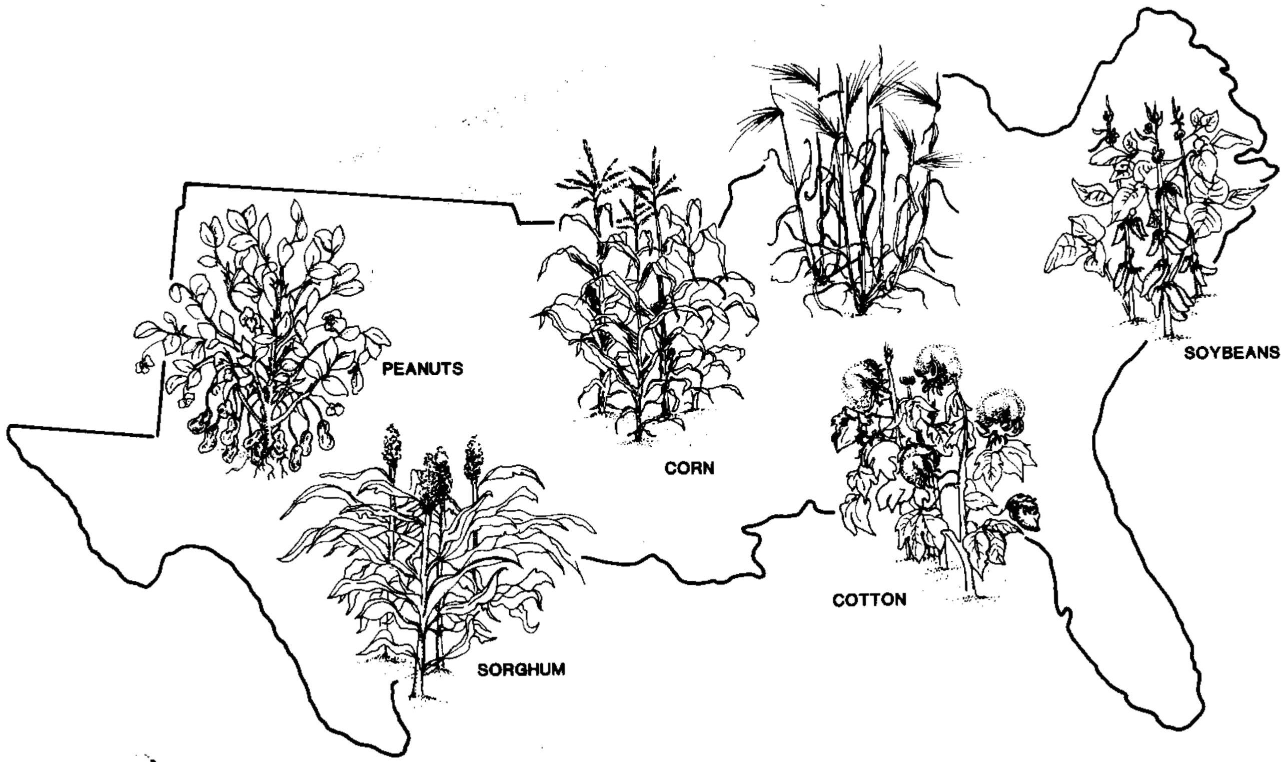
Conservation Tillage: Today and Tomorrow

Southern Region No-till Conference



Proceedings

July, 1987
College Station, Texas

The Texas Agricultural Experiment Station, Neville P. Clarke, Director, The Texas A&M University System, College Station, Texas

Preface

We recognize the importance of tillage in modern agriculture especially in respect to ameliorating biological, chemical, and physical soil impediments to crop growth. Modern tillage practices have contributed to the unmatched productivity of U.S. agriculture. Technology is providing an ever increasing array of tillage and cropping system alternatives to incorporate into our present farming systems. Because of current economic constraints on agricultural production, we must critically evaluate the usefulness of existing crop production practices and find ways to return profitability to our nation's farmers. The conference theme, "Conservation Tillage: Today and Tomorrow", was chosen to stimulate vigorous discussion on the present and future technical components of conservation tillage farming systems. Speakers recognized for their knowledge and experience were asked to discuss critical issues on individual components of conservation farming systems as they relate to our present and future practices. Invitations were also extended for voluntary contributions by persons having research experience on other topics pertinent to the conference theme. The proceedings of the conference contains the papers of the invited speakers and abstracts of those making voluntary contributions. In an effort to keep Texas farmers on the cutting edge of science and technology, the Texas Agricultural Experiment Station, Texas Agricultural Extension Service, and the Texas A&M University System are proud to have played a key role in developing and transferring the conservation tillage technology to our farmers. We appreciate the opportunity to host this annual conference especially during the year we celebrate the 100th anniversary of the Hatch Act and the Texas Agricultural Experiment Station.

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Proceedings of the Southern Region No-Tillage Conference

Conservation Tillage:

Today and Tomorrow

July 1-2, 1987
College Station, Texas

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Conservation Tillage Systems in Texas

B.L. Harris, E.C.A. Runge, and G.K. Westmoreland[1]

Introduction

Adoption of conservation tillage systems is expanding in many areas of Texas, accelerated by continuing technological advances. Economic pressures favoring use of production systems involving reduced tillage naturally favor the maintenance of large amounts of residues on soil surfaces, thereby encouraging use of conservation tillage technologies. Most producers are conscientious in their efforts to reduce soil erosion, and conservation tillage is an answer for many.

Recent passage of the Food Security Act of 1985, especially the conservation compliance provisions, will further accelerate use of conservation tillage in Texas, since it will be the most economical conservation alternative for many producers.

Research by the Texas Agricultural Experiment Station and Agricultural Research Service, field demonstrations by the Texas Agricultural Extension Service (TAEX), conservation plans by the Soil Conservation Service (SCS), and cost-sharing practices by the Agricultural Stabilization and Conservation Service encourage adoption and use of conservation tillage systems as appropriate. Some pioneering producers have taken the lead in adapting these new production technologies. Their cooperation in sharing their experiences with, other producers has sparked the spread of such systems.

Limited research-proven practices, together with inadequate, experience-taught management capabilities of producers relative to conservation tillage practices, are problems in many areas of the state. Weeds continue to be a major problem, particularly in no-till production systems, although new chemicals and experience with existing herbicides provide hope for solving this problem. Many other problems to be overcome remain before conservation tillage can become the "conventional" system. In recent years TAEX, working closely with SCS and other agencies, has focused major program efforts to encourage adoption of conservation tillage practices. In 60 targeted counties, surveys revealed that 37 percent of the producers either had adopted or planned to adopt conservation tillage practices after participating in educational programs. Also, of the producers who adopted conservation tillage, 40 percent reported equal or increased crop yields, 35 percent reduced their production costs, and 43 percent increased their net profits.

The types of conservation tillage practices used in Texas are as variable as the types of soils and cropping systems. The most common are those in which small grain, primarily wheat, is the principal component, although corn and grain sorghum residues are being used increasingly in conservation tillage systems in some areas of the state.

A national consortium of focused conservation tillage interests, established a few years ago and now called the Conservation Technology Information Center (CTIC), is located at 2010 Inwood Drive, Fort Wayne, Indiana 46815. Among its many functions, CTIC accumulates statistical data about the types and extent of conservation tillage being practiced. Those data, developed at the county level, are the best available estimates on the subject and will be used as a primary basis for discussion in this report.

CTIC defines conservation tillage as "any tillage and planting system that maintains at least 30 percent of the soil surface covered by residue after planting to reduce soil erosion by water, or, where soil erosion by wind is the primary concern, maintains at least 1,000 pounds per acre of flat small grain residue equivalent on the surface during the critical erosion period."

CTIC defines the types of conservation tillage as follows:

No-till—"The soil is left undisturbed prior to planting. Planting is completed in a narrow seedbed approximately 1-3 inches wide. Weed control is accomplished primarily with herbicides."

Ridge-till—"The soil is left undisturbed prior to planting. Approximately 1/3 of the soil surface is tilled at planting with sweeps or row cleaners. Planting is completed on ridges usually 4-6 inches higher than the row middles. Weed control is accomplished with a combination of herbicides and cultivation. Cultivation is used to rebuild ridges."

Strip-till—"The soil is left undisturbed prior to planting. Approximately 1/3 of the soil surface is tilled at planting time. Tillage in the row may consist of a rototiller, in-row chisel, row cleaners, etc. Weed control is accomplished with a combination of herbicides and cultivation."

Mulch-till—"The total soil surface is disturbed by tillage prior to planting. Tillage tools such as chisels, field cultivators, disks, sweeps, or blades are used. Weed control is accomplished with a combination of herbicides and cultivation."

Reduced-till—"Any other tillage and planting system not covered above that meets the 30 percent residue requirement."

Types and Trends of Conservation Tillage Systems

Conservation tillage practice trends in Texas are somewhat difficult to trace since the basis for statistical data collection has changed through the years. Before

[1]**Soils specialist, Texas Agricultural Extension Service; professor and head, Department of Soil and Crop Sciences, Texas A&M University; and state resource conservationist, USDA Soil Conservation Service, respectively.**

1983 and before the CTIC was established, data collection and terminology were not uniformly defined. However, data collection since 1984 when the CTIC began operations has been fairly consistent.

Acreage of cropland planted in Texas has fluctuated during the past but has ranged from 20 million to 30 million acres (Table 1). Acreage of no-till production also has varied but has increased overall and now stands at about 270,000 acres. Acreages of ridge-till and strip-till in Texas have been variable and relatively minor at fewer than 90,000 acres. Mulch tillage and reduced tillage probably should be considered together since they are so closely related in Texas. The variation of these two in recent years in part reflects weather fluctuations and consequent production variations. In general, trends are for increases in use of mulch-tillage practices. More than 3.2 million acres are mulch-tilled.

Trends since 1974 show variations in acreage of conservation tillage from year to year but generally demonstrate increases in adoption during the early years at a rate of more than 200,000 acres per year. Expansion leveled off somewhat after 1980. New conservation regulations should spur another expansion of acreage.

Statewide data (Table 2) demonstrate that fall-seeded small grain is the predominant crop in conservation tillage systems in Texas, accounting for more than 2.2 million acres. Full-season grain sorghum and corn account for almost 670,000 and 310,000 acres, respectively. Other crops make up lesser acreages. Most of the small grain in conservation tillage is mulch-tilled, by far the largest of all categories. Small grain and permanent pasture make up the bulk of no-till acreages. Cotton and soybeans produced under conservation tillage systems are mostly grown with mulch- or reduced-tillage practices.

Cropping and Conservation Tillage Systems for Major Production Regions

A combination of Major Land Resource Areas and Texas Crop Reporting Districts was used to identify areas appropriate for discussions about specific types of tillage systems used in the state. Of the 22.8 million acres of croplands indicated in Table 1, the Major Crop Production Regions developed for this study and shown in Table 3 and Figure 1 represent 21.1 million acres. The other less extensive crop production regions are not included in these discussions.

Another source of data for these discussions is the Texas Agricultural Statistics Service (TASS), a division of the Texas Department of Agriculture, located at 300 E. Eighth Street, Room 555, Austin, Texas 78767. Some differences in total "cropland between TASS and CTIC data are due to different statistical techniques for information gathering.

Below are discussions of conservation tillage systems for each major production region in Texas:

Northern High Plains

The Northern High Plains is made up predominantly of soils with clay loam surface horizons and clay-textured subsoils except for the extreme northwestern portion, which has sandy-textured soils. This mostly level to gently sloping region is subject to wind erosion in western sections and to water erosion along breaks into drainageways.

TASS describes this 23-county area of 15 million acres as having 5.3 million acres of cropland, of which corn (473,000 acres), irrigated cotton (430,000 acres), dryland cotton (121,000 acres), irrigated grain sorghum (520,000 acres), dryland grain sorghum (400,000 acres), soybeans (63,000 acres), irrigated wheat (848,000 acres), and

TABLE 1. EXTENT OF CONSERVATION TILLAGE IN TEXAS[1]

Production Year	Acres" Cropland	No Till	Ridge Till	Strip Till	Mulch[3] Till	Reduced Till	Consv.[4] Till
	Acres (1000)						
1974	**23,500**	109	—	—	**1,101**	—	**1,210**
1975	**24,400**	**209**	—	—	**1,179**	—	**1,388**
1976	**26,702**	**209**	—	—	**2,121**	—	**2,330**
1977	**26,948**	**262**	—	—	**2,357**	—	**2,619**
1978	**23,436**	**147**	—	—	**1,501**	—	**1,648**
1979	**29,792**	**122**	—	—	**1,255**	—	**1,377**
1980	**27,483**	**125**	—	—	**3,500**	—	**3,625**
1981	**26,369**	**44**	—	—	**2,554**	—	**2,598**
1982	**29,469**	**45**	—	—	**3,154**	—	**3,199**
1983	**20,399**	**149**	110	33	**2,667**	**2,060**	**5,019**
1984	**24,583**	**336**	9	12	**1,178**	**1,320**	**2,855**
1985	**24,841**	**308**	45	20	**2,141**	**1,590**	**4,104**
1986	**22,819**	**269**	67	20	**3,201**	**219**	**3,776**

'**Data for 1982-1986 from Conservation Technology Information Center annual reports. Data** for 1974-1981 from **Soil Conservation Service estimates.**

[2]**Total cropland planted.**

[3]**Data for production years 1974-1982 involved compiling all conservation tillage practices except no-till in one category called** Reduced/Minimum **Tillage, here combined under "Mulch till" since that represents the most extensive practice by current definitions.**

[4]**Total conservation tillage acreage.**

TABLE 2. INDIVIDUAL CROP ACREAGE BY CONSERVATION TILLAGE TYPES'

Crop category	Acres cropland	No Till	Ridge Till	Strip Till	Mulch Till	Reduced Till	Consv.* Till
Corn (FS)	1,723,039	6,417	6,590	850	239,154	57,140	310,151
Corn (DC)	57,763	2,000	0	0	5,920	0	7,920
Small Grain (SpSd)	378,333	1,489	0	0	15,476	16,455	33,420
Small Grain (FlSd)	7,921,153	165,272	3,700	10,750	2,052,063	0	2,231,785
Soybeans (FS)	334,317	3,850	1,000	350	23,700	5,075	33,975
Soybeans (DC)	15,397	1,350	0	0	1,250	0	2,600
Cotton	5,477,804	5,875	5,126	5,040	87,971	32,035	136,047
Grain Sorghum (FS)	4,986,814	24,606	6,820	2,753	528,011	107,068	669,258
Grain Sorghum (DC)	394,511	9,885	0	100	54,589	50	64,624
Forage Crops	271,932	2,735	0	0	58,207	0	60,942
–Permanent Pasture	436,476	70,961	0	0	111,721	0	182,682
Other Crops	1,258,380	45,880	43,439	200	134,323	1,000	224,842
–Fallow	1,492,708	38,332	0	0	172,707	677	211,716
–Conservation Use	4,479,299	0	0	0	0	0	0
Totals	22,819,443	269,359	66,675	20,043	3,200,664	218,823	3,775.564

'Taken from Conservation Technology Information Center, 1986 National Survey of Conservation Tillage Practices, Texas County Summary.
*Sum of no-till, ridge-till, strip-till, mulch-till, reduced-till
FS—Full Season; DC—Double Crop; SpSd-Spring Seeded; FISd-Fall Seeded
Fallow includes cropland idled for the entire year
conservation use includes cropland idled for set-aside or diverted acres
–Not included in totals

TABLE 3. CONSERVATION TILLAGE SYSTEMS FOR MAJOR CROP PRODUCTION REGIONS IN TEXAS'

Production region	Acres Cropland[2]	No Till	Ridge Till	Strip Till	Mulch Till	Reduced Till	Consv. Till[3]
Northern High Plains	5,182,149	50,065	4,000	3,325	959,389	75,139	1,091,918
Southern High Plains	4,283,226	20,225	12,250	4,315	269,788	42,700	349,278
Northern Rolling Plains	1,671,289	1,960	2,750	2,300	402,700	5,450	415,160
Southern Rolling Plains	2,001,734	1,855	0	0	217.135	14,588	233,578
North Central Prairies and West Cross Timbers	869,368	19,480	0	0	187,144	1,925	208.549
Blackland Prairie and Grand Prairie	2,878,000	28,593	800	3	562,226	1,700	593,322
Northeast Texas	393,174	52,355	2,780	0	76,680	15,515	147,330
South Central Texas	1,080,113	26,423	300	10,000	116,009	7,960	160,692
Upper Coast Prairie	1,076,898	6,180	1,056	0	72,409	23,431	103,076
Coastal Bend	666,298	0	0	**0**	105,550	0	105,550
Lower Valley	962,647	100	41,739	0	30,085	21,100	93,024

'Major Production Regions based on Major Land Resource Areas and Texas Crop Reporting Districts.
Total cropland planted.
[3]Total conservation tillage acreage.

dryland wheat (2.13 million acres) comprise the major crops.

Mulch tillage is the predominate type of conservation tillage practice used, accounting for 87 percent of the total in conservation tillage acreage. Reduced-till accounts for 7 percent. No-till production systems represent only 5 percent, but the acreage is expanding.

Fall-seeded small grain, principally wheat, represents about 65 percent of the total conservation tillage in this region. Full-season grain sorghum is about 15 percent and full-season corn about 14 percent of the total conservation tillage being practiced. The USDA-ARS Laboratory at Bushland has shown clear advantages for farmers to adopt a wheat-fallow-sorghum cropping system. Where irrigation water is available, irrigated wheat-fallow should be followed by either dryland or irrigated sorghum. Wheat can be double-cropped after sorghum in irrigated systems. Yields have been superior with the conservation tillage systems, and profits have averaged $30 per acre more for no-tillage over conven-

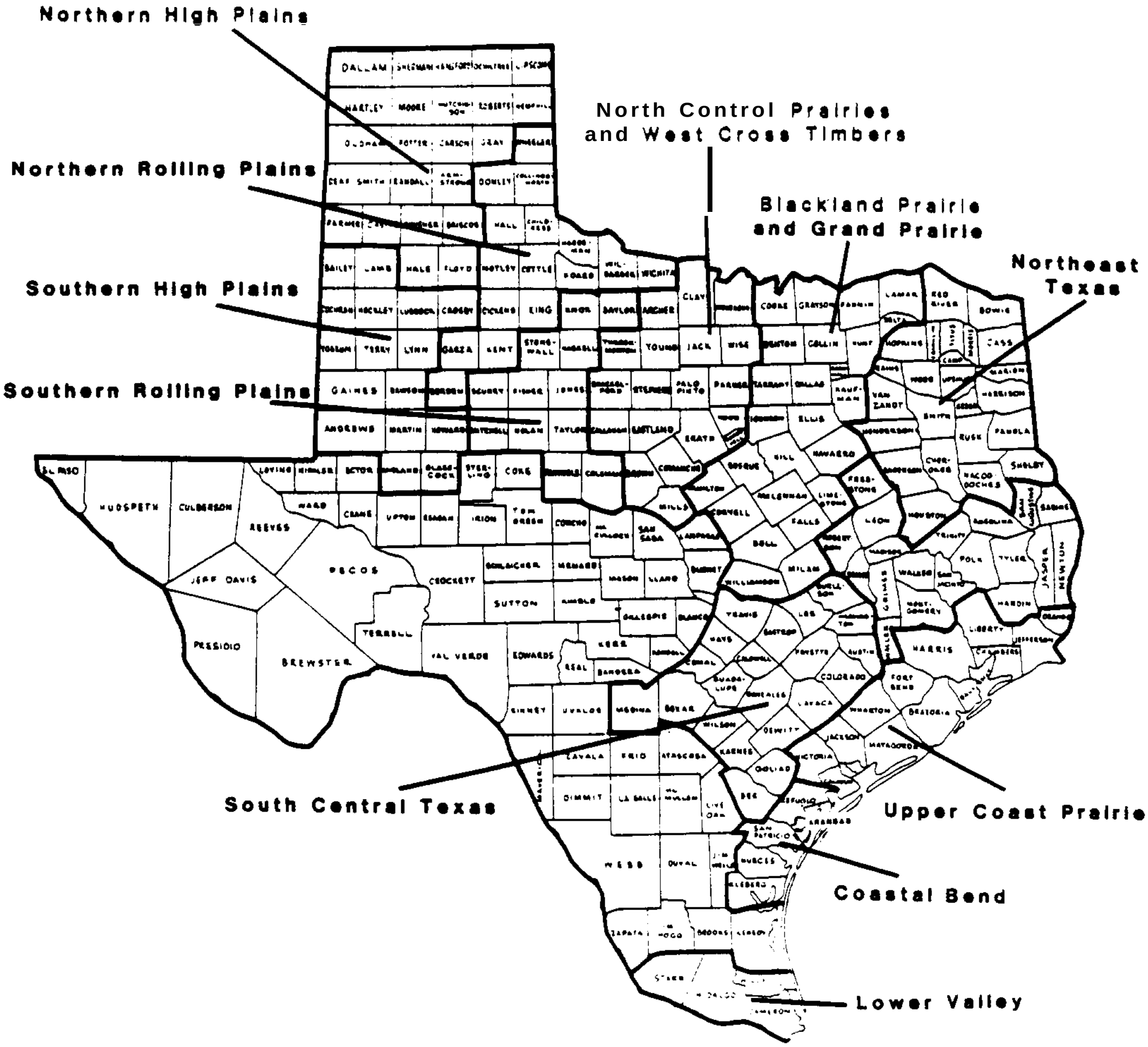

Figure 1. Major Crop Production Regions
(Portions of west and southwest Texas not Included)

tional systems involving inversion tillage practices in long-term research at Bushland.

Southern High Plains

The Southern High Plains, an area of sandy soils ranging from fine sands in the southwestern part to fine sandy loams in the northern areas, is comprised of 16 counties totaling 9.9 million acres, of which about 4 million acres are "planted croplands." Of those lands, according to TASS data, corn (70,000 acres), irrigated cotton (921,000 acres), dryland cotton (1.5 million acres), peanuts (47,000 acres), irrigated grain sorghum (141,000 acres), dryland grain sorghum (579,000 acres), soybeans (17,000 acres), irrigated wheat ((130,000 acres), and dryland wheat (470,000 acres) comprise the major crops. As with the Northern High Plains, nearly 270,000 acres of the 322,000 acres of conservation tillage systems are in mulch tillage in this region. Reduced tillage, a practice similar to mulch tillage, accounts for about 43,000 acres. Only limited amounts of other conservation production systems are used.

Fall-seeded wheat and other small grains make up about 55 percent of the total acreage of conservation systems. Full-season corn, cotton, and grain sorghum individually make up about 11 percent of the total conservation tillage systems. Double-cropped grain sorghum is about 10 percent of the total.

Conservation tillage systems are particularly difficult in the Southern High Plains region since the area has a dominance of cotton production and therefore low residue levels. Both dryland wheat and grain sorghum have relatively low production potential in most years, and inadequate irrigation is available for corn production. In about one year out of five, crop failures can be anticipated with wheat and grain sorghum. In many years, rainfall will be inadequate to allow planting of small grain following cotton. Severe wind erosion is common in the Southern High Plains, which makes surface residue cover valuable. A problem arises, however, in attempts to grow plant material that will provide adequate cover to protect the soil surface.

A few innovative farmers have developed no-till cotton production following wheat. However, the acreage of such systems is very limited. Also, farmers have commonly experienced near crop failures with attempts at conservation tillage because of weed control problems with herbicides on coarse, sandy soils.

Northern Rolling Plains

In general, this area has a gently rolling topography with cropland areas ranging from 1 percent to 5 percent slope. Soils vary in texture, ranging from small areas of sands to larger areas of fine sandy loams to clay loams. Both wind erosion and water erosion are problems for this region.

TASS indicates that this 16-countv area of 8.7 million acres has about 1.7 million acres of cropland, of which corn (4,000 acres), irrigated cotton (36,000 acres), dryland cotton (496,000 acres), peanuts (6,300), irrigated grain sorghum (4,000 acres), dryland grain sorghum (76,000 acres), irrigated wheat (20,000 acres), and dryland wheat (890,000) comprise the major crops. Wheat, the dominant crop in this region of the state, represents more than 82 percent of the conservation tillage systems being used. Full-season grain sorghum makes up about 5 percent.

Mulch tillage makes up 97 percent by area of the conservation tillage systems practiced in this region (Table 3). Although other types of conservation tillage systems are minor in extent, some innovative systems have been developed for producing crops such as peanuts on sandy soils. Strip tillage, a relatively new practice in the area, has been quite successful in peanut production and is of great value in controlling wind erosion.

Research at Chillicothe-Vernon has shown definite advantages for using furrow diking in wheat, sorghum, and cotton rotations under reduced-tillage systems. Reduced production cost has been a primary driving factor in adoption of conservation tillage practices. Wind erosion control and protection of fragile soils from damaging runoff waters have been additional benefits. Principal problems with conservation tillage systems have been diseases, compaction, and weed control. Soil compaction is a particularly prevalent problem in this region, and considerable research has been directed toward preventing and correcting it. Destruction of plowpans is often necessary for successful conservation tillage systems in this region.

Southern Rolling Plains

This area is dominated by gently rolling landforms and soils with fine sandy loam surface textures. Soils with finer-textured surfaces occur more frequently in the eastern parts of this region. Both wind and water erosion are important problems with which farmers must deal.

TASS indicated that in this 12-county region of 7.26 million acres, about 2 million acres of cropland are planted each year. Corn (2,000 acres), irrigated cotton (27,000 acres), dryland cotton (505,000 acres), peanuts (7,500 acres), irrigated grain sorghum (6,000 acres), dryland grain sorghum (214,000 acres), irrigated wheat (15,000 acres); and dryland wheat (960,000 acres) are the principal crops.

Mulch tillage represents 93 percent of all acreage in conservation tillage in this area (Table 3). Reduced tillage, which is very similar, makes up most of the remainder. Fall-seeded wheat makes up about 86 percent of the acreage in conservation tillage, followed by full-season grain sorghum (6%) and foragecrops (7%). Few, if any, conservation tillage systems have been reproted for any other crops. As with the previously discussed areas, conservation tillage practices involve use of chemicals and sweep tillage to maintain a predominance of surface covering residues and avoid the use of inversion types of tillage implements. Rotation systems are common in this region, but few conservation tillage systems are coupled with them. Most of the conservation tillage being practiced is with continuous wheat production.

North Central Prairies and West Cross Timbers

Soils of this region vary from fine sandy loams to clay loam surface textures. Wind erosion is much less of a problem here than in the western areas of the state, but water erosion hazards are more severe.

TASS indicates that this 19-county area makes up a total of 10.47 million acres, of which 1.2 million acres are planted to crops annually, principally corn (2,000 acres), cotton (21,000 acres), peanuts (86,500 acres), grain sorghum (30,000 acres), and wheat (506,000 acres).

Mulch tillage constitutes about 90 percent of the total conservation tillage practiced in this region (Table 3). No-till production systems make up about 9 percent. Fall-seeded small grain, primarily wheat, makes up about 84 percent of the conservation tillage acreage in this area. The remainder, about 9.3 percent, is primarily in peanut production areas. In this region, about 5 percent of the conservation tillage acreage are attributed to permanent pastures.

Blackland Prairie and Grand Prairie

The Blackland Prairie is an extensive region of deep, clayey soils of relatively uniform texture throughout. The Grand Prairie also is dominated by soils with fine-textured surfaces, but they commonly overlie limestone or similar material at shallow depths. Rolling topography with slopes varying from 1 percent to 5 percent dominate, and water erosion is a severe problem.

