tilling" a seedbed. However, neither system exposes the land to moisture losses or wind and water erosion prior to planting or during early crop-growth stage. On the other hand, no-tillage--no-traffic farming usually requires a drastic tillage to remove all existing harriers to water, air, and root movement before its establishment; but, after being established, it becomes typical of the standard no-till system.

A. Standard No-Tillage Farming

As well as reducing runoff and erosion, no-tillage farming can reduce the time, effort, and cost of preparing a field for planting, Often this translates into the possibilities of multiple cropping which can increase the production capahilities of every acre. Phillips and Young (1973) have discussed the many advantages to be gained from no-tillage farming, La1 (1976) and Smith and Lillard (1976) have demonstrated that no-tillage farming Substantially increased the production of each crop grown over that obtained with conventional tillage-oriented farming.

However, production from each no-tillage crop is increased only when the soils farmed are already in a good physical condition. Initially, *soils* must be without barriers to root and water movement and must not be compacted during crop production. Well-aggregated soils with a stable fabric strength capable of supporting the cultural equipment used to produce the crop can withstand trafficking. Soils with such physical characteristics are found only in near-virgin areas or in well-managed, established pastures. Unfortunately, most of our heavily farmed fields lost these attributes years ago, and we have too few acres today that are well-suited to standard no-tillage techniques.

For the no-tillage method of farming to be successful, the farmer must obtain a crop stand using newly designed planters. These planters are specifically designed to place seeds into soil not previously prepared for their entry by cutting through the surface residue and loosening a shallow, narrow seedbed. Where and when soil conditions are inadequate for deep, rapid moisture percolation and root penetration, this method fails because a suitable rootbed has not been provided.

Fields ideally suited for no-till farming can gradually lose their productive capacity through mismanagement. Mismanagement of soil structure deteriorates the surface soil condition so that the minimum effort exerted by most no-till planting tools cannot merge the seedbed with the rootbed. Vehicles too heavy for the once stable aggregates may shatter the surface aggregates and compact the soil surface. Application of cultural operations when soils are weakened by rains, or by excessive slippage of drive wheels applying shear stresses, easily fracture the once stable soil fabric and lead to surface compaction. Increases in compaction of the surface soil will seriously reduce the amount of moisture entering a soil to be stored for crop use. Soil compaction is also responsible for reducing root development which reduces the rate of moisture and nutrients retrieved. As soil compaction becomes more prevalent, crop yields will decrease and the field will become less desirable for additional no-till farming. Decreased yields are not necessarily characteristic of the no-till system since a few long-term experiments have shown that production can be maintained with proper management. Instead, it is evidence that better management is required to make the standard no-till farming system work on a sustained basis.

B. No-Tillage-Plus Farming

Just as some no-till planters can be adapted to obtain a slightly deeper or wider seedbed, so can the no-till planter be modified to pierce still deeper barriers to root and water movement. Normally, such planters will require some form of coulter *to* cut through the surface trash in front of an in-row subsoiler, followed by a device to pulverize, condition, and firm the seedbed prior to planting. Called "no-tillage plus,"--the plus refers to "plus subsoiling" --the technique offers most of the advantages of no-tillage farming in soils that require deep remedial action below the planted row- Lands tilled and trafficked for several years with standard equipment develop compacted horizons, and only no-tillage-plus can provide rootbeds that readily absorb the water necessary for profitable production when lands are in poor physical condition.

Most conventionally farmed fields have deep bands compacted by indiscriminant traffic, and, unless deep chiseling is done directly beneath the row, crops are denied most nutrients and moisture stored in subsoils. With no-tillage-plus, soil is loosened directly under the row by deep chiseling as the crop is planted. Such chiseling, or shallow subsoiling, should he just deep enough to pierce the harriers to rapid root development, and allow roots normal access through the compacted surface barrier, dense harrowsole, and restrictive plowpan. Roots are then able to develop at their genetic capahilities so that rapid early growth is assured and the mass of the root system can proliferate and retrieve the moisture stored in the deeper subsoils.

No-tillage-plus does not provide ready access to horizontal root development through the surface soil between the rows. About two-thirds of the fertile surface soil horizon remains compact, thus denying the nutrients and moisture it contains to the current crop. Unless sufficient fertilizers are placed in the loosened zone near each planted row, the crop may have difficulty obtaining adequate nutrition from the surface soil at rates which allow rapid growth.

Depriving crops of the nutrients and moisture in the fertile surface soil horizon is not new, For a long time now, roots have not developed in the interrow zone of surface soil in fields tilled in the conventional manner. It is not commonly realized how much interrow damage is done by trafficking while performing our present cultural practices since yield increases from new technology, including better varieties, additional nutrient availabilities, and improved pesticides, mask the losses resulting from compaction.

Compaction does not occur only on wet soil or only under heavy vehicles. Serious compaction can occur in well-tilled soil-when it is quite dry under the wheels of light tractors and sprayers, and even under the equipment support-, guide-, and depth-wheels. It cannot be stressed strongly enough that regardless of the type of implement used to till a field, all subsequent traffic can compact the tilled horizon. This includes all secondary tillage implements and planting equipment. In fact, the benefit of primary tillage is frequently lost before the planted seeds germinate. Therefore, that part of the fertile horizon not loosened under the no-tillage-plus technique is in no worse condition than the interrow soil in field.: tilled and trafficked conventionally. In addition, because no-tillage-plus loosens the zone beneath the planted row through the plowpan, it offers better rooting conditions than the conventional system.

Two important factors that can limit production with no-tillage-plus are: (1) settlement within the excessively loosened seedbed and (2) inadequate seedbed prepararion.

Some form of seedbed conditioning is required to assure thdt seeds or young seedlings are not washed into the suhsoiler slot since suhsoiling often leaves the soil beneath the planted row in an unstable condition. The loosened soil contains lumps that can temporarily bridge the subsoiler slot, forming a large void near the bottom of the slot which leaves the seedbed vulnerable to settlement during heavy rains. Settlements can be disasterous to stand establishment, especially during the first 3 weeks after planting.