TASS indicates that this 25-county area has about 13.9 million acres, of which about 3.6 million acres are planted to crops annually. Of that acreage, corn (190,000 acres), cotton (126,000 acres), oats (340,000 acres), grain sorghum (660,000 acres), soybeans (15,000 acres), and wheat (1.4 million acres) constitute the major crops.

Mulch tillage makes up about 94 percent of the total conservation tillage acreage in this area (Table 3). No-till is used on about 5 percent of that area. Of that total conservation tillage acreage, fall-seeded small grains constitute about 65 percent. Full-season grain sorghum and full-season corn individually constitute about 9.5 percent of the total conservation tillage practiced. Continuous small grain production is the dominant cropping system in which conservation tillage is employed. However, throughout this region, crop rotation is practiced widely, and numerous examples of proper residue management and avoidance of inversion types of tillage implements can be found. In general, in such conservation systems, residues are left in place throughout the winter with the principal disturbance being bed reshaping using disk bedders.

Northeast Texas

Eastern and southern counties of this region are dominated by sandy soils ranging from loamy fine sands to fine sandy loams. The northern part has extensive areas of clay loams or finer-textured soils. Wind erosion problems are of little or no consequence, but water erosion hazards are severe in many areas.

TASS indicates that this 24-county area contains 11.16 million acres, of which 916,000 acres are planted to crops annually. Primarily, corn (16,000 acres), cotton (12,000 acres), oats (35,000 acres), rye (41,000 acres), grain sorghum (20,000 acres), soybeans (22,000 acres), and wheat 17,000 acres) are the major crops.

Mulch tillage and reduced tillage constitute 52 percent and 11 percent, respectively, of the total conservation tillage acreages in this region (Table 3). This area of the state has the greatest acreage percentage of no-till production in the state — 36 percent.

More than 65 percent of the conservation tillage in this area is fall-seeded small grain. More than 7 percent is on spring-seeded small grain. Conservation tillage in permanent pastures makes up about 21 percent of the total.

South Central Texas

Soils in this region range from extensive river valley, water-lain medium- to fine-textured soils to upland soils dominated by loamy fine sand and fine sand surface textures with heavy clay subsoils. Water erosion is a severe hazard on most of the upland soils. Soils tend to be finer-textured in the surface in the southern and western part of the region.

TASS indicated that this 21-county area of about 11.32 million acres has about 1.6 million acres annually planted to crops. Corn (230,000 acres), cotton (29,000 acres), oats (210,000 acres), peanuts (31,000 acres), grain sorghum (290,000 acres), and wheat (190,000 acres) are the major crops.

Mulch tillage makes up about 72 percent of the conservation tillage acreage in this area and no-till about 16 percent. Strip tillage is used on about 6 percent of the conservation tillage acreage.

More than 65 percent of the conservation tillage in this area is fall-seeded small grain. More than 7 percent is on springseeded small grain. Conservation tillage in permanent pastures makes up about 21 percent of the total.

Upper Coast Prairie

Extensive areas of soils with fine sandy loam surfaces and clayey-textured subsoils occur in the western counties of the region. Throughout the rest of the area, soils with clayey-textured surfaces dominate. Topography tends to be nearly level to gently sloping with most slopes less than 2 percent. Wind erosion is not a major problem, and water erosion problems are mostly related to sheet erosion and to a lesser extent rill erosion along breaks into drainageways.

TASS indicates that in this 13-county region, 7.67 million acres occur, of which about 1.2 million are planted to crops, including corn (248,000 acres), cotton (54,000 acres), oats (15,000 acres), rice (272,000 acres), grain sorghum (280,000 acres), soybeans (195,000 acres), and wheat (32,000 acres).

Mulch tillage and reduced tillage make up 70 percent and 23 percent, respectively, of the total conservation tillage acreage in this area. No-till production systems account for 6 percent.

Full-season grain sorghum and corn make up 52 percent and 33 percent, respectively, of the total crop acreage produced under conservation tillage systems. Fall-seeded small grains constitute about 5 percent. Spring-seeded small grains and permanent pastures each make up about 3 percent of the total.

In general, conservation tillage systems in this region favor maintaining surface residues produced by previous grain sorghum and corn crops, and avoiding the use of inversion types of implements.

Coastal Bend

This area is dominated by soils that are clayey-textured throughout their profiles, although small areas of soils that have fine sandy loam surfaces and clayey textured subsoils do occur. In general, the slopes are nearly level to gently sloping with most slopes less than 1.5 percent.

TASS indicates that this five-county area totals 2.24 million acres with 685,000 acres annually planted to crops. Of that cropland, corn (78,000 acres), cotton (150,000 acres), oats (4,000 acres), grain sorghum (400,000 acres), and wheat (16,000 acres) make up the major crops.

All of the conservation tillage reported for this region is mulch tillage. Eighty percent of the conservation tillage acreage involves full-season grain sorghum; 16 percent is in corn. These systems involve the maintenance of surface residues with disturbance being primarily the use of disk bedders to shape beds. Alternatively, on flat-planted fields, light disking is used to control weeds and to prepare a seedbed.

Lower Valley

This area is dominated by zones of soils that vary in texture with distance from the Rio Grande River. Closest to the river are clayey-textured soils. On terraces farther from the river, soils with fine sandy loam surfaces and more clayey-textured subsoils occur. Slopes in general are nearly level to gently sloping with dominant slopes of less than 2 percent.

TASS indicates 2.75 million acres in this four-county area are present with 969,000 acres annually planted to crops. This region has a diverse agriculture with many crops being grown, primarily corn (96,000 acres), cotton (301,000 acres), oats (1,000 acres), grain sorghum (380,000 acres), wheat (3,000), and vegetables (86,000 acres). The long growing season makes double-cropping possible, and irrigation is used to supplement rainfall on most fields.

Of the conservation tillage acreages used in this area, 23 percent are reduced-till, 32 percent are mulch till, and 45 percent are ridge-till. Conservation tillage systems involving cotton constitute about 15 percent of the total acreage. Full-season grain sorghum makes up about 34 percent and vegetable production 44 percent. The majority of the ridge-till systems are in vegetable production. Mulch tillage is used mostly with grain sorghum production, and reduced tillage is used for cotton production where conservation tillage practices are involved.

Problems With Adoption of Conservation Tillage Systems

In general, problems encountered with adopting conservation tillage systems in Texas are the same as elsewhere in the United States. Weed control is the major problem, and diseases and insect problems also are reported. However, entomologists in the High Plains and Rolling Plains are increasingly indicating reduced insect problems on conservation tillage fields, possibly due to albedo. Research is underway to further elucidate this phenomenon. Limited availability of proper planting equipment has resulted in poor stands in many conservation tillage systems. Timeliness of operations is a major problem with conservation tillage on soils with a high percentage of clay. Problems with late-season weed control and low yields have affected some areas. Attitudes biased toward clean tillage are commonplace, and lack of understanding by landowners and individuals with financial institutions are a problem in some cases. In general, the lack of appropriate management skill has been a major limitation. The lack of farmer experience in dealing with such systems and a lack of appreciation for timeliness by many producers have led to disastrous results. For example, timing weed control with cultivation is far more flexible than with chemicals. In addition, the failure of chemicals to be effective in weed control is variable from year to year, dependent to some extent on weather. Such variations cause inexperienced producers trouble.

The new conservation provisions of the 1985 Food Security Act should stimulate widespread adoption of conservation tillage practices in many areas of the state. As one of the alternatives for controlling erosion, conservation tillage will be preferred in terms of cost by many. The conservation provision effects will be concentrated in those areas most susceptible to wind erosion and water erosion. The areas in Texas where erosion problems are most severe include the High Plains, Rolling Plains, North Central Prairies, West Cross Timbers, Blackland Prairie and Grand Prairie, and South Central Texas. Conservation tillage will be invaluable in maintaining the viability of agricultural production in many of these areas.

Financial institutions now have a major impact on the use of conservation tillage systems. Farmers throughout the state are facing some of the most critical financial challenges ever. Many are in limbo as to whether they will be allowed to continue farming. In such a situation, bankers and other lenders have a major impact on farmer decision-making. Most of the lenders are requiring that producers use "proven" production systems that are conventional and commonly used throughout the area in which they are located. Such requirements do not allow for use of conservation tillage practices in most areas.

Future Needs

The need for new technology has never been greater. Research is needed to define alternatives for adoption of these relatively unknown systems. Coincidental with expanded Extension educational programs to acquaint producers with available options, the conservation planning expertise of SCS will define more clearly than ever the areas where conservation tillage systems are needed. In general, a major increase in adoption of conservation tillage systems is expected in Texas.

Nitrogen Requirements of Conservation Tillage Systems[1]

F.N. Hons, N.A. Locke, R.G. Lemon, and V.A. Saladino[2]

Introduction

Conservation tillage has been one of the most rapidly adopted agricultural practices of the past 15 years (CTIC, 1983). The primary impetus for conservation tillage has been decreased soil erosion; fuel, labor, and machinery costs; and increased soil water storage and yields (USDA, 1975). Conservation tillage may be broadly defined as tillage practices that reduce soil and water losses as compared with conventional tillage methods (Mannering and Fenster, 1983). The Soil Conservation Service more strictly defines conservation tillage as any system with 30 percent or greater of the previous crop's residue remaining on the soil surface following planting. Conservation tillage systems include no-till, ridge till, strip till, mulch tillage, reduced tillage, and minimum tillage. No-till is the most extreme example of conservation tillage, with the only primary soil disturbance created by coulters positioned ahead of planter units.

Tillage practices can influence soil nutrient availability. Conventionally tilled grain crops often yield greater than no-till treatments when the rate of nitrogen (N) fertilizer recommended for conventional tillage is applied to both systems (Thomas et al., 1973; Bandel et al., 1975; Blevins et al., 1977). When slightly higher N rates are added, no-till yields may be equal or superior to conventionally tilled crops. The increased N requirement for no-till may be due to several factors. Kitur et al. (1984) suggested that the large amount of surface residues associated with certain conservation tillage soils might result in considerable immobilization of surface-applied N. Conservation tillage soils may also be wetter and have larger continuous pores than conventionally tilled soils, enhancing leaching and denitrification losses (Thomas et al., 1973; Rice and Smith, 1982). Differences in fertilizer N requirements are usually most evident when comparing conventional and no-tillage systems. With increasing degrees of tillage in other reduced-tillage systems, however, differences will be less distinct.

Fertilizer N placement often is an important consideration in conservation tillage systems. Mengel et al. (1982) reported that subsurface banding of N resulted in greater no-till corn yields and suggested immobilization and volatilization as possible reasons for the reduced effectiveness of surface-applied N in high-residue systems. Nitrogen source may also influence yields in conservation tillagc systems. Surface residue accumulation is often associated with increased urease activity near the soil surface (Dick, 1984). Urea or urea-containing fertilizers applied to these soils may lose N through volatilization, resulting in decreased N efficiency and lower yields (Bandel et al., 1980).

Although several aspects of conservation tillage, including moisture storage and weed control, have been investigated in Texas (Unger, 1978, 1984, 1986; Unger and Wiese, 1979), little information is available concerning fertility requirements of conservation tillage systems within the state. Most reported research concerning fertility management with conservation tillage has been conducted in other states with corn as the primary crop (Moschler and Martens, 1975; Legg et al., 1979; Rice and Smith, 1983). Research concerning the nitrogen requirements of conservation tillage in Texas is imperative if this practice is to become a viable alternative.

NITROGEN FERTILIZATION OF CONSERVATION TILLAGE SYSTEMS

Tillage, Cropping Sequence, and N Rate Effects on Yield

A study was initiated in the fall of 1982 on a calcareous (pH 8.2) Ships clay (Udic Chromustert)-Weswood silt loam (Fluventic Ustochrept) intergrade in Burleson County to delineate the effects of tillage, cropping sequence, and N fertilizer rate on crop yields. The study consisted of five cropping sequences and two tillage treatments with variable N rates applied to all crops except soybean *[Glycine* max (L.) Merr.] (Table 1). The wheat *(Triticum aestiuum)*-soybean doublecrop produced two crops each year, while the sorghum (Sorghum *bicolor* L. Moench)-wheat-soybean sequence yielded three crops every two years. The continuous (monocropped) treatments resulted in one crop each year. Conventional tillage included three diskings after each harvest, bedding, rolling cultivation of beds, bed shaping, planting, and seasonal cultivation. Each crop was planted into the undisturbed residue of the previous crop in the no-till treatments. Fertilizers were subsurface banded in sorghum and soybean, and surface broadcast in wheat.

Grain Sorghum

Cropping sequence had no effect on sorghum yields in 1985, but a significant tillage x N interaction did occur (Figure 1). At 0 and 45 kg N ha^{-1}, conventional tillage resulted in greater yields than no-till, possibly because of decreased decomposition and mineralization associated with no-till surface residues (Dick, 1983). Yields were equivalent at the two higher N rates, however. Immobilization of applied N by surface residues should not have been a problem since all treatments were subsurface banded.

[1]Contribution of the Soil & Crop Sciences Dept., Texas Agric. Exp. Sta., Texas A&M Univ., College Station, TX 77843.

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TABLE 1. CROPPING SEQUENCE AND N RATE VARIABLES

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

†13 kg P ha^{-1} applied to each crop.

The main effects of cropping sequence, tillage, and N rate were significant for sorghum yield in 1986, while all interactions were non-significant (Table 2). Winter and early spring 1986 were drier than normal (Table 3). Sorghum was planted in late March. Continuous sorghum emerged to an adequate population density, whereas poor germination in the sorghum-wheat-soybean sequence resulted in an inadequate density. Heavy residues in the latter sequence inhibited proper seed placement, and high winds following planting quickly depleted seed zone moisture. Sorghum in the sorghum-wheat-soybean sequence was replanted four weeks later after rainfall. Continuous sorghum experienced drought stress during early growth and development, while the replanted sorghum received above-average rainfall in late spring and early summer, resulting in higher yields for the sorghum-wheat-soybean sequence.

Conventionally tilled sorghum produced higher yields than no-till sorghum in 1986 (Table 2). Midge *(Contarina sorghicola)* populations were high and may have resulted in greater damage to the no-till sorghum, which flowered seven to 10 days later than conventional tillage sorghum. Although the tillage x N interaction was not significant in 1986, grain yields tended to be lower with no-till at low N rates as observed in 1985.

Hard Red Winter Wheat

Crop sequence x N rate and tillage x N rate interactions were significant for wheat grain yields in 1985 and 1986. In addition, the sequence x tillage interaction was significant in 1986. Continuous wheat with 0 and 34 kg N ha^{-1} produced greater yields than the other sequences in 1985, while the sorghum-wheat-soybean sequence yielded greater than the other sequences at the highest N rate (Figure 2). Wheat in the sorghum-wheat-soybean sequence receiving no N resulted in the lowest yield each year, presumably because of the nitrogen-depleting capacity of sorghum. Yield trends were similar in 1986, although yields were lower than 1985 because of drought that extended from December 1985 to May 1986. The tillage x N rate interaction for wheat yield (Figure 3) was similar to that reported for sorghum (Figure 1). No-till wheat exhibited lower yields at the

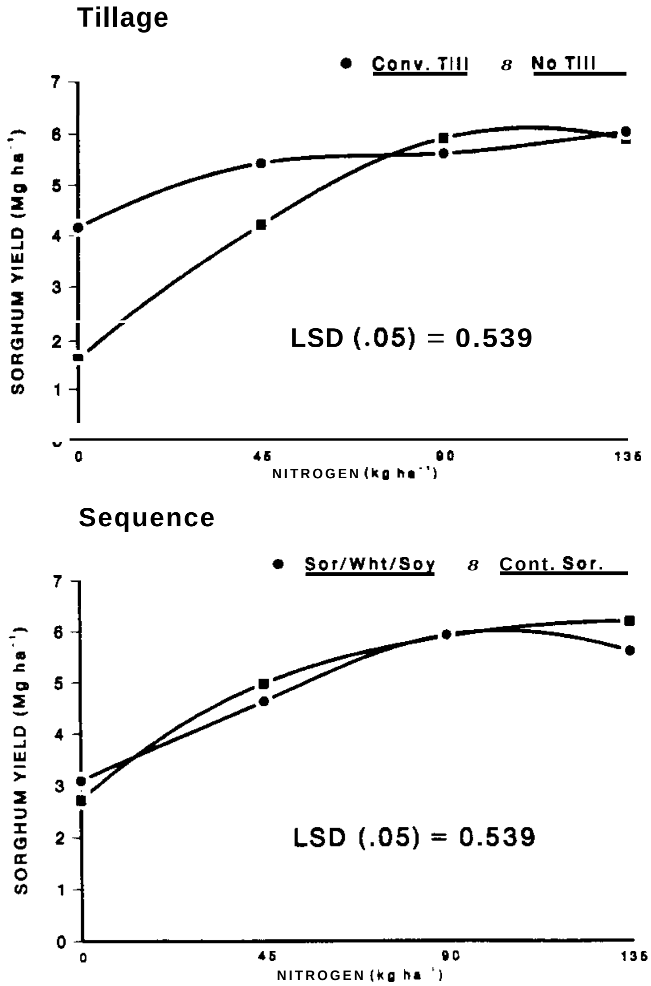

Figure 1. Effects of tillage, crop sequence, and N rate on sorghum yields, 1985.

TABLE 2. CROPPING SEQUENCE, TILLAGE AND N RATE EFFECTS ON GRAIN SORGHUM YIELD, 1986

Treatment	Grain Yield
N Rate, kg ha^{-1}	Mg ha^{-1}
0	3.55 c†
45	5.08 b
90	5.68 a
135	5.68 a
Sequence	
Sorghum-wheat-soybean	5.65 a
Continuous sorghum	4.32 b
Conventional	5.36 a
No-till	4.63 b

†Means within N rate, sequence, or tillage treatments followed by the same letter are not different by LSD (0.05).

TABLE 3. RAINFALL FOR BURLESON COUNTY SITE, 1985 AND 1986

Month	1985	1986	SO-year Average	Percentage of Average 1985	Percentage of Average 1986
	mm			%	
January	68.3	26.4	75.4	90.6	35.0
February	89.7	52.1	76.5	117.3	68.1
March	55.6	15.7	73.9	75.3	21.3
April	33.3	53.3	96.0	34.7	55.6
May	130.8	220.0	125.0	104.7	176.0
June	29.2	103.1	79.5	36.7	129.7
July	58.4	58.2	69.1	84.6	84.2
August	14.0	102.9	56.4	24.8	182.4
September	108.5	147.6	63.0	172.2	234.3
October	201.2	119.6	80.5	249.8	148.6
November	131.3	74.7	84.1	156.2	88.8
December	45.2	144.3	98.3	46.0	146.8

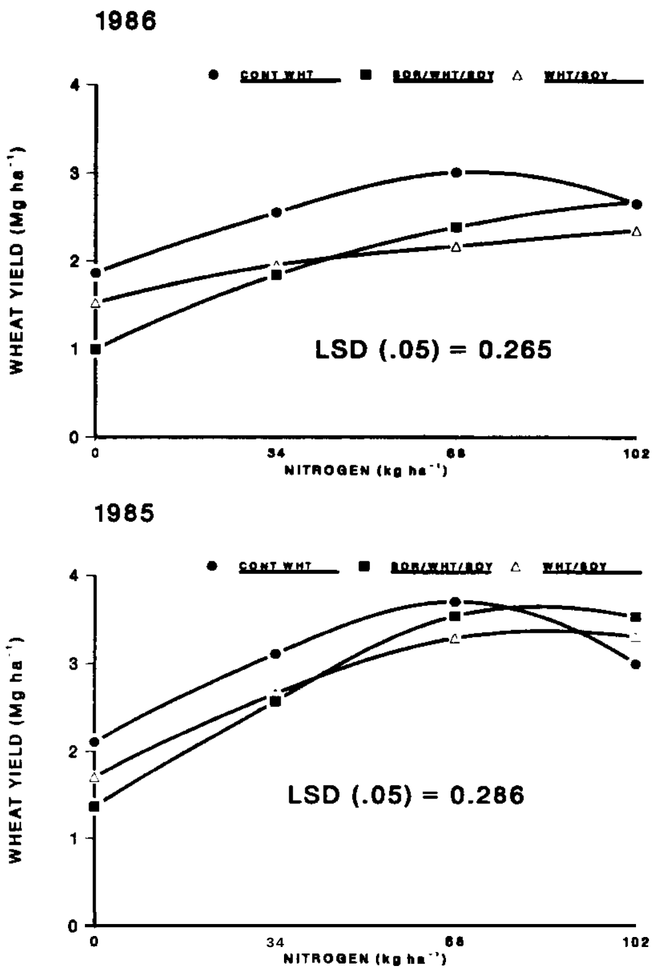

Figure 2. Cropping sequence and N rate effects on wheat grain yield, 1985 and 1986.

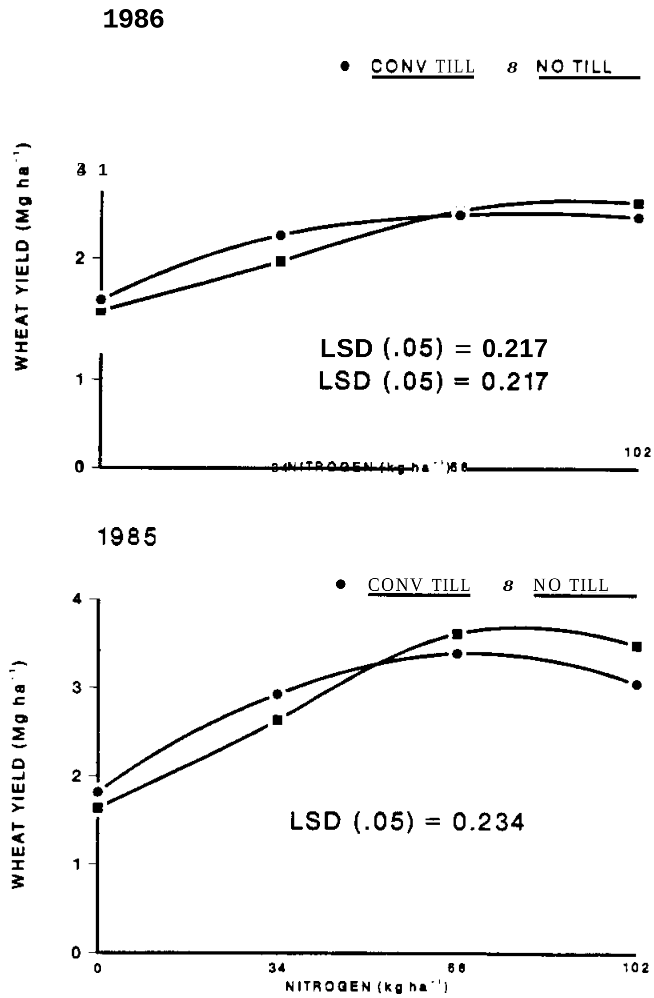

Figure 3. Tillage and N rate effects on wheat grain yield, 1985 and 1986.

lower N rates but equivalent or higher yields at the higher application rates. The sequence x tillage interaction was not significant for the sorghum-wheat-soybean rotation in 1986 but was significant for the other sequences. No-till yields were lower than with conventional tillage in continuous wheat but higher in the wheat-soybean rotation (Figure 4). The reason for the above interactions is not known, although differences in stand establishment may have had an effect.

Soybean

Soybean yields tended to be lower in 1985 than 1986 (Table 4), presumably because of extremely dry conditions from June to late September 1985. Rainfall was above average for most of the 1986 season (Table 3). No marked trends associated with tillage or sequence were evident, although yields tended to be lowest with the wheat-soybean doublecrop. The sorghum-wheat-soybean sequence produced soybean yields equal to or greater than continuous soybean, and may therefore be more economically feasible than the monocrop treatment.

TABLE 4. SEQUENCE × TILLAGE INTERACTION FOR SOYBEAN YIELDS, 1985 AND 1986

Sequence	Yield: Conventional Till	Yield: No-Till
	Mg ha^{-1}	
	1985	
Sorghum-wheat-soybean	**1.83** ab[†]	**1.79** abc
Continuous soybean	**1.97** a	**1.61** c
Wheat-soybean	**1.58** c	**1.73** bc
	1986	
Sorghum-wheat-soybean	**3.02** bc	**3.59** a
Continuous soybean	**3.22** b	**3.19** b
Wheat-soybean	**2.85** c	**2.89** c

'Means within a year followed by the same letter are not different by LSD *(0.05).*

TABLE 5. TILLAGE EFFECTS ON SORGHUM GRAIN AND STOVER YIELDS

Tillage Treatment	Grain 1985	Grain 1986	Stover 1985	Stover 1986
	Mg ha^{-1}			
No-Ell	**5.89** b[†]	**4.80 a**	**5.20 a**	**4.43 a**
Conventional	**6.43** a	**5.31** a	**5.20** a	**4.69** a

'Means within a column followed by the same letter are not different by LSD (0.05).

Tillage and Nitrogen Placement Effects On Sorghum Yield and Fertilizer Nitrogen Uptake

Depleted $^{15}NH_4{}^{15}NO_3$ was used to measure the effects of tillage (conventional and no-till) and N fertilizer placement (surface broadcast and subsurface banded) on monocrop grain sorghum yield and fertilizer N uptake on a Weswood silt loam soil in Burleson County in 1985 and 1986. Winter wheat preceded this study so that sorghum followed wheat in 1985 and sorghum in 1986. Conventional tillage produced significantly more grain than no-till in 1985 (Table 5). Tillage had no effect on grain yield in 1986 and did not influence stover yield either year.

No-till sorghum removed more fertilizer N than conventionally tilled sorghum in 1985 (Figure 5), even though grain yields were slightly lower with no-till, suggesting that immobilization or slow N mineralization from surface wheat residue may have limited soil N availability. Nitrogen was probably not the major yield-limiting factor in no-till sorghum since the sorghum apparently was able to use fertilizer N when soil N was not available.

Dry weather during plant emergence and establishment in 1986 may account for a grain yield 16 percent lower than observed in 1985. Tillage had no effect on fertilizer N uptake in 1986 (Figure 6). Conditions that limited yields in 1986 may also have reduced crop demand, resulting in similar N uptake for both tillage systems.

Fertilizer placement had no effect on grain yield either year of the study or stover yield in 1986 (Table 6). Banding did increase stover yield in 1985, however.

Placement did not affect fertilizer N uptake at anthesis either year of the study (Figures 7 and 8). Panicle development following anthesis provided a stronger N sink, however, with subsurface banding resulting in significantly higher fertilizer N use at harvest than surface broadcasting. A greater uptake efficiency with

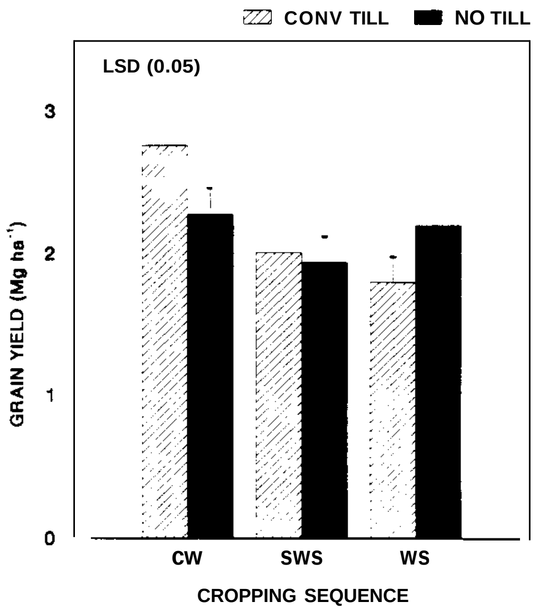

Figure 4. Sequence and tillage effects on wheat grain yield, 1986.