In the convrntional system, farmers can harrow repratedly before planting, if necessary, to prepare a seedbed. Not so with no-tillage-plus, since farmers must assure the proper pulverization for a good seedbed during a single pass. With no-tillage-plus, farmers must adjust all actions of the machinery prior to the first pass because they do not have a second chance before planting. Skill is required to assure adequate pulverization for a satisfactory seedbed in any no-till operation; a good seedbed is a pre-requisite for adequate plant emergence--and an adequate stand is re-quired for good production.

C. No-Tillage--No-Traffic Farming

The ultimate in no-tillage farming would allow for the crop to take advan-tage of the entire fertile surface soil horizon, as well as the deep, sub-surface material; it would allow for the capture of most of each rain, and allow roots to develop to their genetic capacity, In addition, the rooting volume would not be lost progressively because of the additional compaction that occurs through continued conventional traffic. With the no-till--no-traffic technique, superior yields can be expected and sustained indefinite-ly when all other crop needs are properly managed and maintained. However, no-till--no-trafficfarming is difficult, if not impossible, using the machinery and implements available today.

Fields must first be put into an ideal physical condition with only a few narrow, permanently established wheelways for equipment travel. All opera-tions from preplanting through postharvesting must he done from these wheel-ways so that soil barriers will not be re-formed within the farmed portions of the field. Deep profile modifications are possible to improve soil characteristics between wheelways, but regardless of improvements, the soil cannot be maintained in a productive condition when subjected to the forces of man's machines.

Our long term studies have shown that when deeply modified soils were used to produce crops, natural settlement was not objectionable. Without traf-fic, such soils remained permeable to water and loose enough for good root proliferation without annual tillage. Our untilled, untrafficked strips captured more of each rain and reduced both runoff and the amount of soil and field-applied chemicals that left the strips to become pollutants. Yields not only equalled those of test strips tilled each year and kept free of traffic, but were superior to those from strips tilled annually and trafficked in the traditional manner. Additional analyses indicated that no-till--no-traffic not only reduced operational costs, but benefited from more timely application of all operations.

To my knowledge, only one farmer in the United States has undertaken the equipment alterations necessary to perform no-tillage--no-traffic farming on a realistic scale. He is pleased with his production and cost reductions over the past 4 years. His vehicles operate on only 60-inch centers, which means that only about two-thirds of the surface of his fields can be used for production, since one-third forms the traffic network. He uses the same wheelways during all operations, including harvesting, without trafficking his beds, and is able to multiple-crop into loose soil without tillage.

I visualize that, in the future, all operations, including harvesting, will. be done from spanning units that span much wider areas so that from 96 to 98 percent of the field will be free of wheel traffic. More of the field will be free to absorb the rains and remain free of barriers to rapid root proliferation. The only downward thrust upon the soil would be under the wheels of spanners that would fully support all weights now applied to the field, including that of the harvested crop.

Conclusions

Traffic, following tillage, is the major culprit responsible for soil compaction. Compacted soil prevents the effective entry of rain and irrigation waters into soil and prevents utilization by roots of moisture stored within and often beyond the compacted soil bands. When roots are unable *to* function at rates required for adequate moisture and nutrient retrieval, crop production declines. Depressed interrow trafficways accumulate and channel erosive volumes of water from fields, which not only denies water to the crop, but erodes fields, floods lowlands, and pollutes streams and lakes. Soil and water conservation measures are required to improve mechanized farmlands for sustained production.

Standard no-tillage farming is well-suited to lands already in excellent physical condition, but such lands are few, and their physical condition can be expected to deteriorate with sustained use.

No-tillage-plus can be used on lands that are already in poor physical condition. It can sustain crop production, but cannot produce yields that soils are capable of producing and that may be called for in the 21st Century.

The newest concept in keeping with the no-till principle is no-tillage--no-traffic farming. This system, promises both sustained and optimum production. Its value needs to be proved, however, before farmers and industry will be willing to abandon present farming implements and techniques for a whole new system of agriculture that demands an entirely new array of vehicles, tools, and practices.

References

1. Good, L. G. and D. E. Smika. 1978. Chemical fallow for soil and water conservation in the Great Plains, J. Soil and Water Conservation *33:(2):89-90.*

2. Phillips, S. H. and H. M. Young, Jr. 1973. No-tillage farming. Reiman Associates, Milwaukee, WI.

3. Lal, R. 1976. Soil erosion problems of an alfisol in western Nigeria and their control. IITA Monograph No. 1, ITTA PMR 5320, Ibadan, Nigeria.

4. Smith, E. S. and J. H. Lillard. 1976. Development of no-tillage cropping systems in Virginia. TRANS. of the ASAE 19:(2):262-265.

NO-TILL PLUS ....
PLUS IN-ROW SUBSOILING

J. C. HARDEN, J. W. HARDEN AND L. C. HARDEN

No-till plus is a new concept which combines two proven practices, no-till and in-row subsoiling in a "once over" operation. No-till plus is more than no-till farming, more than subsoiling, more than "once over" farming, more than multi-cropping. It is, in effect, all of these. No-till plus can be defined as a cropping system that includes the following elements in order to be successful.

1. The planting of a winter cover crop such as small grains or legumes for use as forage or grain, and for use as a mulch for spring-planted crops.

2. No-till seeding of corn, soybean, or other crops into the cover crop.

3. The application of herbicides, fertilizers, and insecticides may be applied in one trip over the field along with seeding.

4. The use of a no-till planter that allows growers to subsoil under the row at the same time they plant.

We have found out that the benefits of no-till farming in a good cover-crop are soil conservation, improving water quality, and better weed control. No-till in a good mulch slows the movement of water across the field thereby allowing more water absorption. We also have a savings in energy, time and labor because of less trips over the field. No-till is a tool to successful double cropping, giving us better land utilization. We have noticed less cornstalk borer damage in no-till double cropped soybeans. No-till also adds organic matter to the soil. When no-tilling in a good mulch, we have observed more and healthier roots and less drying out of the top 4 inches of soil. Soil temperatures under a mulch may be *20°* cooler than soil without mulch. Our farm is located in a highly compacted soil in the Coastal Plains area of Alabama. It has been our experience that in-row subsoiling stands alone on its own merits. It reduces soil erosion and allows less run off, due to the fact that the subsoil slot acts as a funnel channeling more water into the subsoil for future crop use. There, we can apply heavy rates of irrigation water at longer intervals. The shattering of the hard pan allows deeper root penetration, up to 7 feet; into the subsoil area which we consider a second reservoir of moisture.