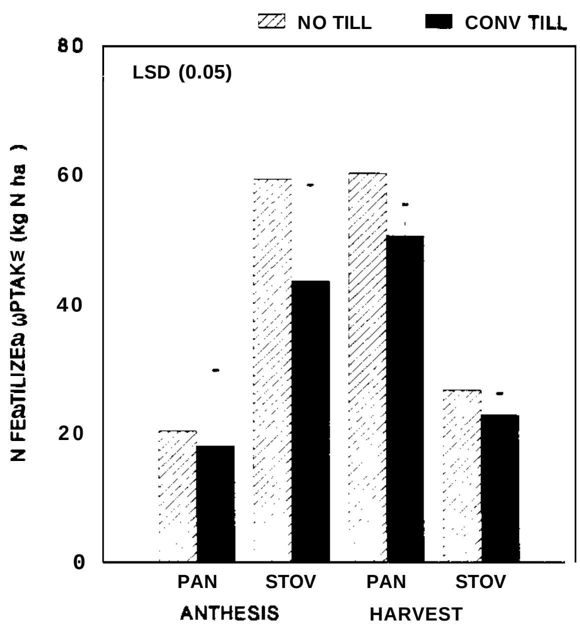

Figure 5. Tillage effect on fertilizer N uptake at anthesis and harvest, 1985. (PAN = Panicle; STOV = Stover)

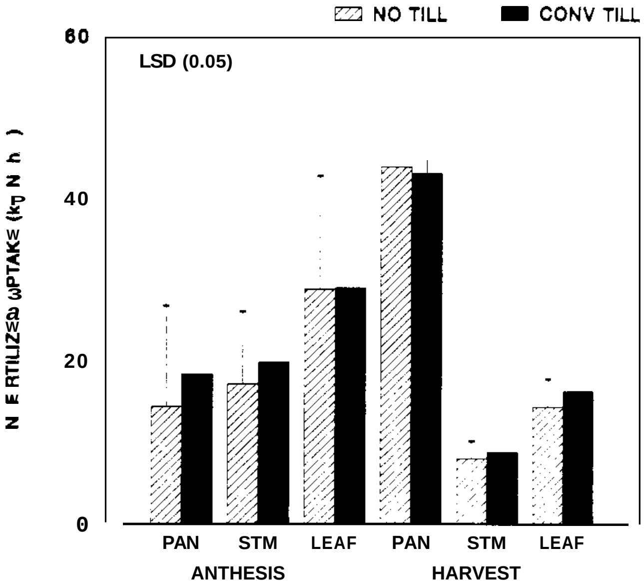

Figure 6. Tillage effect on fertilizer N uptake at anthesis and harvest, 1986. (PAN = Panicle; STM = Stem)

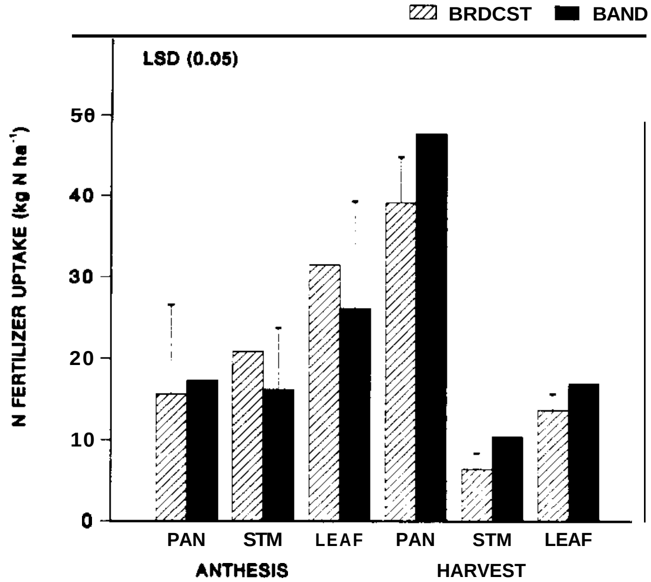

Figure 8. Placement effect on fertilizer N uptake at anthesis and harvest, 1986. PAN = Panicle; STM = Stem)

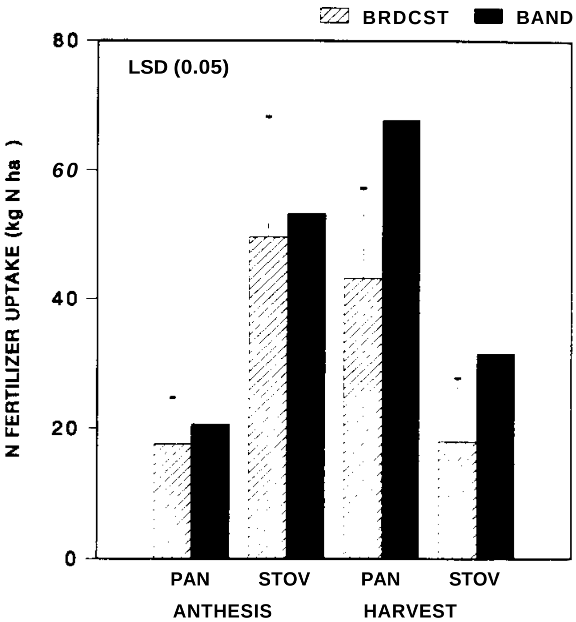

Figure 7. Placement effect on fertilizer N uptake at anthesis and harvest, 1985. (PAN = Panicle; STOV = Stover)

TABLE 6. FERTILIZER NITROGEN PLACEMENT EFFECT ON SORGHUM GRAIN AND STOVER YIELD

	Grain		Stover	
Placement	1985	1986	1985	1986
	Mg ha^{-1}			
Broadcasted	5.95 a[†]	5.00 a	4.97 a	4.44 a
Banded	6.38 a	5.11 a	5.43 b	4.68 a

[†]Means within a column followed by the **same** letter are not different **by LSD *(0.05)*.**

banding was observed with both tillage systems, implying that surface broadcasted N was probably less positionally available, especially during periods of dry surface soil conditions. Some surface broadcasted N may also have been volatilized or immobilized.

Tillage and Starter Nitrogen Effects on Corn Yield

Starter N was applied at planting in Burleson County in 1986 to determine its interactive effect with tillage (conventional and no-till) on corn *(Zea mays* L.) grain yield. All plots received 150 kg N ha^{-1} plus the appropriate rate of starter N. Corn exhibited no yield response to starter N with either tillage system (Table 7). Conventional tillage produced higher yields than no-till, however, possibly because of a decreased population density with no-till.

Tillage and Furrow Diking Effects on Yield and Nitrogen Response of Corn

The effects of factorial combinations of tillage (minimum or conventional), furrow diking (all rows diked or undiked), and N rate on corn yield were evaluated on a Ships clay-Weswood silt loam intergrade in Burleson County in 1986. The conventional tillage treatment included shredding, three diskings, bedding, bed shaping, planting, and two growing season cultivations. Minimum tillage consisted of no-till planting followed by two growing season cultivations. Dikes were established with a paddle diker in both tillage regimes following the second cultivation. Late April, May, and June were much wetter than normal (Table 3), with no observed water stress occuring during pollination or grain fill. As a result, neither tillage nor furrow diking influenced corn yield in 1986 (Figure 9). Applied N did

TABLE 7. TILLAGE AND STARTER N EFFECTS ON CORN GRAIN YIELD, 1986

Tillage Treatment	Starter N	Grain Yield
	kg N ha^{-1}	Mg ha^{-1}
Conventional	0	10.35ab[1]
	4	10.53 a
	8	10.64 a
	12	10.47 a
No-till	0	9.43 bc
	4	9.12 *c*
	8	9.40 bc
	12	10.06 ab

[1]Means followed by the same letter are not different by LSD (0.05)

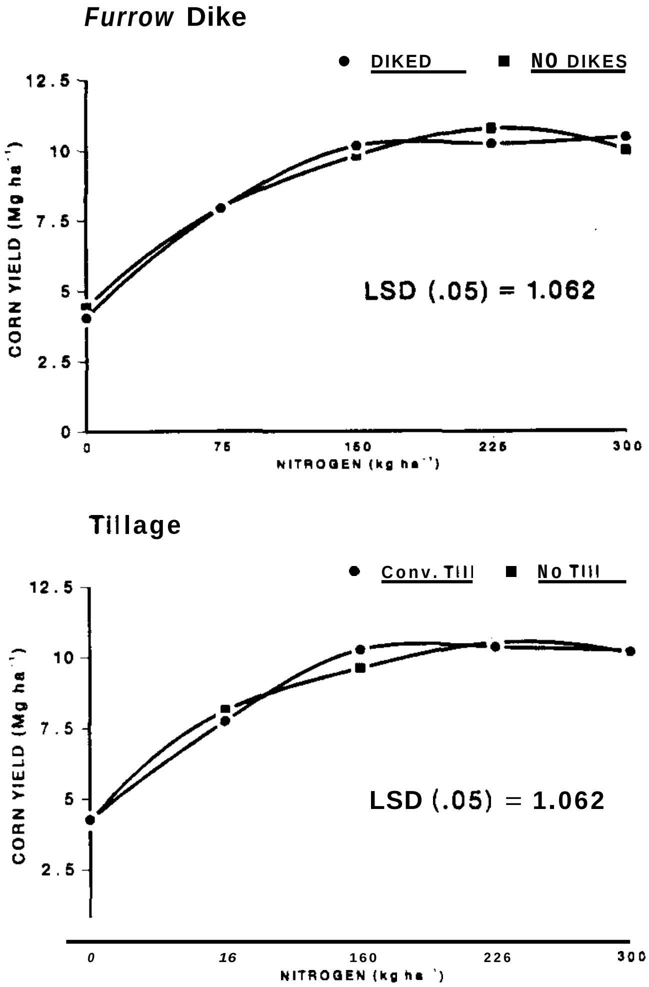

Figure 9. Tillage, furrow diking, and applied N effects on corn grain yield, 1986.

affect yield, with production significantly increased by N addition up to 150 kg N ha^{-1}.

Legume Nitrogen for Grain Sorghum Production

Nitrogen fertilization of non-leguminous crops represents one of the major costs of production. The use of winter annual legumes as a surface mulch or green manure double-cropped with non-legumes may reduce or eliminate the need for fertilizer N (Fleming et al., 1981). However, reduced N mineralization associated with no-till legume residues remaining on the soil surface and soil water depletion by preceding legumes may create difficulties for a following crop. The effects of tillage, annual clover, and N fertilization on grain sorghum yield were determined in 1985 and 1986 in Burleson County on a Weswood silt loam soil. Tillage systems included conventional, no-tillage and a green manure treatment. Clover plots that were to be green manure treatments were disked twice and rebedded before sorghum planting. Mt. Barker *(Trifolium subterraneum)* and Bigbee berseem *(Trifolium alexandrinum)* clovers were used in 1985 and 1986, respectively. Clovers in no-till treatments were desiccated with paraquat (1,1'dimethyl-4,4'-bipyridinium ion) two weeks before sorghum planting. Clovers were not included in conventional tillage treatments.

Clover dry matter and N yields were considerably greater in 1986 than 1985 (Table 8) because of berseem clover's better adaptation to the soils and climate of the area. Treatments with clover (no-till and green manure) but no supplemental N yielded more grain than conventionally tilled sorghum without added N in 1986 (Figure 10). The green manure treatment without additional N also produced considerably more grain than no-till both years of the study. The results suggested that incorporation of the clover as a green manure promoted more rapid decomposition and mineralization of tissue N as compared to the surface mulch. The tillage events may also have enhanced mineralization of residual organic soil N. One problem with an annual clover-grain sorghum doublecrop in this region is the early sorghum planting date (late March to early April) required to avoid sorghum midge damage. The early planting date may reduce clover biomass production and subsequent clover N yield.

Tillage Effects on Phosphorus and Potassium Availability

Surface application of phosphorus (P) and potassium (K) with reduced tillage could result in decreased positional availability of these nutrients. Several researchers in the southeastern U.S. have demonstrated, however, that P and K surface-applied under no-till conditions were as available as when subsurface banded, presumably because of greater near-surface rooting activity and higher soil water contents associated with no-tillage (Hargrove, 1985; Evangelou and Blevins, 1985). Limited research has been conducted with P and K in conservation tillage systems in Texas because of the relatively high concentrations of these elements in soils where much of the tillage research has been accomplished. Because of dry surface soil conditions often encountered in Texas, even with no-till, further studies are needed to compare surface-applied and knifed P and K under conservation tillage systems.

TABLE 8. CLOVER DRY MATTER PRODUCTION, N CONCENTRATION, AND TOTAL N CONTENT OF ABOVEGROUND TISSUE

Year'	Dry Matter	N Concentration	Total N
	Mg ha^{-1}	g kg^{-1}	kg ha^{-1}
1985	**0.89** b[2]	**32.3** a	**27.6** h
1986	**4.30** a	**28.0** b	**120.3** a

'Mt. Barker subterranean and Bighee berseem clovers used in 1985 and 1986, respectively.

[2]**Means within a column followed by the same letter are not different by LSD (0.05).**

Summary

Cropping sequence, tillage treatment, and applied nitrogen can interact to affect crop yield and fertilizer nitrogen uptake. No-tillage with grain sorghum and wheat produced equivalent or greater yields at higher nitrogen rates than conventional tillage, but exhibited lower yields than conventional tillage at less optimal addition rates. Cropping sequence had little influence on grain sorghum or soybean yield, while monoculture wheat tended to yield more than other wheat sequences, especially in dry years.

Subsurface banding of fertilizer nitrogen with grain sorghum resulted in greater fertilizer nitrogen uptake efficiency than surface broadcasting under both conventional and no-till practices. Dry surface soil conditions, even with no-till, may have resulted in decreased positional availability of the broadcast treatment. Improved fertilizer uptake efficiency can potentially improve yields and decrease nitrogen pollution.

Starter nitrogen applications had no effect on corn yields under conventional and no-tillage systems. Soil temperatures in the study locations are generally warmer than those reported in more northern regions of the U.S. and may partially explain the lack of starter response, even with no-till.

Furrow diking and tillage treatments had no effect on corn grain yields in 1986. Diking may he beneficial in years of below-average rainfall, however. Corn responded to nitrogen up to rates of 150 kg N ha'with both coventional and no-tillage systems.

Cool season annual legumes double-cropped with grain sorghum may provide a portion of the sorghum's nitrogen requirement. Incorporation of the legume before sorghum planting tended to increase yields relative to no-till, possibly because of more rapid clover nitrogen mineralization following disturbance.

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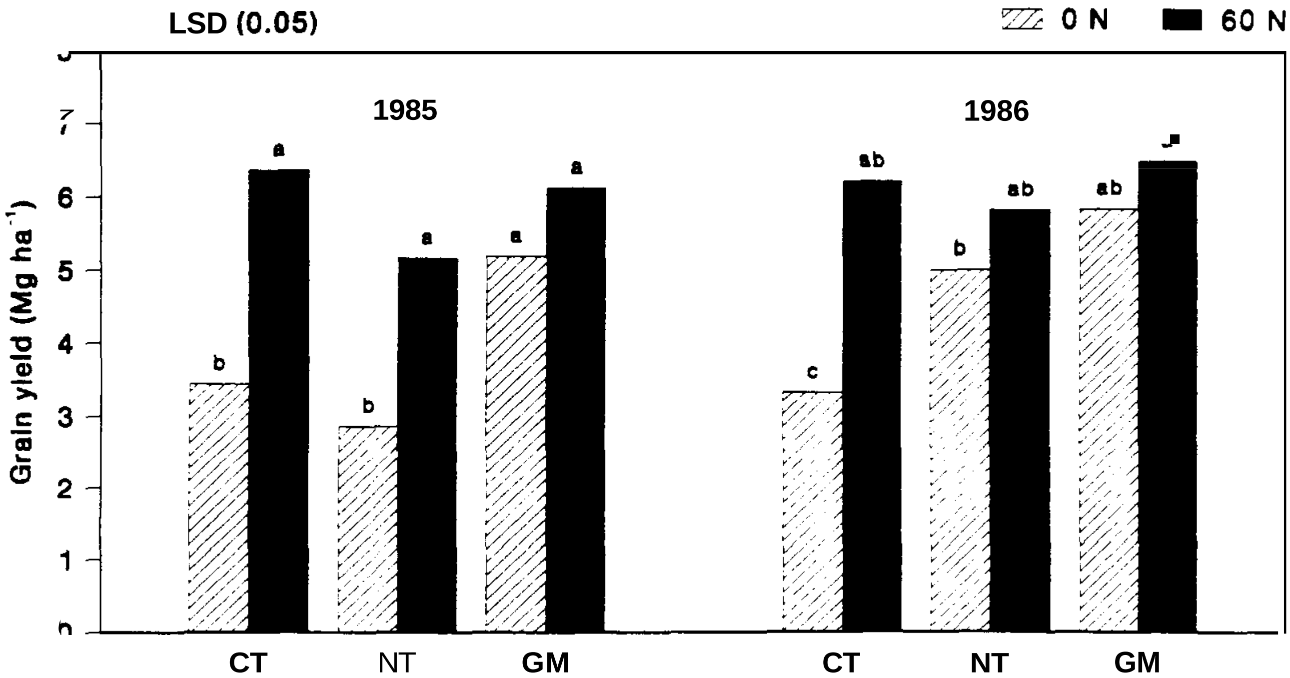

Figure **10. Tillage and clover effects on the yield** of double-**cropped grain sorghum. (CT = Conventional** Till; NT = No-Till; **GM = Green Manure)**

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Water Management With Conservation Tillage[1]

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Introduction

Plant water stress is a common problem in arid and semiarid regions. Additionally, water stress due to short term droughts can severely limit crop yields in subhumid and even in humid regions. Each of the above climatic regions occurs in Texas, but research to develop practices to minimize the adverse effects of water deficiencies has been conducted mainly in the semiarid and subhumid regions, with a limited amount being conducted in the humid regions. In arid regions, water stress is alleviated mainly by irrigation.

One practice that has received much attention for erosion control in recent years and that also has water conservation benefits is conservation tillage. Conservation tillage means different things to different people. However, a commonly accepted definition of conservation tillage is any tillage system that leaves at least 30 percent of the soil surface covered with residues after a crop is planted. Another definition is "any tillage sequence that reduces loss of soil or water relative to conventional tillage; often a form of non-inversion tillage that retains protective amounts of residue mulch on the surface" (SCSA, 1982). The latter definition does not require surface residues to be present, but both definitions recognize the value of surface residues for reducing soil and water losses. We will use the more restrictive definition, namely, that surface residues be present, at least for a major part of the crop production cycle (harvest to harvest). For this report, the objectives were to review the effects of conservation tillage under various cropping conditions in Texas with respect to water conservation and use of the water for crop production. First, we will discuss the results from studies at the humid and subhumid locations, then from studies at semiarid locations in the state.

Humid and Subhumid Locations

Humid and subhumid locations at which conservation tillage research has been conducted are the College Station area, Corpus Christi, Temple, Munday, and Chillicothe. At these locations, the emphasis frequently was on factors other than water conservation and/or management, hut some results pertaining to water are available from the studies.

A study was initiated by Hons (unpublished data) in 1983 on a Ships clay-Weswood silt loam intergrade in Burleson County (near College Station) to determine the effect of tillage and cropping sequence on crop yields and nitrogen fertilizer uptake efficiency. Cropping sequences evaluated included grain sorghum-wheat-soybean, wheat-soybean, and continuous monocultures of sorghum, wheat, and soybeans. The sorghum-wheat-soybean sequence produced three crops in two years, while the wheat-soybean double-crop sequence produced two crops each year. Each monoculture resulted in one crop each year. Tillage and no-tillage treatments were compared. Neutron attenuation was used in 1985 to determine the water use by soybeans in each of the cropping sequences. The 1985 cropping season was much drier than normal and severely retarded pod development in late August and September. Yields in 1985 were about 50 percent to 60 percent of those achieved in 1984. A significant tillage x cropping sequence interaction for yield was observed in 1985 (Table 1). Tillage treatments did not significantly influence yields in any of the cropping sequences except for continuous soybeans, where yields were higher with conventional tillage than with no-tillage. Tillage and cropping sequence also significantly interacted to influence soybean water use efficiency (Table **1).** No-tillage soybeans exhibited greater water use efficiencies in the sorghum-wheat-soybean and wheat-soybean sequences than conventional tillage soybeans. Tillage had no effect on water use efficiency in monocrop soybeans, possibly because of the small quantlty of residue produced by this sequence. No-tillage soybeans in the sorghum-wheat-soybean sequence exhibited the greatest water use

TABLE 1. TILLAGE AND CROPPING SEQUENCE EFFECTS ON SOYBEAN YIELDS AND WATER USE EFFICIENCY, BURLESON COUNTY, TEXAS, 1985

Cropping sequence	Tillage treatment	Yield	Water use efficiency
		Mg ha^{-1}	kg m^{-3}
Sorghum-wheat-soybean	No-till	1.79 b'	**0.81** a
	Conventional	**1.83** ab	0.76 b
Wheat-soybean	No-till	1.73 bc	0.71 c
	Conventional	1.58 c	**0.60** d
Continuous soybean	No-till	1.61 c	**0.60** d
	Conventional	1.97 a	**0.64** d

'Column values followed by the same letter or **letters are not significantly different at the 5% probability level.**

[1]Contribution from USDA-ARS, Bushland, Texas, and TAES, Vernon, Corpus Christi, College Station, Munday, and Lubbock, Texas.
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[6] Research scientist, TAES, Munday.
[7] Professor, TAES, Lubbock.
[8]This paper reports the results of research only. Mention of a pesticide in this paper does not constitute a recommendation for use by the U.S. Department of Agriculture or the Texas Agricultural Experiment Station nor does it imply registration under FIFRA as amended.

efficiency, followed by conventional tillage soybeans in this sequence. The third greatest efficiency was produced by no-tillage soybeans in the wheat-soybean sequence, with all other crop sequence and tillage combinations giving statistically equal results. Efficiencies appeared to increase with increasing residue in the system. Conventional tillage soybeans in the wheat-soybean sequence and both tillage treatments with monocrop apparently did not result in sufficient residue to significantly improve water use efficiency.

Matocha (unpublished data) evaluated the effects of conventional, minimum, and no-tillage treatments on soil water contents, and corn and grain sorghum yields at Corpus Christi. Starter fertilizer and insecticide [carbofuran—(2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate)][8] treatments were evaluated also. Soil water contents were determined either at the period of peak demand by the crop or at crop harvest, but differences among treatments generally were slight. Grain yields generally were lower, significantly so in two cases, with no-tillage than with the other tillage treatments (Table 2). The yield decreases were attributed to increased weed pressure.

On the same soil, Matocha and Bennett (1984) compared two forms of conservation tillage with conventional, deep chisel, and deep moldboard tillage systems for cotton production over a six-year period. Glyphosate [N-(phosphomethyl) glycine] and paraquat (1,l’-dimethyl-4,4’-bipyridinium ion) were used in separate applications in the no-tillage system, while paraquat alone was used in the minimum-tillage system. Soil water content measurements in the fall season showed substantial improvement in rainfall harvesting as a result of primary deep tillage. However, treatment effects on soil water content at planting and during the growing season were minimal. Lint production in minimum- and no-tillage systems equalled or exceeded yields of other systems in four out of five seasons (a hurricane destroyed one harvest). Fiber quality values were largely unchanged by tillage treatments.

At Temple, where annual precipitation averages 840 mm, Gerik and Morrison (1984) obtained similar soil water storage and sorghum grain yields by using no- and conventional-tillage treatments on an Austin silty clay soil. Although water storage and yields were not significantly affected by the treatments, no-tillage has potential for the region because of lower production costs and because it permits using narrow rows for sorghum, which has potential for higher yields. Using narrow rows is impossible with clean tillage because the sorghum must be cultivated for weed control. Also on the Austin soil at Temple, wheat yields in a three-year study with wide beds were not significantly different in two years but were significantly lower with no-tillage in a droughty year because of less tillering (Gerik and Morrison, 1985).

At Munday in the Rolling Plains, Bordovsky (unpublished data) compared reduced and conventional tillage for grain sorghum production. For reduced tillage, glyphosate was used to control weeds between harvest and planting, and cultivation controlled weeds during the growing season. Conventional tillage consisted of disking twice, bedding, and cultivating before planting plus additional cultivating after planting. For both tillage methods, herbicides were used for growing season weed control. The treatments for non-

TABLE 2. EFFECT OF TILLAGE SYSTEM, STARTER FERTILIZER, AND/OR SOIL INSECTICIDE ON GRAIN YIELDS OF CORN OR GRAIN SORGHUM ON ORELLA SANDY CLAY AT CORPUS CHRISTI, TEXAS, IN 1983 AND 1984

Crop, year, and treatment	Grain Yield			
	Tillage System			
	Conventional	Minimum	No-Tillage	LSD **(0.05)**
	Mg ha^{-1}			
Corn—1983				
Tillage only	**3.33**	**2.94**	**2.15**	**0.78**
Tillage + Fert. +Insect.	**3.14**	**3.38**	**2.60**	NS[1]
Corn—1984				
Tillage only	**4.24**	**4.10**	**4.00**	NS
Tillage + Insect	**3.38**	**3.53**	**2.80**	**0.63**
Sorghum—1983				
Tillage only	**4.00**	**4.21**	**3.90**	**NS**
Tillage + Insect	**4.52**	**4.75**	**4.96**	NS
Sorghum **—1984**				
Tillage only	**2.12**	**2.14**	**2.40**	NS
Tillage + Fert. +Insect.	**2.89**	**2.28**	**2.14**	**0.64**

[1]NS = not significant.

irrigated sorghum had no significant effect on grain yield, water use, or water use efficiency. Grain yields for five years averaged 2.59 and 2.56 Mg ha^{-1} with conventional and reduced tillage, respectively. Under irrigated conditions, continuous grain sorghum yields with reduced tillage and clean tillage averaged 4.75 and 4.60 Mg ha^{-1} for the respective treatments. As for yields, differences in water use and water use efficiency were not statistically significant under irrigated conditions.

Also at Munday, irrigated wheat yields were significantly lower with reduced than with clean tillage for one crop out of four (5.86 vs. 4.46 Mg ha^{-1}) and averaged 4.13 Mg ha^{-1} with clean tillage and 3.48 Mg $^{-1}$ with reduced tillage (Gerard and Bordovsky, 1984). The lower yields with no-tillage resulted from a decreased number of heads, which possibly resulted from fewer plants due to planting problems in large amounts of surface residues and/or reduced tillering.

Clark (1983) reported the results of a tillage study conducted on an Abilene clay loam at Chillicothe in the Rolling Plains Resource Region, in which diked, alternate row diked, and non-diked treatments for conventional- and reduced-tillage systems were compared. Rainfall was 85 percent of normal. The tillage systems did not significantly influence cotton yields, but furrow diking before the spring planting resulted in significant yield increases (Table 3). Diking alternate furrows or every furrow resulted in yield increases of 16 percent and 36 percent, respectively.

Semiarid Locations

Conservation tillage research in semiarid Texas has been conducted at Bushland and Lubbock, where annual precipitation averages about 470 mm, with most of the precipitation occurring during May to September. Conservation tillage research involving dryland, irrigated, and irrigated-dryland cropping systems has been evaluated at the semiarid locations.