It is our opinion that by subsoiling we can reclaim nitrogen, potash, sulfur, and magnesium that has leached out of the top soil. Our no-till plus acreage exceeds 1,000 acres each year. We follow a crop rotation of

---

J. C. Harden, J. W. Harden, and L. C. Harden are farmers, businessmen, and conservationists; Route 1, Banks, Alabama. (L. C. Harden is Chairman of the Research Committee, Soil and Water Conservation Districts of Alabama)

rye, forage legumes, corn, soybean, and peanuts. No-till plus makes it possible for us to carry on a multi-cropping program. We keep enough rye seed for the following year's cover crop. Planting a cover crop is a minimal expense as compared to the dollar returns we get each year from this cover crop. No-till plus is made possible by a piece of equipment with a no-till coulter to cut the mulch followed by a subsoiler capable of shattering the existing hardpan. A patented slot filler wheel rotates in the slot behind the subsoiler closing it. Circular spider wheels bring any excess soil back into the slot. A double disc opener then places the seed directly over the slit at the proper depth. Finally, a packer wheel firms the soil to insure good soil seed contact.

To us this new concept, no-till plus, has meant at the end of the year higher yields with less investment, and at the same time it is improving our soil.

WEED CONTROL IN NO-TILL SOYBEANS

W. M. Lewis

Weed control in no-till planted soybeans is almost completely denendent upon herbicides. no-till soybeans are most commonly planted as a doublecrop following winter small grain harvest. In some cases the small grain winter cover crop may be grazed, cut for hay or silage, or left as a mulch. Occasionally soybeans are no-till planted into Previous crop residues. In each of these cropping systems, herbicides must be applied to control any grass and broadleaf weeds present at planting, kill any cover crop, and provide residual action against germinating weed seeds. Therefore, a herbicide treatment for no-till soybeans must serve a dual ourpose--kill existing vegetation at planting and provide residual weed control. A postemergence herbicide may also be needed to control broadleaf weeds 3 to 4 weeks after soybean planting for a complete weed control program.

Weed Control Methods

In planning a weed control program, four methods should be considered: 1) crop rotations, 2) crop competition, 3) cultivation including seedbed preparation, and 4) herbicides. How do these apply to no-till planted soybeans?

Crop Rotation. Most growers fail to realize the value *of* crop rotation for weed control. Certain weeds may be easier or cheaper to control in corn than in soybeans and vice versa. For example, large-seeded broadleaf weeds, such as cocklebur, jimsonweed, and Pennsylvania smartweed, can be easily controlled in corn witn preemergence herbicides or by a postemergence application of 2,4-D, Banvel, Evik, or Lorox over a period of several weeks. Thus in corn, you have greater flexibility in time of application, number of applications, and herbicide selection. For economical control, these weeds are more difficult to control with preemergence herbicides in soybeans and timing of postemergence applications is very critical and some crop injury may occur. This again emphasizes the need for greater managerial skills in a no-till system. Rotating crops also helps prevent buildup of problem weeds because we are able to use different herbicides to control a broader spectrum of weed species. The rotation of herbicides, as well, will reduce the possibilities of herbicide buildup in the soil.

Crop Competition. Crop competition is vital to the overall management system of no-till and especially doublecrop soybeans. These later plantinss should be in narrow rows, 15 to 20 inches. Soybean plants in narrow rows form a canopy a few weeks after planting to successfully shade out weeds germinating later. Cultural practices, such as good seed, proper fertilization and liming, effective insect and disease control, and narrow rows are very important in giving the crop the competitive edge in shading out weeds late in the season. Dense small grain stands can also reduce the potential weed infestation and weed size at planting time for doublecrop no-till soybeans.

W. M. Lewis is Professor of Crop Science, Department of Crop Science, North Carolina State University, Raleigh, NC 27650.

Cultivation and Seedbed Preparation. If the weeds present dictate cultivation and/or plowing or disking for seedbed preparation, then no-till is not the planting system to choose. For example, johnsongrass, bermudagrass, and yellow and purple nutsedge cannot be controlled well enough in a no-till system. However, certain preplant soil incorporated herbicides are effective in controlling these perennial weeds.

In no-till doublecrop soybeans, our experience indicates that the small grain should be planted in a conventional seedbed rather than overseeding it in the previous crop. The stand of small grains has been better and hence greater yields. Also weed control and yield of the no-till planted soybeans have been greater following small grains which were conventionally planted. When fields are fall tilled and planted to small grains, cutleaf evening-primrose, horseweed, whiteheath aster, and wild lettuce, which are difficult to control with paraquat, are not a problem. In addition, perennial weeds such as trumpetcreeper, horsenettle and briars are less prevalent where fields have been tilled in the fall. The effects of tillage on weed control is one reason we do not advocate continuous no-till planting but do suggest no-till as one alternative planting system within a total crop management system.

Herbicides. To plan a weed control program for no-till planted soybeans, you must know the weeds present in the field, the soil organic matter and texture, and the capabilities of herbicides labeled for no-till soybeans. The first step in any weed control program is to identify the weeds present. Survey your fields in the late summer or fall for the next year's crop, because the weeds present in the fall will surely be back next year. Record the weeds identified and their severity on a "weed map" of your farm. First, the existing weeds will indicate whether or not to no-till plant. Next they aid in selecting the herbicide to provide residual weed control and in determining possible needs for additional postemergence applied herbicides. The weeds present at planting and their size will influence the choice and rate of the herbicide to control existing vegetation and will further help in selecting preemergence and postemergence herbicides. To select the appropriate herbicide and rate for your soil, the soil organic matter and soil type must be known. Once the weeds have been identified and the organic matter and soil texture determined, you must match this information with the capabilities and limitations of herbicides labeled for use in no-till soybeans.

The tank mixtures of herbicides labeled for planting treatments in no-till soybeans are listed in Table 1. Paraquat and Roundup kill emerged annual grass and broadleaf weeds. Residual control of annual grass and broadleaf weeds is provided by Lorox, Lexone (or Sencor), Lasso, or Surflan in the combinations as listed. The rate ranges in pounds of active ingredient per acre are also indicated. Specific rates for the residual herbicides are determined by the soil texture and soil organic matter and can be found on the herbicide labels.

All the labeled herbicides providing residual weed control in no-till soybeans have restrictions covering soil texture and/or soil organic matter (Table 2). Treatments involving Lorox or Lexone (or Sencor) should not be used on sand or loamy sand soils low in organic matter for the soybeans may be injured.

The relative susceptibility of weeds to the preernergence surface-applied herbicides used in no-till soybeans is presented in Table 3. Lasso and Surflan provide good to excellent control of annual grass weeds while Lorox or Lexone (or Sencor) give moderate to good control. Lorox or Lexone (or

Table 1. Tank mixtures of herbicides labeled for no-till soybeans.

Herbicides	Rate: lb active per acre
Paraquat 2CL + Lorox 50WP	0.25 + 0.5-2.5
Paraquat 2CL + Lexone 50WP	0.25-0.5 + 0.375-0.75
Paraquat 2CL + Sencor 50WP	0.25-0.5 + 0.375-1
Paraquat 2CL + Lasso 4EC + Lorox 50WP	0.25-0.5 + 2-3 + 0.5-1.5
Paraquat 2CL + Lasso 4EC + Lexone 50WP	0.25-0.5 + 2-2.5 + 0.25-0.75
Paraquat 2CL + Lasso 4EC + Sencor 50WP	0.25-0.5 + 2-2.5 + 0.25-1
Paraquat 2CL + Surflan 75WP + Lorox 50WP	0.5 + 0.75-1.5 + 0.5-1
Paraquat 2CL + Surflan 75WP + Sencor 50WP	0.5 + 0.75-1.5 + 0.25-0.5
Roundup 4WS + Lasso 4EC + Lorox 50WP	1.5-4 + 2-3 + 0.5-1.5

Table 2. Label restrictions on soil texture and organic matter (OM) for herbicides applied in combination with Paraquat or Roundup for no-till soybeans.

Herbicide		Sand or loamy sand		Sandy loam or loamy sand		Any Soil		
	b	<1/2	<2	<1	<2	<1/2	<1	>3
	%OM							
Paraquat Plus								
Lorox	x					x		
Lexone[a]					x	x		
Sencor					x			
Lasso + Lorox	x					x(D)	x(M)	
Lasso + Lexone		x						
Lasso + Sencor			x					
Surflan + Lorox								x
Surflan + Sencor				x				x
Roundup Plus								
Lasso + Lorox	x						x	

[a] Do not use on sand soil

[b] No limitation on %OM

D = According to Dupont label; M = According to Monsanto label

Table 3. Relative susceptibility of weeds to preemergence surface-applied herbicides for no-till soybeans.

	Lasso	Lexone Sencor	Lorox	Surflan
Annual grasses				
Broadleaf signalgrass	E	P	P	G
Crabgrass	E	G	G	E
Fall panicurn	E	G	G	G
Foxtails	E	G	G	E
Goosegrass	E	G	G	E
Annual small-seeded broadleaf weeds				
Florida pusley	G	F	G	G
Lambsquarters	F	E	G	G
Pigweed	E	E	E	G
Ragweed	F	G	G	P
Annual large-seeded broadleaf weeds				
Cocklebur	P	F	F	P
Jimsonweed	P	E	F	P
Morningglory	P	F	P	P
Smartweed	P	G	F	P

E=Excellent control, G=Good control, F=Fair control, P=Poor control

Table 4. Postemergence herbicide rate table.

Weed	Size (inches)	Basagran (pt)	Preemerge (pt)	Dyanap (pt)	Tenoran (lb)
Cocklebur	up to 2	1.5	1.0	2.0	3.0
	2-4	1.5	2.0	3.0	x
	4-6	1.5	x	4.0	x
	6-10	2.0	x	x	x
Smartweed	up to 2	1.5	1.0	2.0	3.0
	2-4	1.5	2.0	4.0	x
	4-6	1.5	x	x	x
	6-10	2.0	x	x	x
Jimsonweed	up to 2	1.5	1.0	2.0	3.0
	2-4	1.5	1.0	2.0	x
	4-6	1.5	2.0	3.0	x
	6-10	2.0	x	x	x
Morningglory*	Up to 2	3.0	1.0	2.0	3.0
	2-4	x	2.0	3.0	x
	4-6	x	x	4.0	x
	6-10	x	x	x	x
Sicklepod	up to 2	x	x	x	3.0
	>2	x	x	x	x

x=Do not use

*There are some variations in susceptibility among species.

Sencor) also gives partial control of large-seeded broadleaf weeds such as cocklebur and morningglory.

Weed Control Programs for No-Till Soybeans

Control of Existing Vegetation. Paraquat and Roundup in the tank mix control emerged annual grass and broadleaf weeds. Paraquat rates are 1 to 2 pt/A. Use the lower rate when emerged annual weeds are small, 1 to 3 inches tall. Increase to 2 pt/A when weeds are 4 to 6 inches tall. We have found that crabgrass, fall panicum and lambsquarters over 3 inches tall are difficult to control with Paraquat. For these weeds Roundup is better. Also select Roundup when annual broadleaf weeds exceed 6 inches tall and perennial weeds are present. Paraquat may be used to control winter small grain cover crops. Use 1 pt/A for rye and 2 pt/A for wheat, oats or barley.