Dryland Systems

Apparently, the first conservation tillage system used in Texas on dryland was stubble mulch tillage, which was first used at Bushland in the early 1940s. This tillage method, which undercuts the surface to control weeds and retains most crop residues on the surface, was initially introduced to control wind erosion. It proved highly effective for controlling erosion provided sufficient residues were available. This, however, was not always the case, and soil-roughening tillage sometimes was needed to enhance erosion control. Where sufficient residues were available, water conservation as well as soil conservation benefits from stubble mulch tillage were soon realized. However, because of limited residue production by non-irrigated crops in the semiarid region of Texas, water conservation and wheat yields with stubble mulch tillage were only moderately greater than with clean tillage. Based on a long-term study (1942-1969), plant-available soil water contents at wheat planting averaged 91 and 103 mm with clean (one-way disk) and stubble mulch tillage, respectively. Grain yields averaged 0.59 and 0.69 Mg ha-l with the respective tillage methods for continuous wheat (Johnson and Davis, 1972).

Fallowing is primarily used in semiarid regions, with a major objective being increased water storage in soil for use by a subsequent crop. Fallowing is most successful on soils that have a large water storage capacity but that generally are not filled to capacity during the interval between crops because of limited precipitation, low infiltration rates, and/or high evaporation rates. These conditions prevail on some of the major soils in the semiarid region where fallowing is most prevalent in Texas.

In the long-term dryland study at Bushland, plant-available soil water content at wheat planting averaged 154 mm with stubble mulch and 128 mm with clean tillage in a wheat-fallow system. Grain yields averaged 1.06 and 0.93 Mg ha' with the respective treatments (Johnson and Davis, 1972). However, water storage and yields with either tillage method for the fallow system were not doubled as compared with those for the continuous wheat system. Because yields on a total area basis were lower with the wheat-fallow system, this system is not considered as suitable for the semiarid region of Texas as it is for the Central and Northern Great Plains, where yields generally are doubled by fallowing. From an economic viewpoint, it may be satisfactory because fewer planting and harvesting

TABLE 3. YIELD RESPONSE OF COTTON TO TILLAGE TREATMENTS AT CHILLICOTHE, TEXAS, 1981 (FROM CLARK, 1983)

Tillage system	Subsoiling depth	Lint yield: Furrows diked: None	Alternate	All	Average
	m	Mg ha^{-1}			
Conventional	—	**0.214**	**0.294**	**0.314**	**0.274** a
Reduced	**1.0**	**0.255**	**0.261**	**0.314**	**0.277** a
Reduced	**0.5**	—	**0.259**	**0.330**	**0.294** a
Average		**0.234** c[1]	**0.271** b	**0.319** a	

'Means within a row or column followed by the same letter are not significantly different at the 5% probability level.

operations are involved and because it reduces the risk of crop failure.

No-tillage retains more residues on the surface than stubble mulch tillage, but early results from ongoing studies on dryland for annually cropped wheat or grain sorghum indicate that no-tillage is less satisfactory than stubble mulch tillage for these crops at Bushland from a yield viewpoint (personal communication, O.R. Jones). Possible factors involved include residue phytotoxicity, inadequate weed control, herbicide carry-over, increased runoff (after sorghum) due to surface sealing, and inadequate fertility. Again, the economics of the systems must be compared to assess the suitability of these systems for a given situation.

An unusual form of residue management is the use of cotton bur or gin trash mulches to control wind erosion on sandy soils in cotton-producing areas of West Texas. Besides controlling erosion, precipitation storage is also increased by the mulches. At Big Spring on Amarillo sandy clay loam, the gain in soil water was about 40 percent as surface coverage increased from 0 percent to 100 percent (Fryrear and Koshi, 1971). Full coverage was achieved with about 11.0 Mg ha^{-1} of mulch. Water storage efficiencies were 41 percent, 58 percent, and 73 percent for the 0, 11.2, and 22.4 Mg ha^{-1} gin trash treatments, respectively. Precipitation averaged 337 mm in 1968 and 1969. Soil water content was increased to a 3-m depth, and cotton lint yields averaged 197, 260, and 282 kg ha^{-1} with the respective treatments.

Fallowing in Texas generally involves winter wheat, either in a one-crop/two-year (wheat-fallow) or a two-crop/three-year system. In the latter, winter wheat is grown in rotation with a summer crop. As indicated above, the wheat-fallow system generally is considered unsuitable for Texas from a water storage and grain yield viewpoint but may be suitable economically. The low effectiveness is attributed, in part, to its long (about 16 months) fallow period. For this system, most water storage occurs during the first summer after wheat harvest with little additional storage during the second summer. As a result, precipitation storage efficiency for the system is low. A more effective system with respect to water storage and total production is a wheat-fallow-sorghum-fallow system of two crops in three years (Unger, 1972), which has a fallow period of about 11 months between each crop. Under dryland conditions, however, even this system resulted in relatively low precipitation storage and/or crop yields, regardless of tillage method used (clean, stubble mulch, or no-tillage) (Wiese and Army, 1958; Wiese et al., 1960; Wiese et al., 1967). As for annual cropping, water conservation and crop yield benefits from conservation tillage as compared with clean tillage in the semiarid region of Texas were low because of low residue production by dryland crops.

The fact that low residue amounts were a major factor contributing to low water storage and crop yields under dryland conditions was illustrated by Unger (1978), who placed wheat straw at various rates on Pullman clay loam at Bushland after wheat harvest (start of fallow). Water storage, subsequent sorghum grain yields, and precipitation use efficiencies were more than doubled by the high residue treatments (8 and 12 Mg ha^{-1}) as compared with the no-residue treatment (Table 4). While applying crop residues to large areas may not be practical in all situations, crops such as irrigated wheat often produce more than 6.0 Mg ha^{-1} of residues, which could enhance water storage and crop yields when they are managed on the soil surface by suitable conservation tillage techniques.

Systems Involving Irrigation

Annual cropping with full irrigation generally results in the highest total production. However, the Ogallala aquifer, which supplies water for irrigation in the semiarid region of Texas, is being depleted, and the cost of irrigation (pumping water) has increased greatly in the last 10 to 15 years. Consequently, much research has been conducted in recent years to develop alternatives to full irrigation of annual crops. The goal has been to make more effective use of precipitation in the cropping system.

When irrigated wheat was followed by 11 months of fallow and grain sorghum was grown with or without irrigation, water storage from precipitation was increased, which reduced the amount of irrigation water required and/or increased sorghum grain yields. In a study by Musick et al. (1977), precipitation storage efficiencies during fallow after wheat were 35 percent and 21 percent with no-tillage and clean tillage, respectively, on level bordered plots, and 47 percent and 28 percent with no-tillage and clean tillage, respectively, on graded furrow plots. Because of the greater water storage, sorghum yields on level bordered plots averaged 5.10 Mg ha^{-1} with no-tillage and 4.08 Mg ha^{-1} with

TABLE 4. MULCH RATE EFFECTS ON SOIL WATER STORAGE DURING FALLOW, SORGHUM GRAIN YIELDS, AND PRECIPITATION USE EFFICIENCY, BUSHLAND, TEXAS, 1973-1976 (FROM UNGER, 1978)

Mulch rate	Precipitation storage[1]	Grain yield	Precipitation use efficiency[2]
Mg ha^{-1}	mm	Mg ha^{-1}	kg m^{-3}
0	72 c[3]	1.78 c	0.32 c
1	99 b	2.41 b	0.44 b
2	100 b	2.60 b	0.46 b
4	116 b	2.98 b	0.53 b
8	139 a	3.68 a	0.67 a
12	147 a	3.99 a	0.77 a

[1]Fallow period precipitation averaged 318 mm. Storage determined to a 1.8-m depth.

[2]Based on grain yield divided by total precipitation from start of fallow to end of sorghum growing season plus net soil water depletion.

[3]Column values followed by the same letter are not significantly different at the 0.05 level (Duncan's Multiple Range Test).

disk tillage when 150 mm of growing season irrigation water was applied. With 300 mm of irrigation, the respective yields were 6.46 and 5.97 Mg ha^{-1}. On graded furrows, yields averaged 5.42 Mg ha^{-1}, with an average of 169 mm of irrigation water retained on no-tillage plots and 4.26 Mg ha^{-1} with 93 mm of irrigation water retained on disk-tillage plots. The higher yields on no-tillage plots resulted from greater water storage during fallow and enhanced irrigation water infiltration during the growing season. The latter occurred even though the disk-tillage plots contained less water than no-tillage plots at sorghum planting time.

In attempts to further enhance precipitation use for sorghum production, Unger and Wiese (1979)and Unger (1984) followed irrigated winter wheat with a fallow period, then grew grain sorghum without irrigation. The irrigated wheat produced an average of about 8 Mg ha' of residue. In the study by Unger and Wiese (1979), 15 percent, 23 percent, and 35 percent of the fallow-period precipitation was stored as soil water with disk-, sweep-, and no-tillage treatments, respectively, and sorghum grain yields averaged 1.93, 2.50, and 3.14 Mg ha^{-1} for the respective treatments. Precipitation storage during fallow averaged 29 percent, 34 percent, 27 percent, 36 percent, and 45 percent for moldboard-, disk-, rotary-, sweep-, and no-tillage treatments, respectively, in the study by Unger (1984). Grain yields with the respective treatments averaged 2.56, 2.37, 2.19, 2.77, and 3.34 Mg ha^{-1}.

Baumhardt et al. (1985) evaluated the irrigated wheat-fallow-grain sorghum rotation at Bushland and at Lubbock. Disk- and no-tillage treatments were used during the fallow period. Water storage tended to be or was significantly greater with no-tillage at Bushland but was similar for both tillage treatments at Lubbock. At Lubbock, the soil was more permeable and shallower; thus, precipitation more readily filled the soil profile with water regardless of tillage method. Without irrigation, sorghum grain yields were significantly greater with no-tillage than disk tillage in both years at Bushland but in only one year at Lubbock. With irrigation, grain yields were significantly greater with no-tillage at Lubbock but not at Bushland.

Besides grain sorghum, crops evaluated in rotation with irrigated winter wheat at Bushland were sunflower and corn. In the system with sunflower, average increases in soil water during fallow after wheat were 38, 53, 61, and 71 mm with disk-, sweep-, limited-, and no-tillage treatments, respectively. Seed yields of the non-irrigated sunflower ranged from 1.23 (for sweep and limited tillage) to 1.38 (for no-tillage) Mg ha^{-1}, but the differences were not significant (Unger, 1981). In the study with corn, grain yields were lower with no-tillage due to a severe nitrogen deficiency in one year, even though analyses before planting indicated that the soil contained sufficient nitrogen. The next year when nitrogen fertilizer was applied, yield differences were not statistically significant. Water use was not significantly affected by tillage method the first year but was significantly lower with no-tillage as compared with disk or sweep tillage the second year (Unger, 1986).

Using conservation tillage for annually irrigated crops often is difficult because of planting problems in heavy residues and because of poor weed and volunteer plant control. These problems may be especially severe when crops such as wheat, corn, or grain sorghum are grown continually. In such cases, limited- rather than no-tillage systems generally have been most successful.

A study at Bushland by Allen et al. (1976) evaluated the effects of limited, clean, and no-tillage on furrow-irrigated winter wheat. The limited and no-tillage treatments were alternated annually. For no-tillage, weed and volunteer wheat control with herbicides was satisfactory in two years but required a second application of a contact herbicide in the third year because of above-average rainfall. No-tillage seeding with a conventional grain drill also was satisfactory in two years. In the third year, variable plant populations resulted from limited disk opener penetration because of high amounts of surface residues (about 10 Mg ha^{-1}). For limited tillage, satisfactory weed and volunteer wheat control was obtained with herbicides [2,4-D-(2,4-dichlorophenoxy) acetic acid] and tillage (disk bedding and sweep-rod weeding). Tillage as needed gave satisfactory control in clean-tillage plots. With both the limited- and conventional-tillage treatments, seeding and plant establishment were satisfactory each year.

Irrigation water advance in the residue-covered no-tillage and the clean-tillage furrows gave no problems. Average water infiltration for three years was significantly higher with clean than with limited or no-tillage, under both limited and adequate irrigation conditions, but no-tillage resulted in significantly higher yields than clean tillage with limited irrigation and non-significant differences with adequate irrigation. Irrigation water use efficiency was significantly higher with no-tillage than with clean tillage with both irrigation levels.

Because of less severe problems with limited tillage, Allen et al. (1976) considered this method (actually, alternating between limited tillage and no-tillage) a more practical and dependable alternative than no-tillage to clean tillage for continuous irrigated wheat production. Unger (1977) reached the same conclusion from a study at Bushland, in which irrigated and dryland wheat were alternated. and disk-, sweep-, and no-tillage treatments were evaluated. Yields after two years of no-tillage declined compared to those with other tillage methods but exceeded those with other tillage methods when these plots were tilled before establishing the fourth crop.

In a two-year study for continuous irrigated grain sorghum at Bushland, average grain yields were similar following clean- or no-tillage seeding. For the first crop, residues from a previous grain sorghum study were present. Residues in the furrow of no-tillage plots slowed irrigation water advance and increased water penetration depth and storage compared with clean tillage. No problems occurred when irrigating the first no-tillage crop, but some bed-furrow maintenance was needed before irrigating the second crop. Also, uncontrolled volunteer sorghum resulted in higher forage production but lower grain yield (Allen et al., 1975a). Because of difficulty in controlling volunteer plants, a system of continuous no-tillage is considered impractical for grain sorghum under conditions at Bushland unless "safened" seed is used. Volunteer problems were encountered also for continuous no-tillage corn (Fowler, 1972).

Although no-tillage may be impractical for continuous grain sorghum, favorable results have been obtained with limited tillage for that crop at Bushland. **A** study by Allen et al. (1980) showed that a mulch-subsoil treatment (limited tillage) consisting of applying anhydrous ammonia in the furrow by subsoiling 0.20 m deep in the fall, and sweep-rod weeding and planting in the spring resulted in significantly higher yields (5.92 vs. 5.16 Mg ha^{-1}) and irrigation water infiltration (386 vs. 347 mm) than clean tillage under limited irrigation conditions. With adequate irrigation, yield (6.86 vs. 6.35 Mg ha^{-1}) and infiltration (483 vs. 437 mm) differences were not statistically significant. Differences in water use efficiency with both irrigation levels were not statistically significant.

In a study involving irrigated grain sorghum double-cropped after wheat, no-tillage seeded sorghum emerged sooner, grew taller, and matured up to five days earlier than sorghum seeded after clean tillage. Sorghum was irrigated for emergence on both tillage areas all years except in 1972, when timely rainfall occurred after planting. For the five-year study, grain yields averaged 5.69 Mg ha^{-1} with no-tillage and 5.07 Mg ha^{-1} with clean tillage. Because of the higher yields and no difference in total water use, water use efficiency averaged higher with the no-tillage treatment (Allen et al., 1975b).

Summary

In semiarid regions of Texas, water deficiencies limit crop yields, which in turn, in many cases, result in inadequate amounts of crop residues to enhance infiltration and reduce evaporation. Hence, yields of annual crops in these situations generally were not or were only slightly enhanced by conservation tillage. At more humid locations, crop yields again were little affected by conservation tillage when weed control was satisfactory because the higher rainfall level provided generally adequate water with all tillage systems. The higher residue amounts with higher crop yields may have contributed to the lower yields in some cases, as at Corpus Christi, because of greater problems of weed control under high residue conditions. Consequently, improved weed control and/or residue management systems are needed to make conservation tillage more acceptable for annual cropping in the subhumid and humid regions of Texas.

Where water is available for adequate irrigation, similar yields generally have been obtained, regardless of tillage system employed, provided weed control and planting were adequate. This is because irrigation largely negates the water conservation benefits of conservation tillage. In contrast, conservation tillage often enhances yields under limited irrigation conditions because of the water conserved from precipitation.

Fallowing in Texas is used primarily in the semiarid western part of the state. One of its purposes is to increase soil water storage for a subsequent crop. However, under dryland conditions, residue amounts generally are too low for conservation tillage practices to greatly enhance water infiltration and/or suppress evaporation. Increased water storage and crop yields have been obtained when residues from irrigated crops have been managed by conservation tillage methods. An irrigated wheat-fallow-grain sorghum cropping system, with sorghum grown with or without irrigation, has been particularly suitable for the semiarid region of Texas. In this region, water for irrigation is limited and being depleted, soils have adequate capacity to store a large part of fallow period precipitation, and sorghum responds well to the stored water under limited irrigation or dryland conditions.

Some crop production problems regarding conservation tillage have not been solved, but conservation tillage has potential for conserving water and/or enhancing crop yields, especially in the drier regions of the state. Increased water conservation will have a major impact on maintaining crop production at satisfactory levels when the irrigation water supply further declines and when irrigated-dryland or dryland cropping systems become more common. Satisfactory crop production under such conditions will have a major impact on maintaining the economic viability of the major crop-producing area of West Texas. It also will strengthen the economic viability of other crop producing areas of the state. Although this report did not pertain to soil conservation, conservation tillage is widely recognized as being highly effective for conserving the soil. Hence, increased adoption of conservation tillage for water conservation and/or crop yield benefits also will enhance soil conservation and, thereby, result in increased compliance with erosion control regulations.

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Conservation Systems that Meet Tolerance Limits on Highly Erodible Lands

By Arnold D. King[1]

The Conservation Compliance provision of the Food Security Act of 1985 has had a dramatic impact on the Soil Conservation Service and the farmers we serve. We are tooling up to help our farmers plan and install conservation practices that will get them in compliance, if they are not already there. The legislation enforces our objective of using land within its capability, so that productivity is maintained for the benefit of future generations.

The bottom line is that farmers who plan to continue producing commodity crops on land identified as highly erodible are required to have approved conservation plans by 1990, and the planned practices must be installed by 1995. Farmers must comply if they wish to participate in many USDA programs. This poses a tremendous workload, and we are concentrating most of our efforts toward these responsibilities. Erosion prediction will play a big role in applying conservation provisions of the Food Security Act. It is very important that models reflect state-of-the-art erosion prediction technology.

We have about 45.5 million hectares of land identified as highly erodible, using the formula RKSL/T for water "T'erosion and IKClT for wind erosion. These formulas include the parameters of the wind and water erosion equations that indicate potential erosion without the influence of management.

As we apply conservation practices, these potential erosion rates are reduced to reflect predicted erosion rates under different levels of management.

A few major practices used to reduce erosion to acceptable on cropland levels include the following:

1. Grassed Waterways
2. Diversions
3. Terraces
4. Contour Farming
5. Stripcropping
6. Windbreaks
7. Conservation Tillage

In addition, many cultural practices, such as summer fallowing, improved cropping sequences, fertility management, deep breaking, chiseling, and other management inputs, work together to provide acceptable protection from wind and water erosion on cropland.

Soil conservationists do not depend on single practices to reduce erosion to acceptable levels, and practices do not always perform adequately when applied alone. Terraces usually do not result in adequate erosion control unless a crop residue practice is included to protect against sheet and rill erosion. And conversely, conservation tillage may need support from terraces, stripcropping, diversions, or waterways to provide protection from concentrated flow erosion. With these interactions in mind, our conservationists work with producers and plan management systems consisting of practices or combinations of practices that, if applied, will result in erosion control and other ecological benefits.

We feel strongly that some form of conservation tillage will be necessary on most of the land identified as highly erodible. With field crops such as corn, soybeans, grain sorghum, and wheat, extensive research and field experience have established conservation tillage as a household word in the agricultural community. For these crops, the technology is well-developed. However, conservation tillage systems for cotton, peanuts, tobacco, and a few others have not been sufficiently field-tested, and accepted methods must be developed. We hope research and development will continue on this very important practice.

Improved weed control technology is the key to increasing acceptance of conservation tillage, and we hope the current trend in herbicide development will continue.

Contour stripcropping is used extensively in some areas. This practice is very effective against sheet and rill erosion and should be expanded to several other areas of the nation. It has proven to be a very efficient method of reducing erosion, and practices such as this, which have not had much appeal, may become more widely accepted by the nation's farmers as we move into conservation compliance.

Contour farming is effective when used with other practices. Acting alone, it sometimes causes more problems than it prevents. Terraces, stripcropping, conservation tillage, and other practices complement contour farming. Another practice that accomplishes similar results is furrow diking, which is used in a few areas in West Texas. South Carolina is evaluating the practice to control erosion and improve sprinkler irrigation efficiency. The practice has a lot of potential for erosion control and water conservation.

In summary, agency personnel, industry, and farmers will work together more closely than ever to get conservation applied to the nation's cropland and to get most of our farmers in compliance with conservation provisions of the Food Security Act of 1985.

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Economics of Conservation Tillage Research in Texas

Wyatte L. Harman and J. Rod Martin[1]

Summary

Cost of production and profit implications from economic analyses of conservation tillage research differ by regions in Texas. In the semiarid regions, such as the High and Rolling Plains, conservation tillage practices usually reduce total costs of production but not necessarily variable or out-of-pocket costs. Returns to land, management, and risk are usually higher partially because of lower production costs but primarily because of higher value of sales associated with moisture conservation and increased crop yields. Cash flow difficulties may be encountered if increased sales income is insufficient to offset higher out-of-pocket expenses and added machinery investment or conversion costs.

One of the most promising conservation tillage systems for the Texas High Plains region is no-till sorghum following irrigated wheat. Maintaining high levels of wheat residue between crops with no-till practices reduces total production costs, provides for erosion control, and increases soil moisture storage for higher sorghum yields. No-till practices with supplemental irrigation in sorghum production increased returns to land, management, and risk $160 ha-' compared with conventional tillage. Under dryland conditions, returns were $98 ha-' higher with no-till. Substantial reductions in machinery depreciation costs by using no-till practices reduced total production costs $65 ha-' with irrigation but only $2 ha-' under dryland conditions. Relatively high no-till chemical costs compared with tillage costs under dryland conditions largely offset savings in no-till machinery depreciation costs.

Other research evaluating a dryland wheatlno-till sorghum/fallow rotation found that maintaining residues of dryland wheat, which are generally less than irrigated wheat, was profitable. Higher returns were largely due to increases in no-till sorghum yields and reductions in machinery depreciation costs.

New research is underway in the High Plains regarding cotton production following wheat as a grain crop and as a cover crop. Preliminary results indicate a high profit potential for no-till cotton planted in wheat stubble and irrigated cotton planted in a terminated wheat cover crop.

In the Rolling Plains, reduced-tillage cotton and sorghum in conjunction with furrow diking were the most profitable tillage systems analyzed. Lower machinery and labor costs decreased total production costs of reduced-tillage cotton by only $10 ha-' compared with conventional cotton. However, higher yields for reduced-tillage cotton resulted in $138 ha-' higher returns to land, management, and risk. Reduced-tillage sorghum returns were $76 ha-' higher than conventional tillage. Reduced-tillage wheat returns increased $37 ha' over conventional tillage.

Furrow diking in producing cotton and sorghum is a profitable conservation tillage practice in the Rolling Plains. The additional net returns above the additional costs of diking compared to check treatments averaged $57 ha-' in cotton production. The additional returns from diking sorghum averaged $69 ha1.

Economic analyses of conservation tillage research in the Blackland Prairie farming area showed that profitable no-tillage systems exist, but these systems are not yet as profitable as conventional tillage. Conservation tillage practices in this higher rainfall region do not increase crop yields and the value of sales as in the semiarid regions. Significantly higher herbicide costs of no-till exceed the savings in machinery and labor costs, reducing returns below conventional tillage.

This economic assessment revealed that additional conservation tillage research, including economic research, is needed in all regions of Texas. Further research is particularly needed in the higher rainfall areas of Texas to develop conservation tillage systems that are more profitable than conventional systems.

Current farm legislation emphasizes the need for more conservation tillage research. This legislation specifies that a conservation plan will be implemented by 1990 or producers will be denied government-related benefits. This has critical implications for producers in the higher rainfall areas where conservation tillage systems are less profitable than conventional systems.

Soil erosion in agriculture threatens crop and livestock productivity. Social concerns include potential damages from eroded sediment, shortened life of reservoirs, increased risk of flooding, increased costs of removing sediment from municipal water supplies, diminished recreational values, and damage to biological systems. These high socioeconomic costs could he minimized through additional research investments to develop profitable conservation tillage systems for agriculture. Society as well as producers would be mutual beneficiaries.

Introduction

Conservation tillage is one of many developments in agriculture receiving national, regional, and state attention as concerns heighten regarding soil erosion. Problems range from rill and sheet to wind erosion over the

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nation. Wind erosion is generally of more concern to Great Plains producers. In North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas, more than 194 million hectares of range and cropland are experiencing wind erosion problems (USDA, 1981). Cropland acreage in the six plains states eroding at an 11 metric ton rate or more exceeds 15 million hectares or about 30 percent of the total cropland. Wind erosion losses in Texas average 33.6 metric tons per hectare, five times more than losses from water erosion.

In discussing environmental impacts of possible reductions in irrigated lands of the West, Stewart and Harman (1984) delineated major areas of highly erodible soil types overlying the Ogallala aquifer in the Great Plains. Conservation tillage was described as having potential to reduce widespread soil losses while conserving underground water supplies and naturally occurring rainfall. The United States Department of Agriculture has projected that more than 80 percent of the U.S. crop acreage will be farmed with some type of conservation tillage practice by 2000 (USDA, 1975).

Adoption rates of conservation tillage in the West are highest in the Northern Plains and lowest in the Southern Plains (Texas and Oklahoma) with the Mountain and Pacific regions intermediate (USDA, 1981). Rates of adoption are related to many factors. Harman and Wiese (1985) summarized several studies, concluding that producers generally accept minimum tillage practices if herbicides control weeds as effectively as conventional tillage practices and if economic advantages can be realized. Farmers adopted no-tillage practices because labor needs, fuel costs, and erosion were reduced. Producers with high education levels tended to adopt no-tillage practices sooner than others. Reasons for not adopting no-till practices were (1) the cost of planters and drills and (2) owned equipment was in good working order. Small farmers tended to be less interested and slow to adopt minimum tillage.

Phillips et al. (1980) summarized the major advantages and disadvantages of reducing tillage practices as follows:

Advantages:

1. Reduced wind and water erosion.
2. Reduced energy requirements.
3. Can be used on sloping land where conventional-tillage practices are not acceptable.
4. Timing of planting and harvesting operations can sometimes be improved.
5. Efficiency of water use can be increased.

Disadvantages:

1. Higher incidences of insects, diseases, and rodents require increased rates of pesticides.
2. Higher management ability is needed.
3. Low soil temperatures may delay planting.

Economic benefits and costs are often the deciding factors in converting successfully from conventional practices to new practices. Harman and Wiese (1985) listed several economic parameters important in estimating relative costs and profitability of alternative tillage systems, including:

1. Tractor fuel, oil, and lubrication costs.
2. Labor time and costs.
3. Herbicide and application costs.
4. Crop yields and related harvesting costs.
5. Interest charges on operating capital.
6. Tractor and equipment depreciation.

Other elements also may change as alternative tillage practices are adopted, such as land rental payments for share-rent situations and management time required per hectare. These two items are important factors to consider for farm operators who rent land on a crop-share basis or those who are planning to expand size of operation.

Effects of conservation tillage practices on variations in income are also important to producers and the rate of adoption. Variations in yields, costs, and benefits of conservation tillage need to be evaluated. Producers vary in their willingness to take risks, particularly in times of economic hardship. Financial commitments, the type of farm organization, and external economic forces can be important factors in forming attitudes toward risk and adopting new techniques of production.