Roundup is used at 1.5 qt/A. In no-till systems it should be considered primarily for control of emerged annual weeds or a cover crop, for at normal application dates perennial weeds may be too young for most effective control. The use of 2 to 4 qt/A of Roundup may further reduce the competition of emerged perennial weeds, especially in doublecrop soybeans.

In doublecrop no-till soybeans, planting and herbicide application should immediately follow small grain harvest. Weeds at this time are smaller and easier to control. Furthermore, because of the competition provided by a properly managed small grain crop, the weed seedlings are frequently small, spindly and succulent. Given a few days after small grain harvest, these weeds develop rapidly and become more difficult to control with foliar applications. If considerably tall weeds are present at small grain harvest, set the combine as high as possible to save the foliage of the weeds in order to have a greater contact area for the foliar applied herbicide. Weed stubble or stems will not be controlled and resprouting usually occurs.

Using ground application equipment, apply tank mixtures with Paraquat or Roundup in 20 to 60 gal of water/A immediately before, during or after planting but before the crop emerges. Thoroughly cover the live vegetation with spray. The amount of water per acre should be increased as the density of stubble, crop residue or weeds increases. In our tests and demonstrations, 40 gal of water/A applied with 40 psi has been satisfactory. If the straw has not been removed or bailed, it may trap the spray lessening kill of existing vegetation and residual weed control. If planning for doublecrop soybeans, put a straw shredder on the combine.

To Paraquat tank mixtures add Ortho X-77 Spreader or DuPont Surfactant WK at 1 pt/1000 gal of spray mixture. Do not add additional surfactant to Roundup.

Residual Weed Control. When the weed infestation and soil information for a field have been gathered, that particular weed complex can be put into one of three groups. These become the basis for selecting the proper pre-emergence or residual herbicide treatment.

1. Annual small-seeded broadleaf weeds plus moderate infestation of annual grass weeds. The tank-mix combinations for this situation are Paraquat + Lorox and Paraquat + Lexone (or Sencor). Grass and broadleaf weed control is frequently of short duration, 3 to 4 weeks, for Lorox. Lexone (or Sencor) may provide slightly improved grass control and better control of morningglory, jimsonweed, and smartweed. Length of control may be of sufficient duration for no-till doublecrop soybeans planted in narrow rows but too short for full-season soybeans. These treatments should not be selected if fall panicum or broadleaf signalgrass is a problem.

Lorox should not be used on sand or loamy sand soils nor on any soil with less than 1/2% organic matter for it may injure the soybeans. Five percent organic matter is the upper limit for use of Lorox, because organic matter ties it up reducing the amount available for adequate weed control. Do not use Lexone (or Sencor) on sandy loam or loamy sand soils with less than 2% organic matter. In these soils Lexone (or Sencor) may injure soybeans, particularly under heavy rainfall which moves the herbicide into the soil where it is absorbed by the soybean roots and moved into the top of the plant. Plant soybean seed at least 1 1/2 inches deep on flat or raised seedbeds to reduce potential injury from Lorox or Lexone.

2. Annual small-seeded broadleaf weeds plus increased control of annual grass weeds. These herbicide combinations offer better and longer control of annual grass weeds: Paraquat + Lasso + Lorox; Paraquat + Surflan + Lorox and Roundup + Lasso + Lorox. Lasso is a consistently effective preenergence grass control herbicide and usually provides approximately 6 weeks of control. Surflan, on the other hand, requires more water for activation, since it leaches less than Lasso, but offers the advantage of longer season grass control. Often rainfall is less reliable following application for no-till doublecrop soybeans and consequently weed control from Surflan is less favorable. Combinations with Lasso are more effective in controlling fall panicum and broadleaf signalgrass. Any of these three tank mixes are possibilities for full-season or doublecrop no-till soybeans. Lasso or Surflan in a tank mixture improves the control of volunteer small grains.

3. Annual small-seeded broadleaf weeds plus increased control of large-seeded broadleaf weeds and of annual grass weeds. Lexone (or Sencor) in the following tank mixtures increases control of large-seeded broadleaf weeds (such as cocklebur, jimsonweed, and morningglory): Paraquat + Lasso + Lexone (or Sencor) and Paraquat + Surflan + Sencor. The statements made in the previous section also apply to these mixtures.

Postemergence Weed Control. Additional broadleaf weed control may be needed 3 to 4 weeks after planting especially for large-seeded broadleaf weeds--cocklebur, morningglory, jimsonweed, and Pennsylvania smartweed. Our experience shows there may be less large-seeded broadleaf weeds in no-till. Postemergence herbicides with suggested rates for controlling weeds of different sizes are presented in Table 4.

Although Basagran is very effective on certain large weeds, particularly cocklebur, it is more effective and economical when applied early to smaller weeds. Sicklepod is resistant and morningglory is partially controlled at high rates. Basagran also gives yellow nutsedge control.

Apply Premerge or Dyanap in 8 to 10 gal of water/A and at 60 psi. Small orifice nozzles are required. Raise the spray boom approximately 30 inches above the soybeans. Application of Premerge may be repeated after 4 to 5 days. Sicklepod is resistant to Premerge and Dyanap. Do not apply when soil or soybeans are wet, when it is windy, or when the temperature is below 75°F or above 95°F.

Apply 3 lb/A of Tenoran before weeds are over 2 inches tall. Add a nonionic surfactant at 1 pt/25 gal of spray. Tenoran is the best postemergence herbicide for control of sicklepod.

If good early season control of morningglory and cocklebur is not achieved, 2,4-DB (Butyrac 200, Butoxone) applied over-the-top 10 days before bloom up to mid-bloom will provide additional control of cocklebur and partial control of morningglory. This late treatment reduces weed interference at harvest but yield has already been reduced by these weeds. Therefore, use 2,4-DB only as a salvage treatment.

Future Herbicide Treatments

Research indicates that Paraquat + Dual + Lorox or Lexone (or Sencor) and Roundup + Dual + Lorox or Lexone (or Sencor) are effective in no-till soybeans. Annual grass weed control has been excellent.