Purpose and Objectives

The purpose of this discussion is to provide producers, scientists, extension professionals, policy makers, and administrators insights into the economic implications of conservation tillage research in Texas. Specific objectives are to:

1. Discuss the importance of economics in evaluating conservation tillage practices and indicate data needed for economic analyses.
2. Analyze economic benefits and costs of ongoing and new conservation tillage research results.
3. Discuss briefly the economic implications of conservation tillage research and additional research needs for Texas.

Importance of Economics in Evaluating Conservation Tillage Practices

Economic analyses of technological advances typically emphasize long-run benefits and costs. There are, however, several short-term impacts on the producer when comparing conservation tillage practices with conventional tillage practices. These include the immediate impacts on crop yields, sales income, variable operating costs, and the farm's cash flow. Longer-term impacts on machinery depreciation costs, yield and income trends, and pay-back on machinery investments must be considered.

Specific data needed for economic analyses of conservation tillage practices include:

1. Description of conventional and conservation tillage operations and dates performed.
2. Chemical application costs, dates applied, and whether custom-hired.
3. Labor time of tillage operations and chemical applications.

4. Comparative yields with indications of statistical significance.
5. Estimates of field operating efficiencies and horsepower requirements of conservation tillage equipment.
6. Investment costs of new equipment or conversion costs of owned equipment.

Such economic data are required to assess the impacts on variable (short-run) and fixed (long-run) costs of adopting alternative production practices or technologies. Once variable or out-of-pocket costs are determined, returns over variable costs (profits) can be estimated. Then, by adding certain fixed-cost items to variable costs such as machinery depreciation, land charges, farm overhead costs, or management fees, long-run profits can be estimated. Often, as in some of the following economic analyses, only those fixed-cost items that change are considered in a comparative analysis using partial budgeting methods. When evaluating conservation tillage practices, machinery depreciation may be the only fixed-cost item affected. Thus, long-run profits, sometimes called returns to land, management, and risk, may not include land charges, farm overhead expenses, or management fees if they are unaffected by the analysis.

Other data indicating long-term yield trends as well as changes in weed pressures, soil productivity, or soil characteristics that may require different levels of inputs in the future, enhance the value of economic analyses. Often, however, long-term research costs and interruptions in research programs prevent projects from being conducted for a sufficient length of time to ascertain long-term effects.

Other important economic impacts beyond the scope of this discussion include the aggregate impacts on crop prices and input costs. For example, increased crop output through increased yields from conservation tillage could increase supplies and, therefore, place downward pressure on crop prices. Similarly, increased use of chemicals and reduced fuel requirements might change the relative price relationship between these two inputs. These and other aggregate price impacts and relationships need to be analyzed to understand the full extent of the economic consequences of conservation tillage.

Economic Analyses of Conservation Tillage Practices

The following section discusses results of economic analyses for various conservation tillage practices in monocrop and crop rotation systems. The discussion emphasizes ongoing and new conservation tillage research by regions of the state for major crops such as sorghum, cotton, and wheat. Multicrop rotations are discussed following the major crops. To keep the presentation brief, a few detailed economic analyses of conservation tillage practices are included. Others are discussed briefly. Some ongoing research that is omitted from this discussion is discussed in the Texas Agricultural Experiment Station companion research monograph, Conservation Tillage in Texas.

Comparisons of conventional and conservation tillage practices used in the research as well as the research results are described briefly for each economic analysis. Some of the research programs are relatively new, being initiated as recently as 1985. Thus, the reader and potential user of these new initiatives should be aware of their very preliminary status at the present time.

Sorghum Conservation Tillage Systems

High Plains

Difficulties exist with volunteer seedling control in continuous no-till sorghum. Wiese et al. (1967) reported early germinating volunteer sorghum in dryland continuous sorghum reduced yields where no seedbed preparation was attempted. The most practical limited-tillage system at the time eliminated one preliminary plowing and one cultivation. Allen et al. (1975) reported no-till irrigated sorghum yields were slightly lower than yields with conventional tillage in the second year of continuous sorghum. Recent development of “safened” sorghum seed that can be used with selected herbicides could enhance the potential of continuous no-till sorghum.

A more promising conservation tillage system recently developed for Texas High Plains producers is no-till sorghum following irrigated wheat in a wheat/sorghum/fallow cropping sequence (Unger and Wiese, 1979; Wiese and Unger, 1983). Sorghum is planted by no-till methods in stubble of the previous wheat crop after an 11-month idle period. Maintaining stubble by chemical means during the 1975-1981 period at Bushland, Texas, resulted in an average 5.6 cm more soil water stored at sorghum planting time than by conventional disk tillage. This additional water storage is roughly equivalent to the gain from a preplant irrigation and resulted in an average 1.12 $Mg\ ha^{-1}$ increase (51 percent) in dryland sorghum yields over the seven-year test period (Unger, 1987). When compared to sweep tillage, no-till sorghum yields were about 0.65 $Mg\ ha^{-1}$ higher (30 percent) from an additional 3.8 cm soil water stored during the idle period.

Since no-till sorghum can be irrigated also by using preexisting furrows of the wheat crop, Musick et al. (1977) evaluated no-till irrigated yields with 15 cm and 30 cm applications of irrigation water. Researchers found that 15 cm water increased yields more than 1.01 $Mg\ ha^{-1}$ with no-till practices compared with conventional disking. With the higher 30 cm application rate, no-till yields were increased nearly 0.50 $Mg\ ha^{-1}$. In another evaluation with graded furrows similar to typical irrigated farming conditions, no-till sorghum yields increased more than 1.23 $Mg\ ha^{-1}$ with about 25 cm irrigation water when compared with disk tillage. The next season irrigation rates were reduced by one half, and no-till sorghum yields were more than 1.01 $Mg\ ha^{-1}$ above conventional disking. Thus, weed-free wheat stubble maintained with chemicals increased sorghum yields over conventional tillage practices at Bushland. In addition, a preplant irrigation is not generally required to obtain satisfactory emergence of sorghum seedlings. This results in some additional water conservation.

An economic analysis of these no-till sorghum practices (including no-till corn) indicated the depletion rate of the Ogallala aquifer could be slowed while reducing on-farm energy requirements and increasing farm profits (Harman et al., 1985). Three pumping lift situations were evaluated for a 10-year period in the analysis. Present value of returns to land, management, and risk (discounted at 5 percent) were 50 percent higher using no-till practices compared with conventional practices in the average pumping lift situation of 108 meters. Under high lift conditions of 130 meters, returns were increased 67 percent with no-till and in the low lift situation of 85 meters, 45 percent. Water pumped over the 10-year period was reduced using no-till practices by 10 percent, 12 percent, and 13 percent for the low, average, and high pumping lift situations, respectively. On-farm energy use with no-till, including both irrigation and tractor fuel, dropped 15 percent for the low pumping lift, 16 percent for the average pumping lift, and 14 percent for the high lift situation. Energy and water use efficiencies (output per unit of energy or water) also increased dramatically. In the average pumping lift situation, energy use efficiency increased nearly 22 percent while irrigation water use efficiency increased 14 percent. Increases also were attained in the other pumping lift situations.

The following economic analyses of no-till irrigated and dryland sorghum systems update previous analyses in Harman et al., 1985, and Harman 1984 by using 1986 input costs, CCC loan rates, and ASCS deficiency payments. The analysis of irrigated no-till sorghum indicated that no-till variable costs were slightly less ($4 ha^{-1}) than conventional tillage variable costs (Table 1). Reduced tillage and irrigation requirements using the no-till system were offset by increased chemical costs. Total production costs (excluding land and management charges) were reduced by about $65 ha^{-1} with the no-till system, largely because of more than $46 ha^{-1} savings in machinery depreciation. Long-run profits (returns to land, management, and risk) were increased by $160 ha' with the no-till system. This includes added income of $95 ha' from the assumed higher sorghum yield of 0.84 Mg ha' using no-till practices.

Dryland conventionally tilled sorghum was compared with no-till dryland sorghum (Table 2). In this case, however, variable costs using no-till practices were $20 ha^{-1} higher than conventional tillage. Increased chemical costs of the no-till system exceeded savings in conventional tillage expenses. However, total costs of production using no-till practices were about the same as for conventional tillage because of a $23 ha-' reduction in machinery depreciation costs, a savings of about 50 percent with no-till. Returns to land, management, and risk with no-till dryland sorghum were $97 ha-' more than with conventional tillage practices.

Allen and Musick (1975) evaluated a "permanent" bed-furrow system of irrigated no-tillage sorghum following irrigated wheat from 1968 through 1973 at Bushland, Texas. Double-cropped sorghum yields were increased more than 0.66 Mg ha' average during the six years by no-till. This yield increase would allow an

TABLE 1. ESTIMATED COSTS AND PROFITS FROM IRRIGATED SORGHUM WITH ALTERNATIVE TILLAGE PRACTICES IN AN IRRIGATED WHEAT/SORGHUM/FALLOW ROTATION, TEXAS HIGH PLAINS

Item	Conventional Tillage[1]	No-till[2]
Yield, Mg ha^{-1}	6.73	7.57
	$ ha^{-1}	
Income:[3]		
Grain	484.56	545.04
Deficiency payment	275.93	310.37
Total	760.49	855.41
Variable Costs:		
Seed	8.90	8.90
Insecticides	14.83	14.83
Fertilizer	38.55	46.26
Herbicides	12.95	61.23
Tractor, equip.	33.58	10.40
Irrigation	211.89	183.35
Labor	58.14	38.05
Interest	13.32	13.99
Harvest, haul	88.96	100.08
Subtotal	481.12	477.09
Returns Over Var. Costs:	279.37	378.32
Fixed Costs:		
Machinery depreciation	80.04	34.15
Irrigation facilities	112.53	97.38
Subtotal	192.57	131.53
Total Costs:	673.69	608.62
Returns to Land, Mgmt. & Risk:	86.80	246.79

[1]Operations included four diskings, sweeping, chiseling, bedding, rolling cultivate and rod weed beds, cultivation of crop and furrow opening for irrigation. Herbicides included 2.2 kg ha^{-1} propazine.

[2]Herbicides included 3.4 kg ha^{-1} atrazine + 9.84 kg ha^{-1} 2,4-D, two applications of Roundup of 0.26 kg ha^{-1} each and 2.2 kg ha^{-1} propazine, all applied by owned sprayer. A furrnw opening operation for irrigation is also included.

[3]Grain price is $0.072 kg^{-1} and deficiency payment $0.041 kg^{-1}.

expenditure of $60 ha' for chemical control over tillage costs at the 1986 target price less harvesting and storage costs. Further, reduced irrigation costs and machinery ownership costs would allow even more for chemical control.

A risk to this system in the northern Texas Panhandle is early frost and low yields, since no-till practices may delay maturity. New, shorter-season sorghum varieties, however, are being developed to aid in averting this risk. In addition, no-till can save several days of land preparation compared with conventional tillage, minimizing somewhat the hazard of crop injury.

Irrigated and dryland no-till sorghum planted in a terminated wheat cover crop was evaluated at Lubbock and Halfway in 1986 (Keeling, 1987). Although 1986

TABLE 2. ESTIMATED COSTS AND PROFITS FROM DRYLAND SORGHUM WITH ALTERNATIVE TILLAGE PRACTICES IN AN IRRIGATED WHEAT/SORGHUM/FALLOW ROTATION, TEXAS HIGH PLAINS

Item	Conventional Tillage[1]	No-till[2]
Yield, Mg ha^{-1}	**1.82**	**2.66**
	---------- \$ ha^{-1} ----------	
Income:[3]		
Grain	**131.04**	**191.52**
Deficiency payment	**74.62**	**109.06**
Total	**205.66**	**300.58**
Variable Costs:		
Seed	**2.97**	**2.97**
Insecticides	**14.83**	**14.83**
Herbicides	**9.71**	**47.15**
Tractor, equip.	**22.24**	**8.03**
Labor	**20.14**	**10.48**
Interest	**3.06**	**5.34**
Harvest, haul	**29.80**	**34.45**
Subtotal	**102.75**	**123.25**
Returns Over Var. Costs:	**102.91**	**177.33**
Fixed Costs:		
Machinery depreciation	**47.64**	**24.96**
Total Costs:	**150.39**	**148.21**
Returns to Land, Mgmt. & Risk:	**55.27**	**152.37**

'Operations included two diskings and three sweepings. Herbicides included 1.7 kg ha^{-1} **propazine applied with owned sprayer.**

'Herbicides included 3.4 kg ha^{-1} atrazine + 0.84 kg ha^{-1} 2,4-D, 0.26 **kg ha^{-1} Roundup and** 1.75 **kg ha^{-1} propazine, all applied with owned sprayer.**

[3]**Grain price is** \$0.072 kg^{-1} **and deficiency payment \$0.041 kg^{-1}**

was a year of favorable rainfall in the southern High Plains, sorghum yields using no-till practices were significantly higher under both irrigated and dryland conditions. Irrigated yields with no-till sorghum following terminated wheat were 1.76 Mg ha' and 1.15 Mg ha-1 higher than conventional tillage at Lubbock and Halfway, respectively. Dryland no-till sorghum yields increased over conventional tillage 0.52 Mg ha1 at Lubbock and 2.09 Mg ha' at Halfway.

Using the experimental yields of 1986, irrigated returns to land, management, and risk based on custom tillage rates were more than \$173 ha' higher than conventional tillage at Lubbock and \$94 ha' higher at Halfway. Under dryland conditions, returns to land, management, and risk increased nearly \$91 ha1 and \$116 ha-' at Lubbock and Halfway, respectively, using no-till practices.

Rolling Plains

The soils of the Rolling Plains characteristically have poor structural stability, which often results in significant losses of water and soil to runoff following even moderate rainfall (Gerard, 1987). Water is the dominant factor influencing yields in this area (Clark, 1985). Since the conservation of water and soil in tillage systems occur simultaneously, it is not surprising that some of the most profitable new farming systems are conservation tillage systems. Tillage systems that reduce water runoff in the Rolling Plains generally have higher yields and tend to be more profitable compared to conventional systems that do not specifically conserve water. Research has been underway for a number of years (Gerard et al., 1983; Gerard and Bordovsky, 1984; Clark et al., 1985). Economic evaluations were initiated in 1985 (Clark, 1985; Martin, 1985).

At the Chillicothe-Vernon research station, C.J. Gerard (1987) analyzed the effects of subsoiling and diking on yields of sorghum from 1979 through 1985. Based on the results of this study, partial budgeting was used to estimate the additional costs and returns from different diking and subsoiling tillage practices by location on the land slope. The additional returns and production costs were based on average increases above a check treatment that received recommended crop production practices.

In Table 3, the additional costs of subsoiling sorghum exceeded the value of the additional returns on the upper and middle slope positions. Added returns exceeded the added tillage costs for all other treatments, making them more profitable than conventional practices. Diking only was the most profitable treatment on average for all slope positions, although diking with subsoiling was most profitable on the upper slope.

Other research at Chillicoth-Vernon included a continuous reduced-tillage sorghum production system using furrow diking and two less tillage operations than the conventional tillage system (Clark, 1985). The reduced-tillage system was clearly superior in terms of economic returns over the conventional system (Table 4). Based on 1985 experimental results, the returns were \$76 ha-' above the conventional system. Although only two diking operations were planned in this research, an additional cultivation with diking was apparently needed to control weeds. However, the additional operation added only \$9.24 ha-' to the total cost of production.

Cotton Conservation Tillage Systems

High Plains

A no-till dryland cotton system following irrigated barley was evaluated at Etter, Texas, from 1983 through 1986 (Harman and Wiese, 1987). The first and most important limitation of this no-till cotton system is absence of labeled herbicides that can be applied to small grain stubble to satisfactorily control weeds until cotton is planted the next spring. Producers using the experimental no-till weed control program in Table 5 are at risk since it is not now labeled for cotton. Barley stubble was maintained with no-till chemical weed control practices for 11 months before planting cotton.

No-till lint yields in 1983 were 0.017 Mg ha1 (9 percent) higher than conventionally tilled yields. In 1984,

TABLE 3. ESTIMATED ADDITIONAL RETURNS OVER ADDITIONAL COSTS OF DIFFERENT DIKING-SUBSOILING TREATMENTS AND LOCATION ON THE SLOPE FOR COTTON AND SORGHUM PRODUCTION IN THE ROLLING PLAINS[1]

Treatment and Position on Slope	Cotton[2]	Sorghum'
Upper Position	-----------$ ha^{-1}-----------	
Subsoiled[3]	—	– 15.29
Half-diked*	30.49	55.72
Diked	68.72	91.53
Diked & subsoiled[5]	42.57	100.32
Middle Position		
Subsoiled	—	– 13.52
Half-diked	16.46	13.47
Diked	72.10	70.05
Diked & subsoiled	63.38	62.96
Lower Position		
Subsoiled	—	32.42
Half-diked	14.85	11.91
Diked	26.93	44.82
Diked & subsoiled	39.19	17.94
All positions		
Subsoiled	—	1.16
Half-diked	19.99	27.03
Diked	56.63	68.84
Diked and subsoiled	47.91	60.42

'All diking treatments include one preplant and one postplant operation.

[2]The analysis assumed 1986 input costs and crop prices received.

[3]Cotton did not receive a subsoil-only treatment.

[4]Half-diked treatment was diking every other row.

'Included diking & subsoiling as one preplant operation and diking only as a postplant operation.

TABLE 4. ESTIMATED COSTS AND RETURNS OF CONVENTIONAL VERSUS REDUCED TILLAGE SORGHUM IN THE ROLLING PLAINS OF TEXAS

Item	Continuous Conventional' (no diking)	Continuous Reduced' (3 dikings)
Yield, Mg ha^{-1}	2.69	3.15
	-------------$ ha^{-1}-------------	
Income:		
Grain @ $0.097 kg^{-1}	261.31	306.43
Deficiency pmt. @ $0.018 kg^{-1}	48.58	56.98
Total	308.59	363.41
Expenses:		
Seed	5.93	5.93
Fertilizer	47.47	47.47
Herbicides	10.08	8.40
Custom Herb. applic.	8.65	—
Machinery	21.52	19.97
Machinery labor	23.18	18.66
Interest	9.32	7.14
Total Preharvest Costs:	126.45	107.57
Harvest, haul	47.42	51.52
Total Variable Costs:	174.53	159.09
Returns Over Variable Costs:	134.36	204.32
Fixed Costs:		
Machinery	52.46	44.72
Total Costs:	226.32	203.81
Returns to Land, Mgmt. & Risk:	83.57	159.60

'Operations included shredder, chisel, fertilize, tandem disk, sweep disk hedder, rolling cultivate, plant and rolling cultivate (eight operations plus one custom herb. application). Herbicide included 1.322 kg ha^{-1} of Milogard.

'Operations included sweep disk bedder, May diker/herb., rodweed/fert. June diker, plant and July diker *(six* operations). Herbicide included 1.10 kg ha^{-1} of Milogard.

1985, and 1986, no-till practices raised yields by 0.2 Mg ha^{-1} (76 percent), 0.022 Mg ha^{-1} (15 percent), and 0.219 Mg ha^{-1} (47 percent), respectively. Over the four years, average yields from no-till practices were 0.115 Mg ha^{-1} (44 percent) higher than with conventional tillage practices. The increase in the no-till yield was largely due to an average yearly increase of 4.5 cm available soil moisture stored during the 11-month idle period after barley harvest.

Thirteen cultural operations may be needed for conventional cotton production (Table 5). These 13 operations can be replaced by four, three of which are chemical applications. More chemical applications will be necessary if the unlabeled atrazine/Cotoran mix is substituted by repeated applications of contact herbicides to avoid risk of atrazine injury to the following cotton crop. Three additional Roundup applications of 0.43 kg ha^{-1} each would cost slightly less than the atrazine/Cotoran mix. Precautionary measures need to be taken to avoid possible drift injury to adjacent crops when applying contract herbicides by air.

A major limitation to the no-till system was that variable costs increased $118 ha^{-1} over conventional tillage (Table 5). Producers having difficulty obtaining adequate operating capital may not be able to get financing for the high chemical costs. Total costs using no-till practices were $45 ha^{-1} higher than conventional tillage. More than $73 ha^{-1} (79 percent) in machinery depreciation costs were saved with the no-till system. Returns over variable costs were $80 ha^{-1} higher for the no-till cotton system after including income from the additional yield of 0.115 Mg ha^{-1} lint. Returns to land, management, and risk were increased $153 ha^{-1} with no-till practices.

No-till cotton planted in a wheat cover crop was evaluated at Lubbock and Halfway in 1986 (Keeling,

TABLE 5. ESTIMATED COSTS AND PROFITS OF CONVENTIONAL VERSUS NO-TILL DRYLAND COTTON FOLLOWING IRRIGATED SMALL GRAINS, TEXAS HIGH PLAINS*

Item	Conventional Tillage'	No-Ti11[2]
Lint Yield, Mg ha^{-1}	,265	,380
	-----------$ ha^{-1} -----------	
Income:[3]		
Lint	274.08	393.70
Seed	27.83	39.98
Deficiency payment	151.62	217.79
Total	453.53	651.47
Expenses:		
Seed	14.83	14.83
Fertilizer	12.36	12.36
Herbicides	14.83	147.86
Insecticides	19.77	19.77
Tractor, equipment	51.94	19.25
Tractor, labor	27.90	18.43
Hoe labor	25.95	25.95
Interest	13.74	26.69
Harvest, haul	37.07	37.07
Ginning bagging & ties	50.51	65.11
Total Variable Costs:	268.90	387.32
Returns Over Variable Costs:	184.63	264.15
Fixed Costs:		
Machinery depreciation	92.96	19.60
Total Costs:	361.86	406.92
Returns to Land, Mgmt. & Risk:	91.67	244.55

***Warning: the experimental no-till chemicals used include atrazine, which may cause crop injury. Producers are at risk using the atrazine/Cotoran mix since atrazine is not labeled preplant for cotton.**

'Operations included shredding, two diskings, chiseling, three sweepings, bedding, rolling cultivate beds, two sandfighter and two crop cultivations.

'Herbicides applied by owned sprayer included 1.7 kg ha^{-1} atrazine + 2.2 kg ha^{-1} Cotoran, 0.56 kg ha^{-1} Roundup + 0.56 kg ha^{-1} Banvel and in April, 2.2 kg ha^{-1} Caparol + 0.56 kg ha^{-1} 2,4-D. One seasonal cultivation is included. Note: Roundup can be used in lieu of the unlabeled atrazine/Cotoran mix to avoid possible crop injury.

[3]Lint price is \$1.035 kg^{-1}, seed price is \$.066 kg^{-1} and deficiency payment is \$.573 kg^{-1}. Roundingofyields may prevent numbers from being accurate.

1987). Irrigated lint yields were not affected by no-till practices, but dryland yields trended lower although not statistically significant. The preliminary economic analysis was based on 1986 experimental lint yields and grades, and on custom rates for tillage operations. Under irrigated conditions, returns to land, management, and risk using no-till were increased over conventional tillage by \$37 ha-' and \$94 ha-' at Lubbock and Halfway, respectively. In contrast, under dryland conditions, returns to land, management, and risk were reduced by \$47 ha-1 and \$67 ha-1 at Lubbock and Halfway, respectively, using the lower experimental yields of no-till.

Significant reductions in tillage costs based on custom rates occurred in 1986 at Lubbock and Halfway using reduced-tillage methods in irrigated and dryland cotton following cotton and sorghum (Keeling, 1987). Compared with conventional tillage practices under irrigation at Halfway, reduced tillage preharvest costs were lowered by \$54 ha^{-1} following cotton and \$64 ha^{-1} following sorghum. At Lubbock, reduced tillage methods saved \$35 ha^{-1} and \$12 ha^{-1} prebarvest costs following cotton and sorghum, respectively.

In most cases cotton lint yields increased, with the exception being a 0.045 Mg ha^{-1} loss in yield at Halfway following sorghum. As a result of the yield increases, higher profits ranging from \$104 ha^{-1} to \$175 ha^{-1} were realized with reduced-tillage practices. At Halfway, where lint yields dropped, profits from reduced-tillage remained \$40 ha^{-1} higher than with conventional tillage practices because of substantial reductions in tillage costs.

Under dryland conditions, production costs using reduced-tillage practices also were lower than conventional tillage. Preharvest costs of reduced-tillage cotton following cotton and sorghum at Lubbock were lowered by \$27 ha-' and \$15 ha-', respectively. At Halfway, cost reductions of \$17 ha^{-1} and \$52 ha-' were attained following cotton and sorghum, respectively. Impacts on lint yields at the two locations were mixed. At Lubbock, reduced-tillage yields were lower following cotton and maintained following sorghum. In contrast, an increase in lint yields occurred at Halfway following cotton and a reduction following sorghum. Returns to land, management, and risk using reduced tillage methods, as a result, were generally about the same or higher than conventional tillage with the exception being Lubbock, where lint yields were lower following cotton.

Rolling Plains

Furrow diking and subsoiling tillage practices in a continuous reduced-tillage cotton system were evaluated from 1980 through 1985 in the Rolling Plains (Gerard, 1987). In Table 3, results of the economic analysis indicate that the added costs and added returns from all diking or subsoiling practices were more profitable than conventional tillage at upper, middle, and lower positions on the land slope. Of the conservation tillage practices evaluated, diking only was more profitable than subsoiling, half-diked, and diking with subsoiling on the upper and middle positions of the slope. Diking with subsoiling was the highest profit practice on the lower slope position. On average, over all slope locations, diking only was the most profitable conservation tillage practice.

An economic analysis of two cotton production systems, conventional and reduced tillage with diking, were evaluated in 1985 at Chillicothe-Vernon (Table 6; Clark, 1985). With returns to land, management, and risk \$138 ha-' above the conventional system, the continuous reduced-tillage cotton system appears very promising in terms of potential to increase returns. Key

TABLE 6. ESTIMATED COSTS AND RETURNS OF CONVENTIONAL VERSUS REDUCED TILLAGE COTTON IN THE ROLLING PLAINS OF TEXAS

Item	Continuous Conventional[1] (no diking)	Continuous Reduced[2] (2 dikings)
Lint Yield, Mg ha^{-1}	0.278	0.353
Lint price \$ kg^{-1}	1.169	1.169
	--------------\$ ha^{-1}----------	---
Income:		
Lint	324.79	412.14
Seed @ \$0.076 kg^{-1}	33.01	42.28
Deficiency pmt. @ \$0.419 kg^{-1}	116.43	147.89
Total	474.23	602.31
Expenses:		
Seed	13.64	13.64
Fertilizer	37.48	37.48
Herbicides	11.12	11.12
Machinery	26.12	21.40
Machinery labor	29.06	23.60
Interest	10.50	8.45
Total Preharvest Costs:	127.92	115.69
Harvest, haul	25.94	25.94
Ginning bagging & ties	57.03	72.45
Total Variable Costs:	210.89	214.08
Returns Over Variable Costs:	263.34	388.23
Fixed Costs:		
Machinery	102.79	89.72
Total Costs:	313.68	303.80
Returns to Land, Mgmt. & Risk:	160.55	298.51

[1]Operations included chisel, tandem disk/herb., sweep cult, sweep disk bedder, apply fertilizer, rolling cultivate, plant, rotary hoe, and two rolling cultivate (10 operations). Herbicide applied included 0.83 kg ha^{-1} of Treflan.

[2]Operations included sweep disk bedder/herb., May diker, rodweed/fert., plant, and June diker (five operations). Herbicide applied included 0.83 kg ha^{-1} of Treflan.

to the increased returns is the increased yield of 0.075 Mg ha^{-1} of the reduced tillage system with two diking operations.

Wheat Conservation Tillage Systems

High Plains

The recent development of new herbicides, Glean and Ally, for continuous wheat production allows a reduction in tillage requirements. Some tillage will be needed, however, to control volunteer wheat and weedy grasses unless repeated applications of contact herbicides are applied. Before the development of the new herbicides, no-till continuous wheat production has met with only limited success, encountering difficulties in controlling weeds. Even now, uncontrolled volunteer wheat in the new crop may lead to an increased incidence of diseases. Wheat streak mosaic virus in the new crop is a common disease that occurs across the Great plains if volunteer wheat is not controlled (Porter, 1985).

Allen et al. (1976) reported yield increases in no-till irrigated wheat averaging 0.314 Mg ha^{-1} at Bushland, Texas. This irrigated system alternated between a year of no tillage followed by limited tillage the next year to rebuild irrigation beds. Management of the limited-tillage second crop, however, was only partially successful because of excessive crop residues on the reformed beds. Recently improved no-till grain drills may alleviate some of these previous difficulties encountered in crop establishment.

Rolling Plains

A potential for soil erosion losses exists in dryland wheat/fallow production systems when land lies idle more than a year between crops. Producing continuous dryland wheat also poses problems, however. In addition to a higher risk of crop failure due to plant water stress, an increase in disease has been observed, particularly after several years of continuous wheat production. At Munday, on land having a long history of wheat production, reducing tillage in 1986 increased the estimated yield loss from diseases more than 10 percent compared with conventional tillage practices (Bordovsky and Worrall, 1987). This was not the case, however, at Chillicothe-Vernon on land that had one year of wheat production history. In this situation, diseases were nil under both conventional and reduced tillage (Worrall, 1987).

In other research at Chillicothe-Vernon using reduced tillage and no-till in 1985, yields of continuous reduced-tillage wheat were about the same as conventional tillage (Clark, 1985). Both of the reduced-tillage systems resulted in higher returns because of total production costs lower than the conventional tillage system (Table 7). In the two reduced tillage systems, substituting one Roundup application in the no-till system for the chisel/sweep tillage operation in the reduced-tillage system reduced machinery depreciation costs \$9 ha^{-1} but increased preharvest costs \$19 ha^{-1}. Thus, returns with no-till were \$10 ha^{-1} lower than the reduced-tillage system.

Multicrop Conservation Tillage Systems

Wheat/Sorghum/Fallow, High Plains

Jones (1987) reported an increase in no-till sorghum yields over conventional tillage yields of nearly 0.4 Mg ha^{-1} following dryland wheat at Bushland, Texas, during 1982 through 1986. Another tillage system using no-till practices during the fallow period following sorghum and prior to wheat seeding also was evaluated. Wheat yields using no-till practices during fallow averaged nearly 0.1 Mg ha^{-1} less than when using conventional sweep tillage.

An economic analysis in Table 8 compares the conventionally tilled wheat/no-till sorghum/fallow rotation

TABLE 7. ESTIMATED COSTS AND RETURNS OF CONVENTIONAL VERSUS NO-TILL AND REDUCED TILLAGE WHEAT IN THE ROLLING PLAINS OF TEXAS

Item	Continuous Conventional[1]	Continuous No-till[2] (Roundup)	Continuous Reduced[3] (sweeps)
Yield, Mg ha^{-1}	2.15	2.14	2.14
	----	--------$ ha^{-1} --------	
Income:			
Grain @ $0.103 kg^{-1}	222.98	222.29	222.29
Deficiency pmt. @ $0.039 kg^{-1}	85.40	85.13	85.13
Total	308.38	307.42	307.42
Expenses:			
Seed	12.85	12.85	12.85
Fertilizer	44.18	44.18	44.18
Herbicides	—	35.21	15.44
Custom Herb. applic.	—	17.30	8.65
Machinery	35.85	6.62	13.54
Machinery labor	19.17	5.04	8.47
Interest	10.53	10.53	9.27
Total Preharvest Costs:	122.58	131.73	112.40
Harvest, haul	39.14	39.12	39.12
Total Variable Costs:	161.72	170.85	151.52
Returns Over Variable Costs:	146.66	136.57	155.90
Fixed Costs:			
Machinery	45.00	8.57	17.40
Total Costs:	206.72	179.42	168.92
Returns to Land, Mgmt. & Risk:	101.66	128.00	138.50

[1]Operations included deep chisel, three chiselisweep, drillifertiliae and fertilize (six operations).

[2]Operations included drill/fertilize and fertilize (two operations plus two custom applications of herb.). Herbicide included 0.017 kg ha^{-1} of Glean and 0.413 kg ha^{-1} of Roundup.

[3]Operations included chiselisweep, drill/fertilizer and fertilize (three operations plus one custom application of herb.). Herbicide included 0.017 kg ha^{-1} of Glean,

and the no-till wheatlno-till sorghumlfallow rotation with conventional tillage practices. Costs were summed for a complete cycle of the two-croplthree-year rotation based on **1** hectare each of wheat, sorghum, and fallow. Tillage and chemical expenses during fallow were included with the wheat expenses.

Reducing tillage practices and increasing chemical use raised variable costs over conventional tillage for the two-croplthree-year rotation by about $16 with the conventionally tilled wheatlno-till sorghumlfallow system and by $41 with the no-till wheat/no-till sorghum/fallow system. Reductions in depreciation costs were $22 and $30, respectively, which includes the yearly depreciation cost of a relatively expensive no-till grain drill for seeding no-till wheat in the latter rotation. Compared with conventional tillage of both crops, total costs were only slightly lower ($6) for the conventionally tilled wheat/no-till sorghumlfallow rotation but were $11 higher for the no-till wheat/no-till sorghum/fallow system. Returns to land, management, and risk were increased $48 and $21 for the respective systems, largely reflecting the additional income from the higher sorghum yield when using no-till practices.

Wheat/Sorghum with Limited Irrigation, High Plains

Declining water supplies, high irrigation costs, and operating capital limitations have forced producers in the Texas High Plains to consider reducing irrigation application rates. Residue levels from wheat stubble are, therefore, reduced compared with higher levels of irrigation. Unger (1978) indicates soil moisture storage increases significantly by maintaining residue levels on the soil surface during the 11-month idle period between wheat and sorghum. Musick et al. (1977) found no-till sorghum yields with low irrigation rates were higher than conventional-till yields, but this was following adequately irrigated wheat with high residue levels.

Harman and Regier (1987), using only one irrigation application on wheat and sorghum, compared yields, costs, and profitability of a conventionally tilled wheatlsorghum rotation with two skip-drilled wheat/no-till sorghum rotations in 1985 and 1986. Wheat was

TABLE 8. ESTIMATED COSTS AND PROFITS OF DRYLAND WHEAT/DRYLAND SORGHUM/FALLOW ROTATION WITH ALTERNATIVE TILLAGE PRACTICES, TEXAS HIGH PLAINS

Item	Conv. Wheat/ Conv. Sorghum[1]	Conv. Wheat/ No-till Sorghum[2]	No-till Wheat/ No-till Sorghum[3]
Wheat yield, Mg ha^{-1}	1.61	1.61	1.55
Sorghum yield, Mg ha^{-1}	1.82	2.19	2.19
<u>Income:</u>		--$ ha^{-1} --------------------	
Grain, wheat @ $0.088 kg^{-1}	141.68	141.68	136.40
Grain, sorg. @ $0.072 kg^{-1}	131.04	157.68	157.68
Grazing, wheat	22.24	22.24	22.24
Wheat deficiency pmt. @ $.073 kg^{-1}	117.53	117.53	113.15
Sorg. deficiency pmt. @ $.041 kg^{-1}	74.62	89.79	89.79
Total	487.11	528.92	519.26
<u>Fallow and Wheat Expenses:</u>			
Seed	7.41	7.41	7.41
Herbicides	11.12	11.12	53.57
Tractor, equip.	22.36	22.36	9.27
Labor	18.90	18.90	11.47
Interest	3.78	3.78	7.76
Harvest, haul	31.63	31.63	31.13
Subtotal, wheat	95.20	95.20	120.61
<u>Sorghum Expenses:</u>			
Seed	2.97	2.97	2.97
Insecticides	14.83	14.83	14.83
Herbicides	9.71	47.15	47.15
Tractor, equip.	23.47	8.03	8.03
Labor	20.83	10.48	10.48
Interest	3.19	5.34	5.34
Harvest, haul	29.80	31.83	31.83
Subtotal, sorghum	104.80	120.63	120.63
<u>Total Variable Costs:</u>	200.00	215.83	241.24
<u>Returns Over Variable Costs:</u>	287.11	313.09	278.02
<u>Fixed Costs:</u>			
Machinery depreciation, wheat	42.35	42.35	34.52
Machinery depreciation, sorghum	47.02	24.96	24.96
Subtotal	89.37	67.31	59.48
<u>Total Costs:</u>	289.37	283.14	300.72
<u>Returns to Land, Mgmt. and Risk:</u>	197.74	245.78	218.54

[1]Operations included five sweepings each for wheat and sorghum. Herbicide, included **0.56 kg** ha^{-1} **2.4-D** on wheat and 1.7 **kg** ha^{-1} propazine on sorghum.

[2]Operations included five sweepings for wheat. Herbicides included **0.56 kg** ha^{-1} 2,4-D on wheat and 3.4 kg ha^{-1} atrazine + **0.84 kg** ha^{-1} 2,4-D, **0.26 kg** ha^{-1} Roundup and 1.7 **kg** ha^{-1} propazine for sorghum.

[3]**Herbicides** for wheat included 0.035 kg ha^{-1} kg ha^{-1} Glean and three applications of Roundup of 0.19 **kg** ha^{-1} each. No-till sorghum herbicides are in [2].

planted each year following sorghum harvest, and sorghum was planted into standing wheat stubble in the two no-till treatments. Wheat stubble from two alternative drilling patterns of 4 in/1 out and 3 in/2 out (20-cm row spacing) at reduced seeding rates per unit land area was maintained by no-till methods from wheat harvest to sorghum planting. Wheat yields in 1985 and 1986 and sorghum yields in 1986 were not significantly different between treatments. Thus, it was possible to reduce wheat seeding rates using alternative drilling patterns without affecting yields of either wheat or sorghum. Soil moisture stored between crops was about the same between the alternative systems.

A preliminary economic analysis indicated variable costs were nearly equivalent with the three tillage/drilling pattern systems. However, machinery and irrigation equipment depreciation costs were reduced a total of $82 for a complete cycle of the two-cropltwo-year rotation (based on 1 hectare of each crop) by the skip-drilled/no-till alternatives compared with conventional tillage. Thus, returns to land, management, and risk of the two skip-drilled wheat/no-till sorghum systems were about $82 higher than conventional tillage practices.

Wheat/Sorghum or Cotton/Fallow, Rolling Plains

An assessment of reduced-tillage practices during the fallow period following cotton or sorghum and preceding wheat seeding was conducted at Chillicothe-Vernon (Worrall, 1987). Impacts on wheat yields in 1986 were mixed using different crop rotations and reduced tillage methods during fallow compared with conventional tillage practices. Following cotton and a fallow period, wheat yields increased 0.54 Mg ha-' or 42 percent with reduced tillage practices, but following sorghum and fallow, reduced tillage yields dropped 0.30 Mg haL or 17 percent. Wheat diseases posed no particular problems for either rotation using reduced tillage during the fallow period.

Sorghum/CottonlWheat Rotation, Blackland Prairie

An important difference between the Blackland Prairie, a high rainfall region, and the semiarid regions of the High and Rolling Plains is that moisture conservation in the Blackland Prairie does not typically increase crop yields. As long as the yield levels of no-till crops are only maintained relative to conventional tillage, higher economic benefits to crops in no-till systems must be totally derived from reducing input use or by substituting inputs with lower total production costs.

Morrison, Gerik, and Chichester developed an experimental system for long-term conservation crop production on high-clay soils at the Blackland Research Center, Temple, Texas. This no-till system uses wide beds, controlled traffic, and crop residue management. Soil is protected from erosion using this system, and experimental results indicate crop yields are maintained. The system incorporates management practices and production procedures common to most continuous no-till systems in North America, in unique combination with other technologies that required machine adaptation for no-till practices in high-clay soils. The technologies used were reported in Morrison et al., 1985.

Three years of results (1982-1984) from this experimental system were used in the economic analysis of no-till compared with aconventional tillage system. The analysis was based on 1986 input costs and crop prices. The crop systems analyzed included sorghum, cotton, and wheat in rotation. Experimental results indicate little difference in yield levels between notill and conventional tillage with similar fertilization and adequate insect control programs. The average no-till yields from the 1982-1984 experiments were assumed for both no-till and conventional crops.

Labor and machinery costs of producing no-till cotton were more than 40 percent lower than conventional tillage (Table 9). Chemical weed control substitutes for labor and machinery, but in the case of no-till cotton, the significant increase in herbicides used and their costs more than offset the savings in labor and machinery costs. Preharvest costs were $150 ha-' lower for conventional tillage compared with no-till. It should be noted, however, that the no-till system was profitable under 1986 cost-price assumptions.

If herbicide costs decline and if an improved no-till system increased the yield relative to the conventional system, no-till could be competitive in terms of net economic returns. Under the assumed cost-price conditions, a 10 percent increase in the no-till yield would make no-till more profitable than conventional tillage.

Net returns from both sorghum systems in the rotation were lower than cotton, but the same general production cost relationships existed for each crop (Table 9). Labor and machinery costs were lower for no-till sorghum, but the sharply higher use and cost of herbicides increased total costs of the no-till system compared with conventional tillage. However, both sorghum systems were profitable, and a 7 percent increase in the no-till sorghum yield relative to conventional sorghum would make no-till more profitable than the conventional system.

Labor and machinery costs were lower for no-till wheat compared to conventional wheat (Table 9). However, higher herbicide costs for no-till wheat offset the savings in labor and machinery costs. Thus, total production costs were slightly higher, $9 ha', for the no-till wheat system, the difference being less than the value of one bushel of wheat. Returns were low for both wheat production systems. A normal return to land would leave low residual returns for management and risk.

Economic Implications

General implications from these economic analyses of conservation tillage research in Texas are (1) conservation tillage practices usually reduce total costs of production where substantial savings in machinery depreciation costs occur, but (2) variable costs or "out-of-pocket expenses" are not always reduced by adopting conservation tillage practices. As a result, cash flow difficulties may be encountered by adopting conservation tillage unless sufficient sales income is realized from increased yields to offset higher out-of-pocket expenses and machinery investment or conversion costs.

Crop yields may be higher with conservation tillage if significant soil moisture savings are realized. Thus, long-term prospects for raising farm profit levels are encouraging in semiarid regions of Texas where water availability limits crop yield potential. In these regions, economic analyses indicated returns to land, management, and risk were usually higher with conservation tillage, particularly where moisture conservation increased yields and the value of sales. This was especially evident in situations where residue was produced by a cover crop or was maintained between crops, and when furrow diking was used to prevent runoff losses.

In higher rainfall regions, such as the Blackland Prairie where rainfall is higher and water erosion is a problem, limited yield benefits from soil moisture conservation, increased grassy weed pressures, and other

TABLE 9. ESTIMATED COSTS AND RETURNS OF CONVENTIONAL TILLAGE VERSUS NO-TILL FOR A SORGHUM/COTTON/WHEAT ROTATION IN THE BLACKLAND PRAIRIE OF TEXAS

	Cotton		Sorghum		Wheat	
Item	Conventional[1]	No-till[2]	Conventional[3]	No-till[4]	Conventional[5]	No-till[6]
Grain yield, Mg ha^{-1}	—	—	5.49	5.49	2.42	2.42
Lint yield, Mg ha^{-1}	0.532	0.532	—	—	—	—
		$ ha^{-1}				
Income:						
Grain	—	—	622.35	622.35	355.82	355.82
Lint	880.29	880.29	—	—	—	—
Cottonseed	64.79	64.79	—	—	—	—
Expenses:						
Herbicide	22.76	168.18	17.00	117.62	16.26	37.90
Mach. & labor	39.39	17.64	40.60	15.22	16.78	9.79
Other costs	117.89	121.15	140.94	140.94	120.91	114.12
Interest	16.11	19.03	13.99	19.00	12.75	13.86
Total preharvest costs:	196.15	346.00	212.53	292.78	166.70	175.67
Harvest, haul, ginning	197.25	197.25	78.70	78.70	40.33	40.33
Total variable costs:	393.40	543.25	291.23	371.48	207.03	216.00
Ret. over variable costs:	551.68	401.83	331.12	250.87	148.79	139.82
Fixed costs:						
Machinery	89.65	58.98	89.08	56.09	40.05	39.61
Total costs:	483.05	602.23	380.31	427.57	247.08	255.61
Ret. to Land, Mgmt., Risk:	462.03	342.85	242.04	194.78	108.74	100.21

[1]Operations included shredder, disk, chisel, disk, chisel, fertilize, cultivate, plant/fert./insect./herb., and two cultivations (10 operations + 2 custom insect. applications). Herbicides applied included 0.827 kg ha^{-1} Caparol and 0.827 kg ha^{-1} of Dual.

[2]Operations included 3 herb. applications, plant/fert./herb./insec., shredder, apply herb. (6 operations + 2 custom insect. appl.). Herbicides applied include 0.827 kg ha^{-1} Roundup (2 appl.), 3.86 kg ha^{-1} Caparol (2 appl.), 1.65 kg ha^{-1} Dual, and 0.42 kg ha^{-1} Fusilade.

[3]Operations included disk, chisel, two disks, chisel, fertilize, cultivate, plant/fert./insect./herb., and two cultivations (10 operations + 1 custom insect. application). Herbicides applied included 0.824 kg ha^{-1} Milogard and 0,827 kg ha^{-1} Dual.

[4]Operations included 3 herb. applications, fertilize, plant/fert./herb./insec., and apply herb. (6 operations + 1 custom insect. appl.). Herbicides applied include 1.24 kg ha^{-1} Roundup (3 appl.), 1.653 kg ha^{-1} atrazine, 1.65 kg ha^{-1} Milogard, 0.206 kg ha^{-1} Dual, and 0.207 kg ha^{-1} of paraquat.

[5]Operations included shredder, chisel, fertilize, cultivate, drill/fert./ (5 operations + 1 custom herb. appl. and 2 custom insect. appl.). Herbicides applied included 0.138 kg ha^{-1} Banvel and 1.455 kg ha^{-1} of MPCA.

[6]Operations included apply herb., apply fert., drill/fert., and apply herb. (4 operations + 1 custom insect. appl.). Herbicides applied included 0.413 kg ha^{-1} Roundup, 0.138 kg ha^{-1} Banvel, and 1.1 kg ha^{-1} MCPA.

problems such as soil compaction may inhibit higher yields and increased profit potentials. Conservation tillage systems being evaluated in these areas are apparently not as profitable as conventional systems. This has critical implications in the event producers are forced to comply with conservation practices.

Adoption rates of conservation tillage will likely accelerate in areas where there is a higher profit potential compared with conventional practices. In other areas, conservation practices may have to be adopted because of recent legislation. The Food Security Act of 1985 (farm legislation) contains conservation regulations that have the potential of significantly affecting producers, processors, agribusiness, and rural communities. One provision of the regulation denies all government benefits to producers who continue to crop highly erodible cropland or converted wetland after December 23, 1985. Land is exempt until January 1990 if it had a cropping history in any of the 1981 through 1985 crop years. Although not analyzed herein, denial of government benefits such as deficiency payments if out of "conservation compliance" could substantially enhance the relative profitability of conservation practices, considering the alternative.

Research Needs

The above-described conservation tillage research programs were designed for the future needs of producers in Texas. Problems that may continue to be challenges to scientists in terms of developing profitable conservation tillage practices include possible increased disease in continuous wheat production and volunteer seedling control in continuous wheat, corn, and sorghum production. These problems may necessitate some mechanical tillage in specific production systems. Continued advances in developing selective herbicides will likely broaden the need for further research and economic evaluations of alternatives in conservation tillage.

Recent comprehensive changes in public policy concerning soil conservation emphasize the need to expand research efforts. A recent analysis of the conservation requirements of the current farm bill by the Texas Agricultural and Food Policy Center at Texas A&M University (Lippke et al, 1986) indicated substantial economic losses could occur in the southern Texas High Plains where cotton is the primary crop. Based on current cultural practices, the impacts of adopting two types of conservation measures, windstrips and crop rotations, were evaluated for an eight-county area south and west of Lubbock, Texas. Depending on the conservation measure, farm receipts were estimated to drop by $21 million to $244 million. Jobs lost ranged from 1,000 to 12,450. Farm survival possibilities were nil using crop rotations on light soils. Windstrips were a better alternative, but even then, the financial position of farms was negatively affected.

While the above analysis highlights the critical need for increasing resources devoted to conservation tillage research in the near future, it was based on current tillage practices combined with windstripping or crop rotations. A similar but expanded study is needed to analyze the impacts of emerging conservation tillage methods such as those in this report. It should consider erosion control through maintaining residue levels with conservation tillage practices, which is an effective method of reducing wind and water erosion (Stewart and Harman, 1984). It should also examine the impact of planting cover crops, which is an alternative in areas where soil moisture for the succeeding cash crop can be replenished by timely rainfall or supplemental irrigation.

Farm program legislation changes from time to time, and concern about “conservation compliance” in connection with the 1985 farm legislation may come and go. However, the potential cost of soil erosion to agriculture and society through decreased crop and livestock productivity will remain. Pierre Crosson (1986) also discusses the cost of erosion in terms of damages from eroded sediment, shortened life of reservoirs, increased risk of flooding, increased costs of removing sediment from municipal water supplies, diminished recreational values, and damage to biological systems. These high socioeconomic costs may require more from society in public funds than it is willing to pay. We believe that additional public and private funding of research to make conservation tillage more profitable on highly erosive soils may not only be the lower cost alternative but also the most cost-effective method of reducing these socioeconomic costs. Producers will benefit from incurring conservation tillage costs in the long run if adequate rewards, specifically higher profits, can be realized through improved conservation tillage systems and if these profits exceed those of conventional farming methods.

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Riding The New Wave of Farming Practices Using Conservation Tillage

V. Levon Harman

My interest in conservation tillage was sparked during a Swisher County Soil Fertility Day program six years ago. Although the presentation by Dr. Allen Wiese, Texas Agricultural Experiment weed scientist at Bushland, Texas, dealt with grain sorghum, I realized the practice might well be applied to cotton, a crop better suited to the semiarid region near Happy, Texas, where I farm 1,300 acres.

Like an ever-increasing number of growers in the Southwest, I have seen the Ogallala aquifer, the lifeblood of irrigated agriculture in portions of a six-state area, decline to the point that crop watering is not always possible. I realized that my farming methods had to change. I felt that the change had to be accomplished in two ways: quickly and cheaply. I felt if I could persuade Dr. Wiese to develop a tailor-made plan for me, I could achieve my goal of evolving into a conservation farming system cheaply and quickly.

Dr. Wiese's plan involved the use of Atrazine and Cotoran applied after the harvest of small grains. The residue of the harvested crop was to serve as a natural erosion control and a barrier to help prevent evaporation. The chemicals would kill any emerged seedlings as well as prevent further infestation. The field would be allowed to overwinter in this condition. Then the plan was to plant the cotton in an undisturbed seedbed the next spring. Finally, Caparol, a cotton herbacide, was to be applied after planting to ensure weed control through the growing season.

After reviewing the plan with Dr. Wiese and Dr. Wyatte Harman, TAEX economist from Amarillo, I embarked on a no-till cotton production program in 1979. The program was quite successful. The no-till dryland cotton resulted in a lint yield of 252 pounds per acre. A conventionally tilled dryland block produced only 100 pounds of lint per acre, thus proving that reduced cultivations had merit in conjunction with a sound chemical program. The first year we tried no-till was also one of the driest in more than 90 years. In fact, it was *so* dry that our conventionally tilled milo did not even head. It was then that I realized that I could not afford to plant the conventional way and hope to make a profit. I felt no-till was the answer.

I had developed such a keen interest in no-till that I launched a similiar program of reduced cultivations in conjunction with a sound chemical program for wheat, comparing it with a block where more traditional farming methods were used. In the spring of 1982, I was able to obtain Glean under the experimental-use label. For the first time, a chemical fallow program for small grains was a reality. With the use of Glean, only 5 bushels of wheat per acre was necessary to recoup my production costs, while the conventionally tilled block required four times that yield to recover my input expenses.

In another experiment, this one with no-till barley, I harvested 70 bushels per acre dryland as compared to 45 bushels per acre with a more traditional number of cultivations. The results of this successful barley experiment served a dual purpose: first, it broadened our cropping diversification, and second, the properties of barley residue are similiar to wheat. Therefore, this enabled us to expand our no-till cropping program because we had a greater acreage of residue.

At this point, I had tried a no-till program with all crops except milo. The expanded acreage of residue allowed me to go forth with a no-till milo plan. I felt that my apprehensions of being a pioneer in the field of no-till farming on the High Plains had passed and I was ready to proceed armed with the knowledge that my experiments and proven yields with cotton, wheat, and barley would be my guide in developing a no-till milo program. My no-till milo averaged from 2,000 to 2,500 pounds per acre dryland while my neighbor to the south averaged only 540 pounds per acre. Finally, I had successfully experimented with a no-till plan that included all my major crops. I have continued to follow the plan with minor alterations as new chemicals become available.

These experiments were carried out at very minimal costs. I already had a sprayer to apply the chemicals for weed control. I did purchase six coulters for my double disk planter to cut through the residue from the previous crop and also prepare a very narrow seedbed. I have converted my conventional-tillage equipment to no-till without large capital expenditures. As the popularity of no-till farming increases, more and more equipment manufacturers are joining in to make the transition in their product lines. I was able to adapt a Tye wheat drill by adding a Tye-manufactured coulter cart designed specifically for minimum and no-till planting. The chemical manufacturers have also joined in to develop products that have properties necessary for no-till production.

After six years of no-till farming, I believe I have been successful in fulfilling my original goal. I have succeeded in storing the natural precipitation and conserving the precious water from the Ogallala aquifer. I have also been able to prove there are other subtle benefits. I know the no-till method of farming has reduced soil losses by controlling wind and water erosion because of a constant residue cover. Another benefit of the no-till system is the improved tilth of the soils. This is due to the disappearance of the plowpan because of reduced traffic.

I do not believe the complex problems of the agriculture sector can be totally resolved with such a simplistic concept as no-till farming. But it has been a method that has helped me reduce operating expenses to make it possible to continue farming.

Measured and Simulated Productivity of Eroded Soils

B.F. Hajek and J.R. Williams[1]

Soil erosion can result in reduced soil productivity and crop yields. Yield reductions of 34 percent to 40 percent were observed on soils of the Piedmont in 1940 (Adams, 1940). Similar observations were made by Frye et al. (1982) on silty soils in Kentucky, by Langdale et al. (1979) on clayey Piedmont soils in Georgia, and by Buntley and Bell (1976) on silty soils in Tennessee. The amount of data on the effects of erosion on yield is limited because it is often difficult to obtain randomized statistical field plot design (Langdale and Shrader, 1982). Langdale et al. (1979) found that the complex nature of erosion caused considerable variability in studies using standard statistical design.

Surface thickness and clay content are the primary indicators of erosion on the soils of the Southeastern United States (Langdale et al., 1979). These characteristics combined with nutrient availability greatly influence productivity.

The Erosion-Productivity Impact Calculator model is a comprehensive model developed for application to erosion-productivity problems (Williams et al., 1984). EPIC can be used to predict current-year crop yields using actual measured input variables, such as climate, or long-term simulations using various management strategies.