A different approach to weed control in doublecrop no-till soybeans is the application of Surflan early in standing wheat or oats. Surflan may be applied over-the-top of small grains from full-tillered to boot stage. Our results indicate weed control is greatly improved with an additional application of Lorox or Lexone at soybean planting.

Embark applied over-the-top of soybeans in the 2 to 7 trifoliate stage will control volunteer corn and sorghum and suppress johnsongrass from rhizomes and seedlings. This treatment has an experimental use permit.

Roundup applied with a recirculating sprayer when weeds are taller than the soybeans effectively controls johnsongrass and other perennial weeds. This practice has an experimental use permit. Roundup does have a label in certain states for spot treatment of johnsongrass in soybeans. Roundup has also been successful in the control of johnsongrass where no-till soybean planting has been delayed until johnsongrass reached the boot stage. However, no preemergence applied herbicide currently gives a high enough degree of control of germinating seed to provide a complete johnsongrass control program.

Summary

A weed control program for no-till soybeans at planting consists of a foliar applied herbicide to control existing vegetation plus one or two herbicides for residual control of annual grass and broadleaf weeds. In addition, a postemergence applied herbicide may be needed to control broadleaf weeds 3 to 4 weeks after planting.

DIRECTED SPRAYS FOR WEED CONTROL

W. S. HARDCASTLE

Several factors influence the use of herbicides as postemergence directed sprays whether they are used in minimum tillage or prepared seed bed plantings if a herbicide is labeled only for directed application, then any other post-emergence application is illegal. Another factor is the lack of effective herbicides for which the crop has sufficient physiological tolerance to allow a non-directed application. This necessitates the use of highly toxic compounds whose utility depends on minimized crop contact. While these compounds are generally very effective herbicides, little or no crop tolerance exists, and if they are applied over-the-top, excessive crop damage can be expected.

Crop leaves can form a canopy over small weeds. This canopy intercepts sprays and protects the small weeds underneath. Because of the canopy effect of the crop, over-the-top applications, even with herbicide tolerance by the crop, are often less effective than directed applications unless high pressures are used for carrier atomization. Atomization is undesirable with herbicides since **it** materially increases the potential for drift and volitization which could damage non-target crops.

Although directed postemergence applications are seldom made earlier than three weeks after planting, preparation for these treatments should start in the summer or at harvest time of the year before the postemergence directed applications are to be made. Fields should be surveyed and a list of weed species and densities should be made.

The establishment of crop/weed height differential is essential for successful directed postemergence applications. Cocklebur, sicklepod (coffeewed), ragweed, and morningqlories are weeds most commonly found at the time that directed postemergence applications are needed. Selection and use of pre-emergence herbicides which are effective on these weeds (or others from your survey list), and **if** the growing season warrants, the use of an early post-emergence herbicide application, will help achieve the crop/weed height differential needed for successful control of these weeds.

Nozzle stability is a very important factor in successful directed post-emergence herbicide applications. Seedbed condition contributes to nozzle stability. The better the seedbed condition, the more effective the direction of postemergence applications. In minimum tillage plantings, seedbeds often erode over winter or during the growing season of the preceeding crop in a rotation. However, effort should be made whenever possible to provide a smooth, level track for the nozzle carriers to move over.

Several acceptable methods are available for mounting nozzles for directed postemergence applications of herbicides. One of the most effective, where straw conditions permit use, is skid mounts, the so-called oiling shoe. This equipment has mounting brackets which allow precise positioning of

---

W.S. Hardcastle is Assistant Professor, Department of Agronomy, University of Georgia, Georgia Station, Experiment, Georgia

nozzles, and support arms are weighted or spring loaded for good ground Contact. Units of this type which are mountable under the middle of the tractor are commercially available. This mounting position also improves accuracy of spray placement. If skid units cannot be used, nozzles may be mounted effectively on a cultivator frame or a preemergence boom can be used. This type of mounting requires support wheels for stability. Direct mounting to the tractor frame is less satisfactory since vertical mobility of the nozzles is lost. With the latter mountings, rigid nozzle drops should be used to position the tips below the top of the crop. Flexible drops are unsatisfactory.

In conventional planted crops, the grower has the option of cleaning row middles with cultivation. This facilitates the application of postemergence herbicides to a band centered on the crop row. In minimum tillage plantings where the maintenance of previous crop stubble and mulch is desirable, this option is seldom available and both plant row and crop middles must be cleaned and maintained chemically.

If crop/weed height differentials have been established by previous operations, there are several choices of nozzles which will direct sprays into the row middles and the crop row simultaneously. Single or double swivel nozzle bodies allow accurate spray pattern placement and give flexibility to the spray unit. Nozzle tips are machined in a variety of delivery angles (Fig. 1)

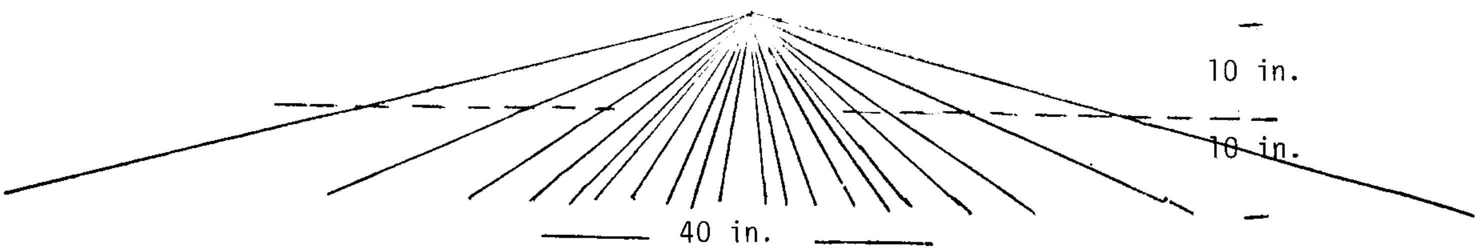

Figure 1

and selections can be made to fit the spray pattern which is needed. Flat fan tips (Fig. 3, 4, & 5) deliver either elliptical or even edge patterns on the ground. The tapered edge tips are designed for boom spraying and the even edge tips for band application. Flood tips (Fig. 2) also deliver a tapered pattern which is spred over a wide band, the' fan angle of flood tips varies with output. Even edge tips are available in 80" and 95" fan angles and in sizes which will deliver spray volumes of 100 and 75 gallons per acre at 3 mph and 40 psi respectively. Tapered edge fans are available which will deliver over 2000 gpa under the same conditions.