The purpose of this research was to conduct an extensive on-farm study to determine the effects of past erosion on corn and soybean yields in the Coastal Plain and cotton in the Tennessee Valley regions. In addition, future yields were simulated for moderately and slightly eroded phases of major soils using the EPIC model.

Farm fields in the Alabama Coastal Plain and Tennessee Valley regions were selected for study. Crops included corn and soybeans in the Coastal Plain from 1981 through 1984 and cotton in the Tennessee Valley from 1982 through 1984. These fields were in map units of the Dothan series in the Coastal Plain (fine-loamy, siliceous, thermic, Plinthic Paleudults) and Decatur in the Tennessee Valley (clayey, kaolinitic, thermic, Rhodic Paleudults). These soils are major cropland soils in these two land resource areas. Each field was under uniform management and planted to a single crop and variety using conventional tillage. Each field had at least two levels of erosion, slight and moderate. In most fields, plots were located on single uniform slopes ranging from 3 percent to 5 percent.

Two plots were located in each field. One was a slightly eroded area and the other was moderately eroded. Each plot was made up of three replicates. Soil data, such as surface soil thickness, color, texture, and slope, were collected from each replicate. Samples of the surface soil and subsoil were collected for P, Ca, Mg, pH, free iron oxides, organic matter, and particle size analyses.

Yields were obtained for each replicate from row segments adjacent to each boring where samples were taken and measurements made. Yield data were analyzed using analysis of variance of completely randomized design. Each field was analyzed as an individual test because of variation in soils, rainfall patterns, and cultural practices between fields.

The cropping condition assumed in the EPIC simulation was a corn-wheat-soybean rotation under conventional tillage in the Coastal Plain and continuous cotton in the Tennessee Valley. Fertilizer rates and applications were according to soil test recommendations (Cope et al., 1981). Initial soil conditions were obtained from averages of slightly and moderately eroded Dothan and Decatur from farmer-operated fields. Properties of these soils used for this study are given in Table 1. Climatic data for the Dothan soils were obtained from records in Henry County, Alabama (Wiregrass Experimental Substation), and from Belle Mina, Alabama (Tennessee Valley Experimental Substation).

Results

Yields

Average yields and percent yield reduction for all years and crops are given in Table 2. In general, differences in soybean and cotton yields between years reflect seasonal rainfall differences. Severe drought stress caused cotton yields to be reduced by half in 1983. The effect of moisture stress on corn and soybean yields was not as great as on cotton. The percent yield reduction of corn and soybean on moderately eroded soils relative to slightly eroded yields was highest in 1983, the driest year. The average percent yield reduction for 1981-1984 on moderately eroded Dothan soils was 24 percent for corn, 41 percent for soybeans, and 28 percent for cotton (1982-1984) on moderately eroded Decatur soils in the Tennessee Valley.

Soil Properties

Regression analysis, means, and standard deviations were used to evaluate soil properties relative to yield differences between slightly and moderately eroded areas within fields. The analysis indicated that surface thickness, surface and subsurface clay content, free iron oxides, organic matter, and surface layer phosphorus content were most frequently related to yield differences

[1] **Professor, Auburn University, AL, and hydraulic engineer, USDA-ARS, Temple, TX, respectively.**

TABLE 1. SOME SOIL INPUT DATA USED IN EPIC SIMULATION. PROPERTIES OF BT HORIZONS BELOW THE BT1 WERE CONSIDERED THE SAME FOR BOTH SLIGHT AND MODERATE EROSION CLASSES OF EACH SOIL

Horizon	Depth	Sand	Silt	Bulk Density	pH	Organic Matter	P	Field Cap
	cm	%	%	t/m-3		%	kg/ha	m/m
				Dothan, slightly eroded, 3% slopes				
Ap	0-25	77.4	15.4	1.70	5.9	1.2	59	0.15
Btl	25-41	54.7	13.7	1.68	5.2	0.6	—	0.24
				Dothan, moderately eroded, 4.5% slopes				
Ap	0-14	71	14	1.75	5.7	1.0	17	0.15
Btl	14-30	57	13	1.68	5.0	0.4	—	0.25
				Decatur, slightly eroded, 3% slopes				
Ap	0-18	16	58	1.45	6.2	1.14	52	0.16
Btl	18-46	13	53	1.50	5.1	0.53	—	0.17
				Decatur, moderately eroded, 4% slopes				
Ap	0-11	13	52	1.45	6.0	1.07	31	0.19
Btl	11-39	9	47	1.50	5.1	0.45	—	0.20

between eroded areas within fields (Tables 3 and 4). All of these properties have previously been related to erosion effects (Langdale et al., 1979; Frye et al., 1982; National Soil Erosion-Soil Productivity Research Planning Committee, 1981). Surface soil thickness and percent clay in the surface and subsurface horizons were best correlated with yield differences. Moderately eroded areas with low yields had thin surface layers (Ap), with high clay contents and abrupt boundaries to relatively clayey Bt subsurface horizons. These moderately eroded areas are easily detected in the field by trained soil scientists.

EPIC Simulation

The EPIC output of interest for this study is the initial yield difference between slightly and moderately eroded initial conditions of these soils and the long-term yield differences between erosion levels. Ten-year averages are given in Table 5. The simulated results show reduced yields on initially eroded soils; however, the difference between slight and moderate yields are less than ob-

TABLE 2. YIELDS AND PERCENT YIELD REDUCTION OF CORN, SOYBEAN AND COTTON ON SLIGHTLY AND MODERATELY ERODED SOILS

Soil Series	Crop	Year	Erosion Level: Slight	Erosion Level: Moderate	Yield Reduction
			-------kg/ha	------	%
Dothan	Soybean	1981	2787	1817	35
		1982	2661	1788	33
		1983	2285	1142	50
		1984	1004	564	44
	Corn	1981	4704	3432	27
		1982	5096	4124	19
		1983	5559	3700	33
		1984	3889	3261	16
Decatur	Cotton	1982	3340	2583	23
		1983	1388	883	36
		1984	3416	2734	20

TABLE 3. SURFACE SOIL CHARACTERISTICS AND CORRELATIONS OBTAINED BY MULTIPLE REGRESSION ANALYSIS

	Clay	Free Iron Oxides	P	pH	Organic Matter	Yield
				(r^2)-------	-------	-------
Surface Thickness	0.57	0.45	0.50	0.22	0.12	0.61
Clay	1.00	0.58	0.42	0.36	0.32	0.48
Free Iron Oxides	—	1.00	0.54	0.10	0.48	0.44
P	—	—	1.00	0.34	0.10	0.28
pH	—	—	—	1.00	0.15	0.17
Organic Matter	—	—	—	—	1.00	0.31

TABLE 4. SELECTED SOIL PROPERTIES OF TWO SLIGHTLY AND MODERATELY ERODED SOILS IN THE COASTAL PLAIN (DOTHAN) AND TENNESSEE VALLEY (DECATUR) REGIONS OF ALABAMA

	Erosion Class	Series			
		Dothan		Decatur	
		Mean	SD	Mean	SD
Surface	Slight	25	2	18	2
(cm)	Moderate	14	2	11	2
% Clay					
Ap	Slight	8	3	26	6
	Moderate	15	4	35	6
Btl	Slight	21	7	34	6
	Moderate	30	5	44	8
% Free Iron					
Ap	Slight	1.27	0.26	2.81	1.12
	Moderate	1.75	0.55	3.85	1.41
Btl	Slight	2.46	0.60	3.85	1.60
	Moderate	3.37	0.85	4.28	1.49
% OM					
Ap	Slight	1.19	0.36	1.14	0.37
	Moderate	1.01	0.23	1.07	0.32
Btl	Slight	0.58	0.41	0.53	0.08
	Moderate	0.14	0.09	0.47	0.10
Phosphorus	Slight	59.00	29.00	52.00	21.00
kg/ha	Moderate	17.00	12.00	31.00	17.00

tained from on-farm plots. EPIC predictions agreed with on-farm results in that yield reductions caused by erosion were greatest for soybeans and least for cotton. Simulated yields of all crops were within the range of yields actually measured.

Long-term simulated productivity of corn and soybean indicates essentially no decline in yields. However, yield difference between initially slightly and moderately eroded conditions became less, reversing for corn and being equal for soybean the last 10 years of simulation. EPIC output indicated that moisture stress days were most closely related to both yield differences between erosion levels and that differences between years were due to effects from the climatic sequence predicted by EPIC's weather routine. The results are given in Figures 1 and 2. The simulated greater rate of yield decline for initially slightly eroded Dothan soils is expected since subsurface soil material is not favorable for productivity and loss of favorable topsoil is critical. On moderately eroded soil, further erosion will probably cause little loss of productivity. A 10-year simulation of cotton yields showed higher yields on slightly eroded areas throughout the period (Figure 3). As with corn and soybeans, moisture stress is the factor causing yield differences between erosion levels and between years.

EPIC simulation using data from eroded and slightly eroded soils from on-farm studies in Alabama predicted small yield differences between erosion levels. If the soil fertility status is maintained, moisture stress is the yield-limiting factor. As slightly eroded areas continue to erode under conventional tillage, yields approach those of soils that are now moderately eroded.

TABLE 5. TEN-YEAR EPIC SIMULATION, CONTINUOUS COTTON, CORN AND SOYBEANS

Soil	Crop	Erosion Class		Yield Reduction
		Slight	Moderate	
		T/ha	T/ha	%
Dothan	Corn	4.16	3.71	11
	Soybean	2.14	1.83	13
Decatur	Cotton	2.82	2.63	7

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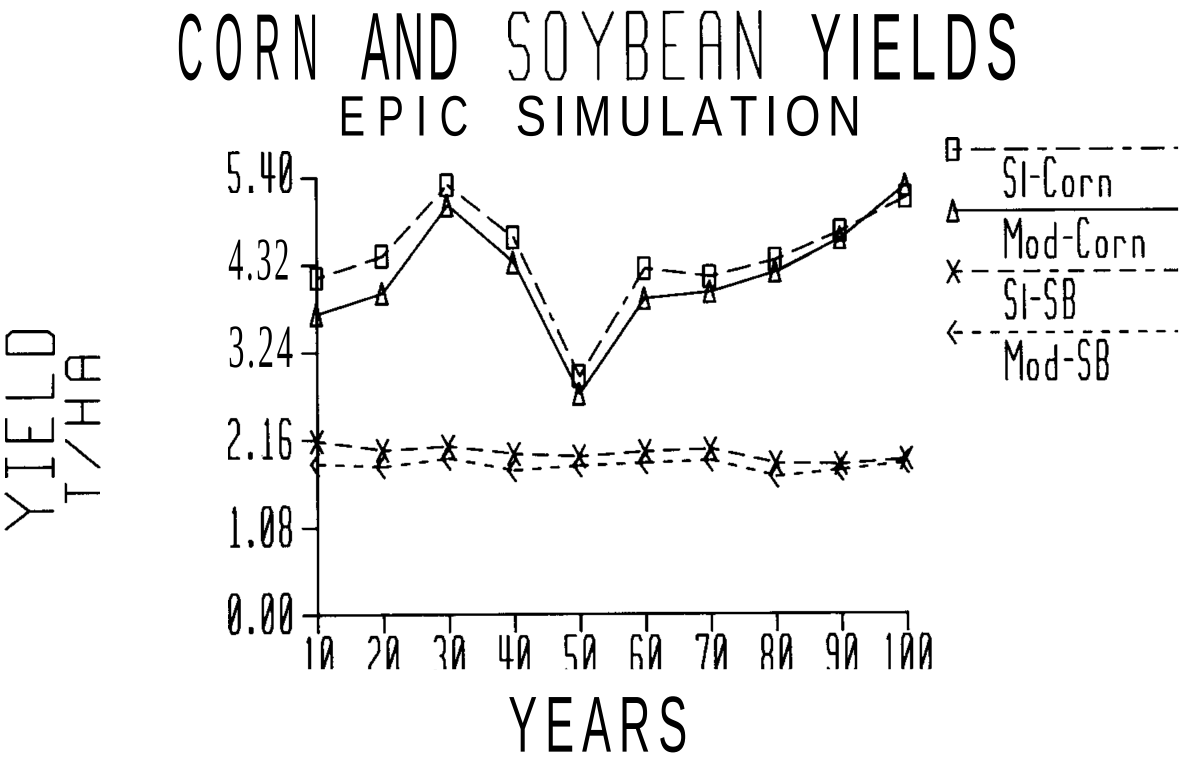

Figure **1.** Corn and soybean yields simulated by EPIC for Dothan soils in South Alabama (Sl—Slight erosion, Mod—Moderate erosion, SB—Soybean).

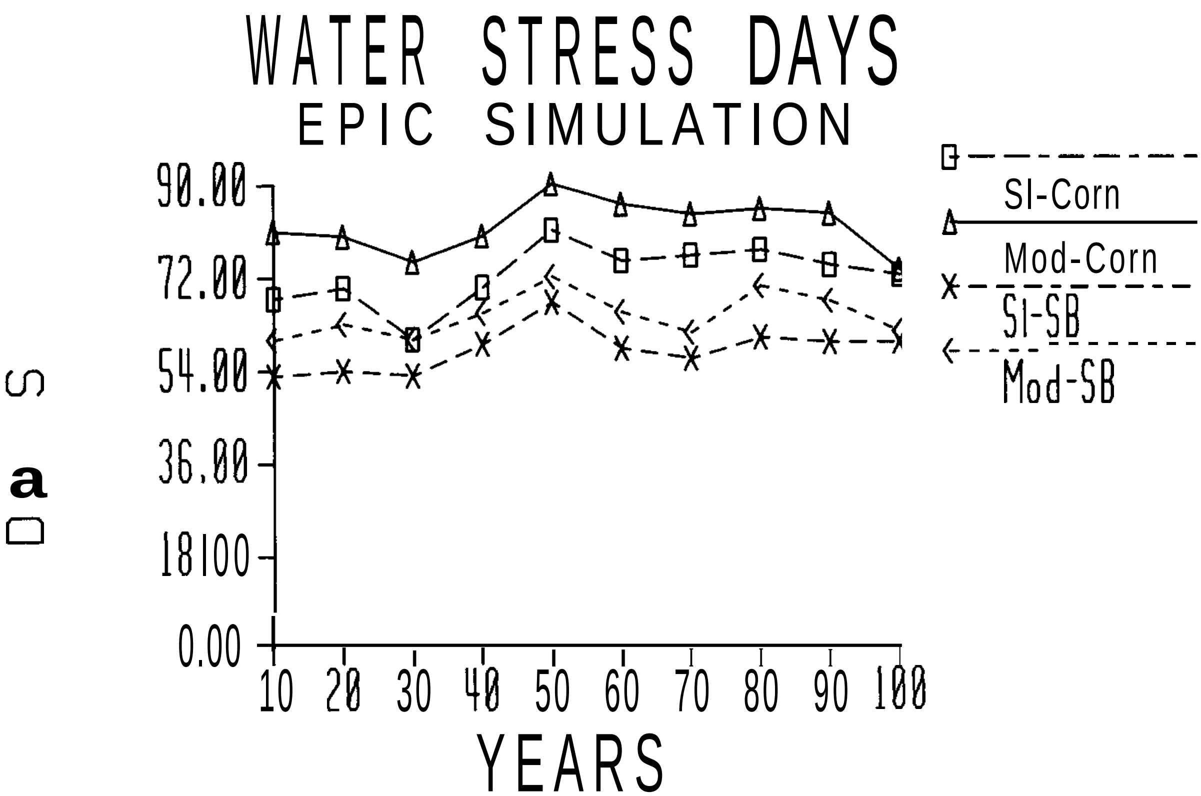

Figure 2. Corn and soybean (SB) water stress days simulated by EPIC for a slightly (Sl) and moderately (Mod) eroded Dothan soil in South Alabama.

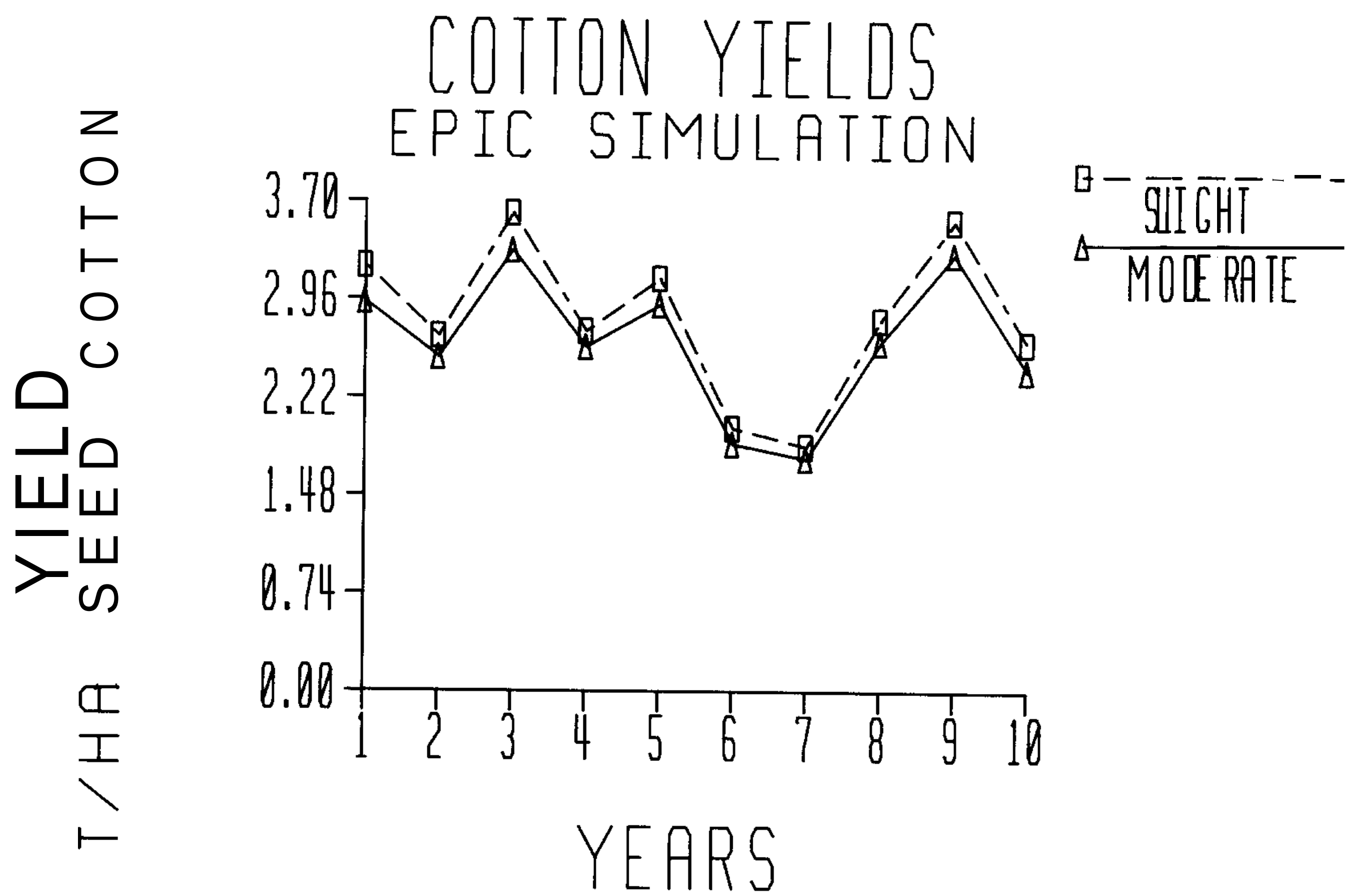

Figure 3. Cotton yields simulated by EPIC for a slightly and moderately eroded Decatur soil in North Alabama.

Planter and Drill Requirements For Soils With Surface Residues

John E. Morrison, Jr. and Ronald R. Allen[1]

Summary

Descriptions are given for machines used for planting in conservation tillage conditions and of soil-engaging components for those machines. The functions of available components are discussed relative to soil and crop residue conditions encountered with conservation tillage. A procedure is outlined for identifying components that will work best under anticipated conditions. Planting machine requirements are matched with available commercial machines, or existing machines can be modified by adding the desired components.

Introduction

Planting into soils with surface residues has become the identifying characteristic of conservation tillage systems. The use of conservation tillage has spread from a research curiosity in the 1960s to established practices in the 1980s (Phillips et al., 1980; Triplett and Van Doren, 1977). With the current and proposed national farm programs that provide incentives for adopting conservation tillage, its use in one form or another is expected to rise from 31 percent in 1985 to 42 percent in 1990 (CTIC Annual Report, 1986). To date, farmers with easily managed soils have dominated the adoption of conservation tillage (Cosper, 1983). Other farmers and less adaptable soils must be brought into the program. This broad conversion to conservation tillage requires the identification of appropriate technologies, including the understanding of planter and drill requirements for soils with surface residues.

Developing and selecting planters and drills for conservation tillage has been limited to regional knowledge and technologies. The best machine for a particular planting operation and field condition has previously been determined by trial and error. Knowledge of these results has been passed along by industry, public agencies, media, and research workers as the basis for advising farmers on machine selection. Technology transfer has now started to close the knowledge gaps between regions as evidenced by the formation of the National Conservation Tillage Information Center (CTIC) and increased activities of professional groups, agricultural extension services, the popular press, and other organizations.

Manufacturers have responded to the increasing market for conservation-tillage machinery. In 1986 there were an estimated 44 planters and 121 drills and air seeders available in the USA for conservation planting (No-Till Farmer, 1986a, 1986b). Additionally, many add-on components are available from specialty companies, and total machines can be constructed with components from several sources. Several of the available machine options might be determined to be adequate for a particular need if there were a systematic process for developing a set of requirements for a machine to perform a particular planting operation (Erbach et al., 1983).

Systematic determination of planting machine requirements starts with the evaluation of soil, residue, crop, weather, and management conditions for each individual farming operation. After these examinations, the machinery requirements can be established and matched with available machines and add-on components for the selection or modification of appropriate planters and drills (Figure 1). This comprehensive approach to machine adaptation is addressed in the following sections.

Conditions Critical To Machine Performance

The conditions that are critical to planting machine performance usually involve soil properties related to soil type, soil moisture content, residue properties, and interactions between soil conditions and residue properties. The following is a summary of current knowledge on the effects and interactions of these critical conditions.

There are thousands of soil series classifications, each with its distinct combination of properties, such as friability, plasticity, minimum and maximum bulk density, type of mineralogy, organic matter content, water holding capacity, and structure when wet and dry. These properties and others may affect the performance of planting machines. However, to date, we do not have a systematic approach to estimate a planter performance index based on functional relationships with these detailed soil properties. Therefore, more generalized groupings of soils have been made according to their apparent properties. Machinery performance has often been reported for soils described as being one of 12 categories based on the relative percentages of sand, silt, and clay particles, such as soil being a "loamy sand' (USDA, 1951). An even more general approach has been

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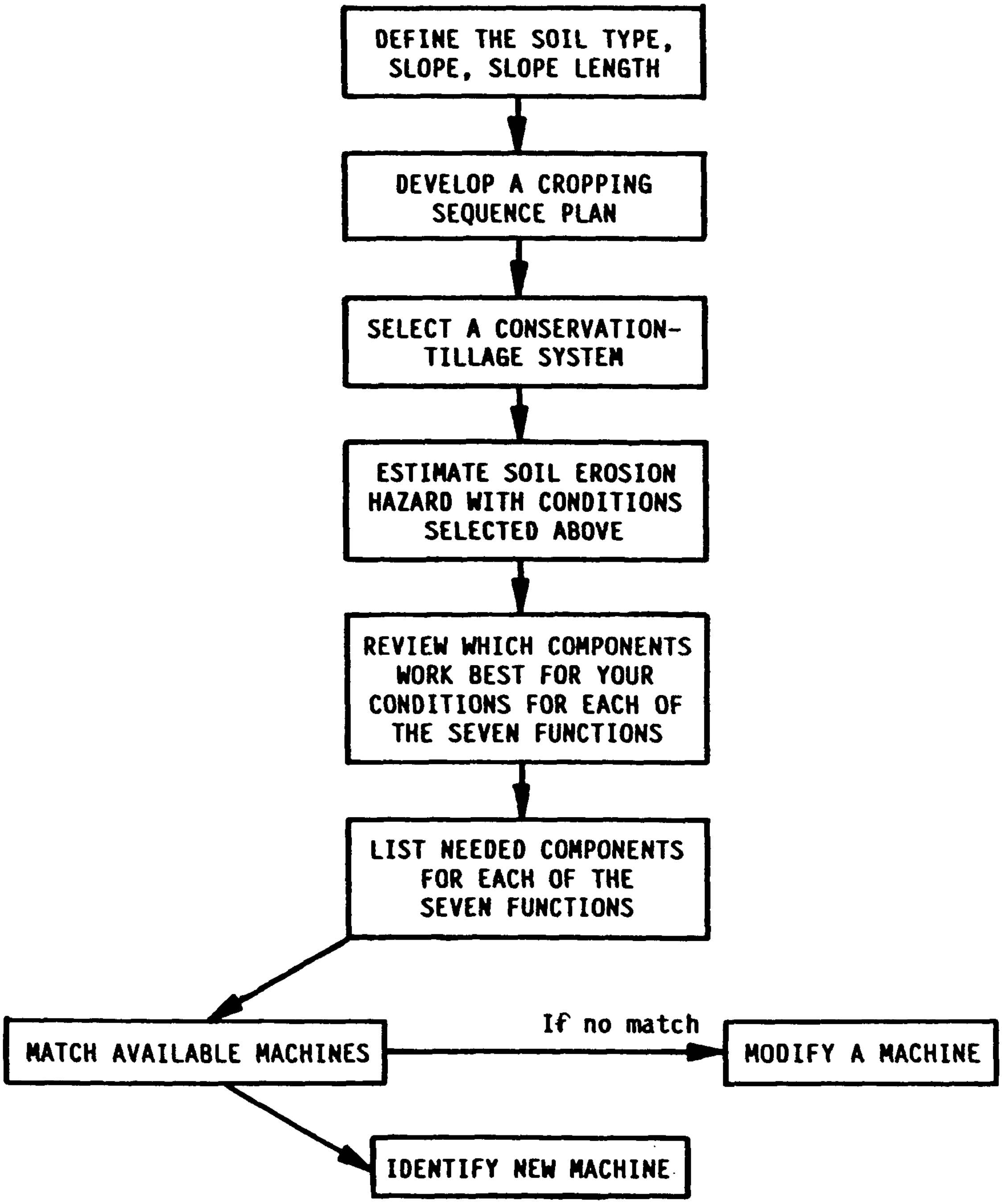


Figure 1. Flow design of procedures to arrive at the selection of an appropriate new or modified machine for conservation planting.

to identify soils as being a) sandy, loamy, or clayey; b) heavy or light; or c) fine or coarse textured.

Based upon accumulated knowledge from empirical observations, descriptions have evolved for planting machine performance interactions with soil properties. Some of these performance conditions are listed below: 1) Heavy, wet, poorly drained soils tend to be adhesive and have seed furrows that are glazed and difficult to close over the seed; 2) Heavy, dry soils tend to be difficult to penetrate with planter openers, produce clods if disturbed by tillage tools, and are difficult for closing seed furrows over the seed; 3) Crusting soils are susceptible to excessive compaction over the seed row, which may reduce plant emergence; 4) Friable, medium-textured, well-drained soils may he planted over wide ranges of moisture content with satisfactory results; 5) Naturally consolidating soils are difficult to penetrate at low moisture contents and are susceptible to excessive compaction by gauge wheels and press wheels when wet; and 6) Soils with consolidated subsoil layers, which must be strip-tilled at planting, can only he planted when topsoil and subsoil properties are amenable to disturbance.