If crop/weed height differential has not been maintained, it is advisable to clean the row middles in one aperation and to clean the crop row in a second operation after the weeds in the row middles have been knocked down. Thorough coverage of the weeds is very important to the success of directed postemergence sprays. To assure this coverage, higher carrier volumes are


Figure 2
Flood Tip

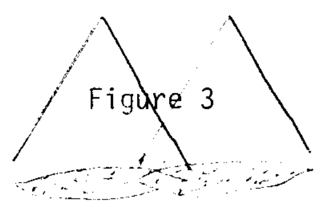
Figure 3
Tapered Edge Fan

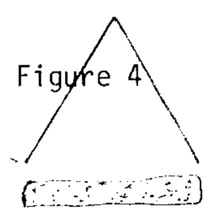
Figure 4
Even Edge Fan

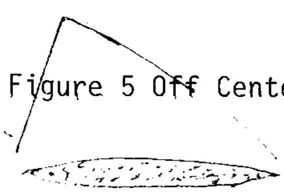
Figure 5 Off Center Fan

used in directed postemergence spraying than are generally used in pre-emergence applications. Where 20 gpa of diluent or less is often sufficient for preemergence boon: spraying, a minimum of 40 gpa and preferably up to 80 gpa of diluent is desirable for directed postemergence spraying with the higher volumes being used when weeds are thick or tall. For maximum weed kill and crop protection, nozzle tips which deliver a spray pattern which is even to the edge, rather than tapered, should be used. If weeds are particularly high or for added crop protection from translocated herbicides, shields which run close to the crop and extend to the ground on either side of the row middles are often effective. Shield units are available commercially or they can be assembled in a farm shop with little difficulty.

Whichever type of tip configuration is used, the spray pattern in the field is of major importance. The sprayer should be set up to correspond to the row number used at planting -- if four row planters were used, a four row sprayer should also be used. Further, the sprayer should follow an identical path as that made by the planters. If the planter pattern is not closely followed, minor differences in row direction can cause excessive spray contact with the crop plants and result in serious damage to the crop.

Recirculating sprayers are specialty equipment which directs a stream of herbicide mixture horizontally above the crop. Residual spray which was not intercepted by weeds is collected and returned to the spray tank for use. This equipment is currently used primarily for johnsongrass control in soybeans where the grass has materially over-topped the beans. Several versions of this type of sprayer are commercially available.

With proper planning and equipment adjustment, directed postemergence herbicide applications can often compensate for ineffective preemergence treatments by removing weeds in the crop and/or be very effective in keeping a crop weed free until harvest.

NO-TILL PASTURE RENOVATION

JOE BURNS

Maybe a better title would be minimum tillage pasture renovation because, in many cases, there is some small amount of tillage performed in order to place the clover seed into the soil. On the other hand, the so-called "spray-seed" method can be completely no-till with clover being broadcast on. the soil surface.

In Tennessee, the term pasture renovation means the seeding of clovers in grass sods, mainly fescue. In other areas, renovation might mean the seeding of sudangrass in pasture sods or seeding fescue or orchardgrass in old lespedeza or bermudagrass pastures, or seeding small grains, ryegrass and legumes in bahia and bermudagrass fields. With few exceptions, the basic principle of successful renovation is to prevent or decrease competition between the existing sod and the newly-seeded clover or grass. This competition can be decreased by: chemical spraying of the existing sod, disking or mechanical destruction of part of the sod or, in the case of berrnudagrass, waiting until the sod is dormant before seeding.

The advantage of having clover in fescue pastures is well documented from research in many states. A clover-fescue pasture, from Tennessee research, produced as much gain from steers as a comparable pasture of fescue fertilized with 80 lbs. of nitrogen per acre. In a Tennessee cow-calf demonstration, renovated fescue produced a three-year average of 105 pounds per acre of calf beef more than fescue alone. This 36-acre pasture was divided in half with one-half seeded with 2 lb. Ladino clover, 4 lb. red clover, and 8 lb. Kobe lespedeza per acre and fertilized by soil test while the other half was not renovated. The results were even more striking when fescue alone was grazed with dairy cattle and compared to renovated (fescue-clover) pasture. The increase was 6 lb. of milk per cow per day for the clover-fescue mixture over the fescue alone. Clover-grass mixtures are also desired by most horse owners, especially when the grass is fescue and they have mares with foals and young horses less than two years old.

Fescue is the major pasture plant in Tennessee, comprising about 5 million acres, and less than 1 million acres have an acceptable clover content of 30 percent or more. This shows the need for more clover in Tennessee pastures (2-4-8, Let's Renovate).

Now, back to the subject of no-till pasture renovation.

Some of the early work on no-till renovation was done in Tennessee by Henry Fribourg et a1 (1) of the Plant and Soil Science staff in 1957. Henry used a disk and also the chemical dalapon to kill part of a heavy stand of fescue before seeding clover. He found that an adequate stand of clover could be obtained if the fescue competition were reduced by either method in fall or spring.

Joe Burns is Forage Specialist, Extension Plant and Soil Science Section, The University of Tennessee, Knoxville, Tennessee.

Strips of fescue were sprayed with dalapon ranging from 36-inch wide alternate strips down to 9-inch sprayed strips with 14-inch unsprayed bands. The 9-inch sprayed strips with 14-inch unsprayed bands resulted in the most desirable combination of fescue and clover after broadcast legume seeding.

Some subsequent work in Tennessee and Alabama has shown that the application of an insecticide is needed for fall clover seedings because of insect damage to the seedlings. Winter seedings do not seem to have the insect damage observed in fall plantings and therefore no insecticide is suggested. In general, in Tennessee, winter and early spring seedings (February and March) have been more successful than fall or later spring seedings.