The interaction between planting performance and soil type can he affected by the tillage history, soil structure, organic matter content, and other factors affecting friabilty, adhesiveness, and hardness in the surface 5-cm planting zone. Planting machines must be operable in the worst soil conditions encountered by the individual operator and must be adjustable or adequate for other less severe conditions.

Soil moisture content is an important factor in determining critical planting conditions. For example, the same soil at high moisture content may he easily cut but adhesive, while at low moisture content it is difficult to cut hut non-adhesive. Nichols (1932) showed that uncemented agricultural soils have the common property of rapidly decreasing shear strength and resistance to cutting with increasing moisture content. The effect of moisture content on adhesion is not as consistent as for shear strength, because an increase in organic matter content sharply reduces the adhesion of soil to tillage implements even for clayey soils (Buyanov and Voronyak, 1970). Organic matter is concentrated in the planting zone of established reduced-tillage fields (Doran, 1980). Therefore, soil adhesion may not he a problem with increasing soil moisture content to normal depths of planting and fertilizer banding, or adhesion may become less of a problem as organic matter increases with continued use of reduced tillage. Higher moisture soils are also more susceptible to root zone compaction and to surface crusting (Larson et al., 1980). If the soil moisture content unpredictably varies from dry to wet at planting, then planting machines will be required that will penetrate hard soils and also tolerate soft, adhesive soils without causing root zone or crusting compaction. Such changing soil properties with moisture content require the establishment of the range of soil moistures in which a planting machine must function.

Surface residues affect the critical conditions for planting. Residues are typically comprised of a distribution of stalks or stubble with or without leaves, roots, and chemically killed weeds. These residues can he loose, attached, standing, lying on the surface, or partially buried.

Standing residues are more independent of soil moisture than flattened residues that absorb moisture from the soil. Residue resistance to cutting by planter furrow openers increases with increases in soil moisture (Allen et al., 1984). Therefore, planting performance may be reduced by the presence of damp surface residues that are difficult to cut (Allen, 1986; Choi and Erbach, 1983). To prevent this, residues should be removed or cut from the path of planter furrow openers so that uncut residues do not become entangled on planter components or deposited in the furrows with the seed. Standing residues are largely missed by planter and drill furrow openers, and do not contribute to cutting resistance or soil and residue interaction problems.

The performance of soil-engaging components of planters and drills is directly affected by the interactions between residues and soils. There appears to he an inverse relationship between the soil moisture conditions that allow low-resistance soil cutting and those that enhance residue cutting. For example, soft soil surfaces are easily penetrated hut may not provide enough resistance for residue cutting. Thus residue may be left uncut or pushed (hairpinned) into the soil (Allen et al., 1984). When soils are hard and difficult to penetrate, there are high resistances to cutting forces, and residue cutting is optimal. In soils substantially covered with residues, the planting zone moisture content is often higher than for uncovered soils during planting seasons. Several investigators have found that the retention of surface residues has changed the soil structure by increasing the total percent of non-erodible aggregates and generally increasing both aggregate sizes and void sizes (Hughes and Baker, 1977; Smika, 1979; Hewitt and Dexter, 1980). Because of the changes in organic matter, moisture, and structure, the planting zone soil under established residue retention is of different tilth and will interact differently with planting machines than soils with buried residues.

The field landscape may influence planting machine requirements because of the need to comply with reductions of erosion hazards. The Universal Soil Loss Equation relates field slope and slope length with other factors, as given by,

$$A = R K L S C P, \qquad (1)$$

where A is the annual erosive soil loss, R is the rainfall and runoff factor, K is the soil erodibility factor, L is the slope length factor, S is the slope steepness factor, C is the soil cover and management factor, and P is the support practice factor (Wischmeier and Smith, 1978). Compliance with certain erosion limits may compel farm operators to adopt cropping and residue management practices that require planting through surface residues. Planting machine requirements must reflect crop selection, row spacings, residue amounts, cropping sequence, and chosen tillage system.

Cropping Sequence Plan

Modern farmers must project their plans for current and future operations before they can objectively determine requirements for planting machines. Cropping sequence planning is a very important part of their total plan. Sequence planning affects the interaction of residue with soil conditions on planting machine performance because of the different quantities, types, and conditions of residues, depending upon their place in the cropping sequence. For instance, freshly combined wheat residues are going to have quite different effects on planting machine performance for solid-seeded doublecrop planting immediately following harvest compared with spring row crop planting after nine months of chemical fallow. The row spacings of the stubble residue and the crop being planted, the soil condition, and the residue type and condition are all factors that are determined by the cropping sequence.

Field operation scheduling is also dependent upon the cropping sequence plan. The requirements for planting machine field speed and width depend upon the efficient scheduling of its use.

Selection of A Conservation-Tillage System

Conservation-tillage systems will generally be in one of the five categories listed below. We recognize that each system will have its particular variations, but designating the system to be used is helpful when characterizing the field conditions for operation of planting machines. The five-system categories are:

1. Reduced Tillage : A system in which the primary tillage operation is performed in a manner to reduce or eliminate secondary tillage operations.
2. Stubble-Mulch Tillage : Tillage or preparation of the soil in such a way that plant residues or other mulching materials are left on or near the surface.
3. Ridge Tillage : A system in which crops are planted on top of permanent raised ridges with intervening furrows for drainage and wheel traffic.

Strip Tillage : A system in which only isolated strips of soil are tilled before planting in those strips.

5. No-Tillage : A procedure whereby planting is made directly into an essentially unprepared seedbed.

General Types of Conservation Planting Machines

Conservation planting machines include row planters, disk drills, hoe press drills, powered blade seeders, and air-type sweep, hoe, and double-disk seeders. Many machines have been developed and marketed in specific regions, but most may be described by one of the six general planting machine categories discussed below.

Row Crop Planters

Row crop planters for conservation tillage planting typically employ separate components for soil and residue cutting, depth control, soil opening for seed placement, and seed slot closure. Some also include components for row preparation, and uncovered-seed firming and seed covering. Equipment options for conservation planters include coulter attachments, row preparation devices to permit ridge planting, fertilizer and pesticide placement attachments, and weights or springs to increase downpressure for row units. Frames and hitches can couple two row crop planters for "solid-seeding." Most of these devices permit the planter to function normally when used for conventional planting and thus, increase the range of suitable uses. Major distinctions between row crop planters involve design specifications for strip-tillage, slot-planting, ridge-planting, and flat-planting.

Narrow Row Seeders

The development of narrow row seeders for conservation seeding is much more recent than row crop planters. Some options are air seeders, air drills, disk drills, hoe press drills, and new attachments including coulters, gauge wheels, and fertilizer side banders. Normally, drills do not meter seed as uniformly as planters, especially at low seeding rates. Depth control is less accurate because there is inadequate space for depth control components. Trash clearance may be limiting when seeding into high-residue conditions, but staggering adjacent row units increases trash clearance and flow.

Air Seeders

Air seeders consist of remote central seed hoppers with seed metering and air delivery systems attached to implements such as chisels, field cultivators, or stubble mulch plows. The seed may be released behind chisel points, chisel sweeps, or large 1.5- to 1.8-m wide V-blades. Press wheels are optional but essential in drier climates to ensure seed-soil contact. When releasing seed behind wide V-blades, operators may need to increase seeding rates because of seed scatter. Seed not directly under press wheel tracks may not germinate. Some air seeders are well-adapted for operating through high residues. The relatively large machines have high field capacities and can be easily folded for transport. Air seeders are commonly used for planting small grains but also may be used for soybeans. Variability in depth of seed placement has been a concern because many air seeders lack individual depth control for each row.

Air Drills

Air drills have bulk seed hoppers and integrate seed metering and air delivery systems with hoe or double-disk furrow openers. Individual row unit suspensions and depth-controlling press wheels follow ground contours and give better depth control than air seeders. Air drills can have field capacities and residue clearances similar to air seeders.

Disk Drills

Conservation disk (no-till) drills use single or double disks for furrow openers and press wheels for soil firming. Most manufacturers offer coulters or staggered double-disk openers for cutting soil and residue. Ballast weight may be added to frames or row units. Seed cup block-offs and moveable openers allow row spacing adjustments. Common uses are for seeding small grains, beans, and other solid seeded crops and for interseeding grasses and legumes.

Hoe Press Drills

Hoe-opener press drills are primarily used in drier climates for seeding small grains where the depth to moist soil may be 3 or more inches. The hoe opener can penetrate and place the seed in moist soil, leaving a small furrow without having an excessive amount of soil covering the seed. Much of the drill weight is carried on the rear press wheels to improve soil firming for seed-soil contact. The openers are widely spaced and staggered for residue clearance. Models with coulters mounted in front of the openers have improved residue tolerance, but large amounts (5,000 kg/ha or more of wheat straw) may cause plugging. Stance and moisture content greatly affect the amount of straw that can be tolerated.

Functional Factors To Consider

Equipment Selection

Selecting a brand and the specific components for a conservation planter can be bewildering. Some manufacturers offer a very wide range of options in components. Other manufacturers offer add-on equipment. The dealer may not be prepared to help in selecting the best component option for specific conditions, particularly if the dealer is unfamiliar with new designs and options.

Advice for selecting component options may be available from the manufacturer's representative, other producers, conservationists, extension specialists, or experienced dealers. Field demonstrations of conservation planters and seeders can be very helpful to evaluate components. In the past, considerable trial and error was involved in selecting component options. However, those who do conservation planting and suppliers who work closely with them have valuable experience that should be sought when selecting components.

Component Tracking

On hillsides and curved rows, the seed slot opener may not follow in the coulter slit, or the press wheel may miss the seed slot. This is usually caused by relatively large fore and aft distances between successive seeder components. Strip-tillage and closer-spaced components will help overcome these limitations. Pivots between the coulter, furrow opener, and press wheel will improve tracking on curve rows. Pull-type planters will track better than mounted planters on curved rows, but mounted planters will track better on hillsides.

Residue Accumulation

For conservation tillage, surface residues will cover 30 percent or more of the soil surface at planting time. The residues may be coarse or fine, tall or short, chopped or long, and attached or loose. Planter components should not be expected to operate through large piles of residue deposited by combine harvesters, although the ability to pass through such piles without becoming inoperable is beneficial.

Residues accumulate on planting machines in two ways. Residues hairpin around soil-engaging components, such as chisel shanks, and around supporting struts and frame members. This is usually prevented by effective residue cutting ahead of each component. Residues also catch between adjacent components. This can be reduced by substantially staggering adjacent components, by using smooth-sided wheels, and by eliminating protrusions and bottlenecks between components. Tillage and components of planting machines that detach residues from the roots create problems; attached residues flow between planting machine components much better than loose residues.

Rocks and Other Obstructions

Rocks and other obstructions will require reduced field speeds for safe operation and to minimize machine damage. Obstructions may be more firmly emplaced in non-tilled soils than in soils loosened by primary tillage. Rolling coulters and disk openers will roll over obstructions with momentary loss of depth control. Rigid shank-type openers should be equipped with trips, shear pins, or other protective devices.

Selection of Machine Components

Planting machines can be characterized by their components that actively engage the soil. The components each perform part of the planting process, such as cutting residue, opening a seed furrow, and pressing the seed into contact with the soil. Together the components must be mutually compatible so that the desired total function of the planting machine is achieved.

Considering all of the soil-engaging machine components from the suppliers, there may be as many as 864,000 possible combinations of components that could be selected for a planting machine. Presumably, one or more of these combinations would be the ideal machine for a particular planting condition. Many conservation planting machine components can also be used for conventional tillage, but conservation-tillage machine requirements are not discussed in this paper.

The same soil-engaging components may be available as options on several different kinds of machines, such as on row-planters, drills, and air seeders, and from several different manufacturers. In such cases, machines from several sources may provide comparable performance for the stated condition. In other case, there may be few or none available, and custom modifications will be required to provide a planting machine to meet the specifications. All components selected for a specific machinery requirement must be compatible in function. Machines will not necessarily require all seven component functions listed below for acceptable performance.

Soil and Residue Cutting

Rolling coulters are generally used for cutting soil and residue, although they may be omitted on machines that have an opener, such as a staggered double-disk opener, designed to perform this task and to open the seed slot. A wide range of coulter options is available. Smooth coulters generally cut better and may be sharpened when required. Rippled coulters tend to be self-sharpening and will tolerate some sticky soils. Narrow fluted coulters and bubble coulters accomplish some soil loosening in the immediate row area; however, their usefulness is limited in sticky soil conditions. Wide-fluted coulters accomplish strip tillage in friable soils, but they throw too much soil out of the row at speeds above 6.4 km/hr (4 mph). Additional problems with wide-fluted coulters include the lack of a clean-cut path for the trailing furrow opener and the production, in some soils, of a ragged row of clods that are unacceptable for uniform seed coverage. Coulters cut residue if the soil surface is hard, but they push residue into soft prepared or loosened soil unless they remain sharp. Large diameter coulters cut residues easier but require more downpressure for penetration. Downpressure requirements range from 150 to 400 lbs per unit for penetration in many residue and soil conditions. A powered coulter used on at least one drill may improve residue cutting and residue flow through the machine under conditions where coulter performance is inadequate.

Components for soil and residue cutting (Figure 2) are as follows:

1. Smooth coulter
2. Notched coulter
3. Coulter with depth bands
4. Offset coulter
   a. Bubble coulter
   b. Rippled coulter
   c. Fluted coulter
5. Straw straightener
6. Powered blade or coulter
7. Strip rotary tiller
8. Dual secondary residue disks

Row Preparation

Some machines include a device for preparing the row area. Devices include those used to clear residue for ridge- and strip-till, or to deeply loosen soil ahead of the seeding unit. Row clearing devices remove dry surface soil along with the residues, which brings the planter into contact with the moist underlying soil. Row clearing is not practical on soils that easily form crusts when compacted while moist, and on soils that are unmanageably sticky when moist. Deep loosening is useable only on soils that are friable (non-clod-forming) at planting time. Some row preparation components provide strip tillage behind a soil- and residue-cutting component.

Components for row preparation (Figure 3) are as follows:

1. Sweep row cleaner
2. Two-disk row cleaner
3. Horizontal disk row cleaner
4. Wide-fluted coulter
5. Ripper chisel
6. Subsoil ripper
7. Packer roller
8. Rolling basket
9. Rotary cultivator
10. Spring tines
11. S-tines

Depth Control

Accurate depth control is essential for uniform emergence. Many row crop planters have depth gauge wheels on the sides of each seed slot opener. Front wheels and rear press wheels are used to give a tandem-wheel depth averaging on some planter units. For no-till drills, the rear press wheels are often used to provide depth control because of space limitations; the opener and press wheel are either mounted on a trailing arm arrangement or on parallel linkage as used on row crop planters. For most air seeders, openers are attached semirigidly to the tillage implement frame, in which case depth is controlled by the liftinglgauge wheels. Seeding depth is a function of applied downpressure and soil strength on machines without positive depth controls. Seeding depth with these machines is as variable as the soillresidue conditions.

Components for depth control (Figure 4) are as follows:

1. Rear press wheels
2. Side gauge wheels
3. Skid plate on each opener
4. Front wheels and rear press wheels tandemed
5. Frame liftinglgauge wheels
6. Depth bands
   a. Bands on front leading coulter
   b. Bands on disk opener

Soil Opening for Seed Placement

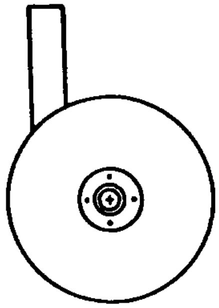
Many row planters and grain drills use either regular or staggered double-disk openers to open seed furrows. Other opener devices used include runners, stub runners, single disks, and hoes. Additionally, some machines precis ely shape the seed groove by using a V- or U-shaped shoe. Air seeders may place the seed behind and under tillage points or blades. Air drills use any of the means commonly used on row planters or drills.

If not preceded by soil- and residue-cutting components, most openers will either collect surface residues or roll over them, crimping them into the seed furrow. The adhesion of moist soil to opener parts may enhance the accumulation of residues. Disk openers are usually self-cleaningand do not accumulate trash and moist soil. Special rotating scrapers are available for double-disk openers in sticky soil conditions. Rigid runner, hoe, and chisel-boot openers may accumulate trash and wet soil. These should only be used in friable, low-clay content soils.

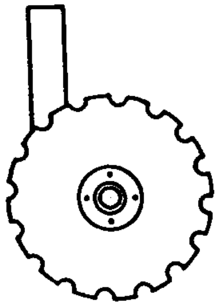
Narrow furrow openers throw less soil laterally so that more soil is available for seed covering and a deep seed trench is not created. Shallower planting with conservation tillage and slower speeds also help reduce lateral soil removal from the row area.

Components for soil opening for seed placement (Figure 5) are as follows:

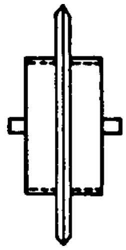
1. Double disk with or without shoe
2. Staggered double disk with or without shoe
3. Runner
4. Stub runner
5. Hoe
6. Single disk
7. Coulter
8. Chisel
9. Wide sweep
10. Triple disk
11. Powered blade or coulter



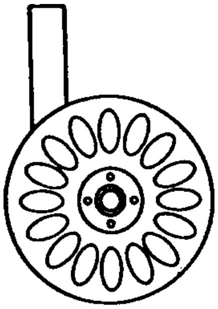
2.1. Smooth coulter



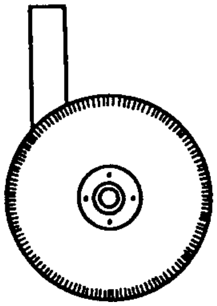
2.2. Notched coulter



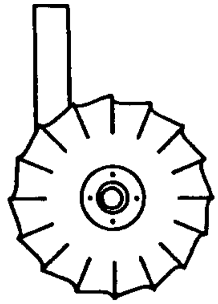
2.3. Coulter with depth bands



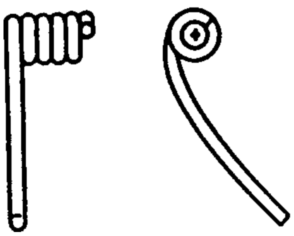
2.4.a. Offset bubble coulter



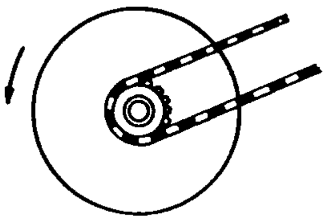
2.4.b. Offset rippled coulter



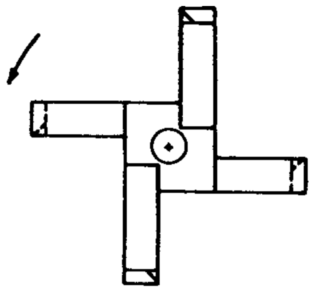
2.4. c. Offset fluted coulter



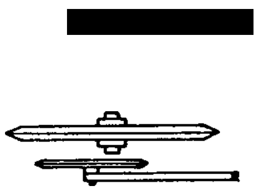
2.5. Straw straightener



2.6. Powered blade or coulter

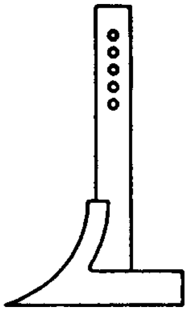


2.7. Strip rotary tiller

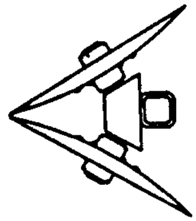


2.8. Dual secondary residue discs

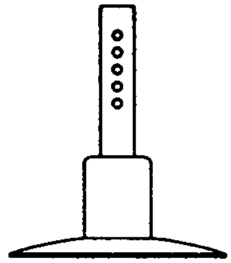
Figure 2. Component options for soil and residue cutting.



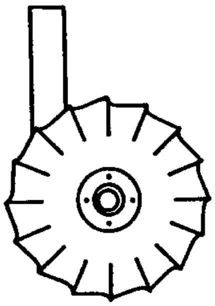
3.1. Sweep row cleaner



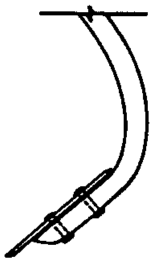
3.2. Two-disc row cleaner



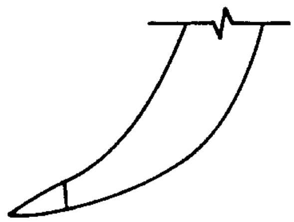
3.3. Horizontal disc row cleaner



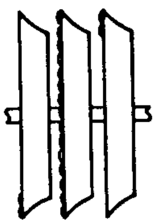
3.4. Wide fluted coulter



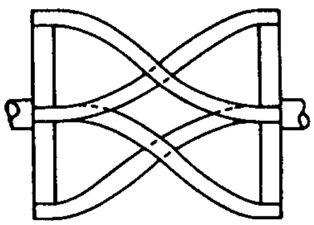
3.5. Ripper chisel



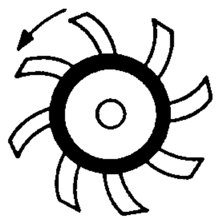
3.6. Subsoil ripper



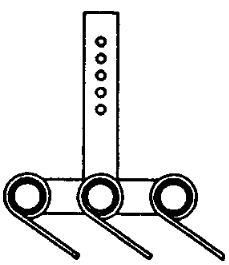
3.7. Packer roller



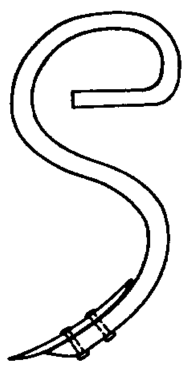
3.8. Rolling basket



3.9. Rotary cultivator

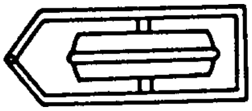


3.10. Spring tines

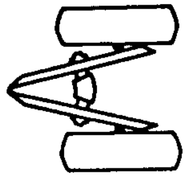


3.11. S-tines

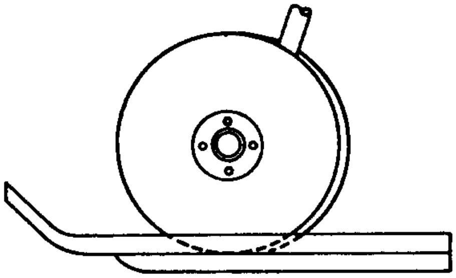
Figure 3. Component options for row penetration.



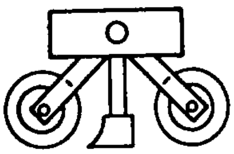
4.1. Rear press wheels



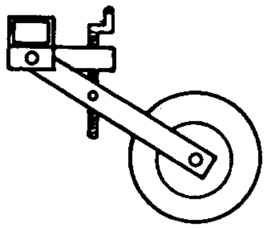
4.2. Side gauge wheels



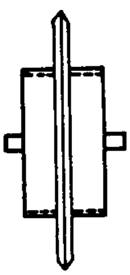
4.3. Skid plate on each opener



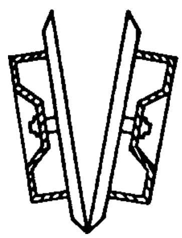
4.4. Front wheels and rear presswheels tandemed



4.5. Frame lifting/gauge wheels

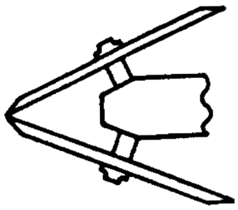


4.6.a. Depth bands on front leading coulter

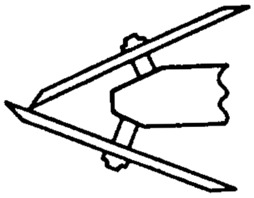


4.6.b. Depth bands on disc opener

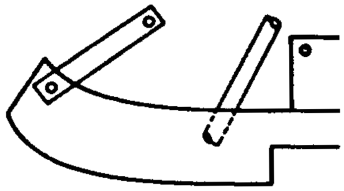
Figure 4. Component options for planting depth control.



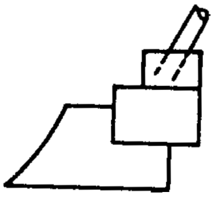
5.1. Double disc



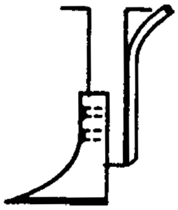
5.2. Staggered double disc



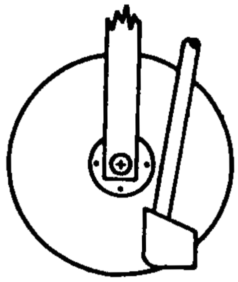
5.3. Runner



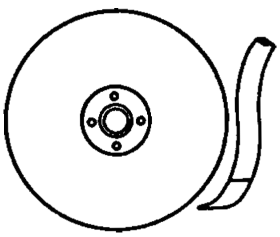
5.4. Stub runner



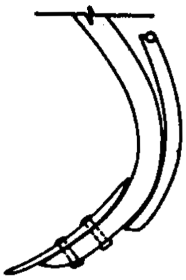
5.5. Hoe



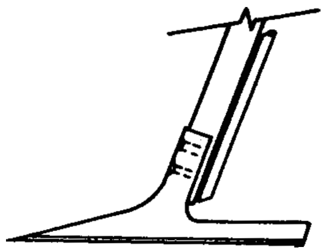
5.6. Single disc



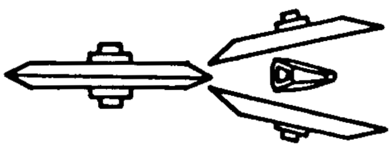
5.7. Coulter



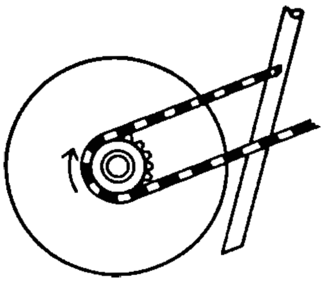
5.8. Chisel



5.9. Wide sweep



5.10. Triple disc



5.11. Powered blade or coulter

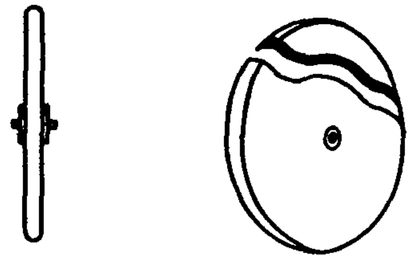
Figure 5. Component options for soil opening for seed placement.

Uncovered-Seed Firming

A seed-firming wheel is sometimes used to press the seed into the bottom of the seed furrow. These devices are semipneumatic rubber wheels ranging from 1X 6 to 1X 10 inches, or solid-plate wheels as narrow as 114 inch. Downpressure, in addition to the weight of the wheel assembly, may be supplied by springs. Uncovered-seed firming wheels improve seed emergence rates under dry soil conditions. They are sometimes used without rear press wheels if followed by seed covering devices. In sticky soil conditions, seed-firming wheels collect soil and can become unuseable because they pick up seed from the furrow.

Components for seed firming (Figure 6) are as follows:

1. Semipneumatic wheel
2. Solid wheel



6.1. Semi-pneumatic wheel **6.2. Solid wheel**

Figure 6. Component options for uncovered-seed firming

Seed Covering

Covering devices must have loose moist soil available to place on top of the seed or must loosen soil and move it over the seed. Moist soil may be available with ridge and strip tillage after row clearing devices have removed dry