Research by Taylor, Smith and Templeton (2) in Kentucky showed 10 to 20 percent greater number of clover plants after spraying paraquat in 4-inch strips over a treatment consisting of clover seeded in rows in Kentucky bluegrass plots, in three of five trials. Also, the clover plants were 20 percent larger after 60 days for two March seedings.

In later research in Tennessee by Fribourg, Jeffery et a1 (3 and 4), Paraquat, Roundup, Dalapon and disking treatments were used to suppress fescue at time of clover seeding. The clover was seeded in 8-inch rows on one-half of each plot and broadcast on the other half. All chemicals were sprayed in 4-inch bands and there was one broadcast treatment of paraquat. Paraquat resulted in the quickest browning of the fescue, with Roundup and Dalapon having slower effects. The disking treatment had a 20 to 25 percent lower yield than the paraquat treatment in 4-inch alternate bands for two seeding dates in late February and early March. Disking to kill about 50 percent of the fescue also slowed the growth of the remaining grass and resulted in lower yields. The clover establishment and growth were about the same in the chemical and disking treatments. When seeded in late February and early March, the growth of clover seeded broadcast was equal to that of clover seeded in rows with a zip seeder, when the yields were taken in early June. From mid-March to mid-April, there was a trend toward better stands when the seed was put in rows in the soil as compared to broadcast seedings.

Clover seeded in fescue in late February and early Parch by any method and all chemical or mechanical treatments produced more growth and had better stands than that seeded in late March and April.

Several researchers have reported that it is easier to maintain clover with fescue if the fescue is seeded in rows. With this information, it is easy to realize that the spraying of a chemical in alternate bands to kill or suppress fescue for a couple of years would be putting fescue in rows. This would allow the clover to have the physical area between bands for growth without heavy competition from the fescue. Also, as has been repbrted, the fescue in the unsprayed bands is not reduced in vigor and can supply much needed forage in early spring. When this fescue growth is removed by grazing, competition is further reduced, trampling and grazing damage to the young clover seedlings (one animal unit per acre) are minimal. It has also been observed that nitrogen fertilization of a pasture renovated by band spraying supplies early season growth without causing excessive competition, if grazed to a stubble height of 2 to 3 inches.

Some of the advantages of no-till or minimum-till pasture renovation are:

I. Heavy stands of fescue can be easily renovated, the paraquat does an excellent job of "suppressing" the fescue if the grass is green.

11. The soil surface remains smooth; disking leaves the pasture rough.

111. Rocky areas can be sprayed without bringing more rock to the surface.

IV. Wet soils can be sprayed before they are dry enough for disking.

V. Fescue can be put in rows by killing or suppressing alternate bands, allowing more space in killed areas for clover growth.

VI. Unsprayed bands of fescue produce higher yields per acre for the first 60 to 90 days after spraying alternate bands than similar areas in a pasture which were disked to kill about 50 percent of a thick stand of fescue.

VII. Soil erosion is less even though erosion is only slight with the disking method because a 59 percent stand of fescue should remain after disking.

Disadvantages:

I. With thin fescue stands, only slight disking would be needed. A 50 percent kill of existing grass by spraying would be excessive.

11. The grass must be green before paraquat is effective, therefore, seeding might be delayed in some areas during February.

111. Most farmers have machinery to renovate by the disking method.

The question now arises, what is a practical method of no-till renovation? (5)

SPRAY-SEED OR ZEBRA METHOD

a. Spray 10-inch alternate bands with a boom sprayer and broadcast the seed with a cyclone seeder, grain drill or cultipacker seeder, etc. Most of the boom sprayers have nozzle openings at 20-inch intervals. The fan spray tip can be turned, in order to only spray a 10-inch band.

b. Spray 4- to 5-inch alternate bands with one of several machines which places the seed in rows in the soil. Powrtill, Zip Seeder, Pasture Pleaser, Bettison Drill, etc.

c. Use 1 quart of paraquat per sprayed acre (one-half area sprayed = 1 pint/A) in 20 to 40 gallons of water. Add 8 0z. of Ortho X-77 per 100 gallons of spray solution.

* * * *

Regardless of the method used, a jingle which is used in Tennessee to emphasize renovation is:

SPRAY OR DISK PASTURES - SEED THEM FAST
PUT SOME CLOVER - IN THAT GRASS!

LITERATURE CITED

1. Fribourg, H. A,, and Lawson M. Safley. 1962. Renovating fescue pastures with dalapon. Tennessee Farm and Home Sci. Prog. Rep. 42.

2. Taylor, T. H., E. M. Smith, and W. C. Templeton, Jr. 1969. Use of minimum tillage and herbicide for establishing legumes in Kentucky bluegrass (Poa pratensis L.) swards. Agron. J. 61:761-766.

3. Fribourg, H. A., L. S. Jeffery, J. R. Evans, J. High, Jr., D. D. Howard, and H. Morgan, Jr. 1978. Clover establishment in fescue sods following renovation with disking and herbicides. Tennessee Farm and Home Sci. Prog. Rep. 105.

4. Jeffery, L. S., H. A. Fribourg, J. R. Evans, D. D. Howard, J. W. High, Jr., and H. Morgan, Jr. 1978. Suppression tall fescue sods with disking and herbicides for pasture renovation. Tennessee Farm and Home Prog. Rep. 105.

5. Burns, J. D. 1978. Renovate grass pastures. Tennessee Agric. Ext Serv. Circ. 714.

University of Georgia

College of Agriculture Experiment Stations

From the cool ruggedness of the northern piedmont to the flat sandy Coastal Plain to the semitropical southern region, Georgia is a study in geographical and climatological contrasts. Since each area of Georgia presents different problems to her farmers, regionalized agricultural research is necessary. To meet this need, the statewide direction and outreach of the University of Georgia College of Agriculture Experiment Stations was planned to place research information of a regional nature only a short driving distance away from any point in the state. The Experiment Stations and their locations are indicated below: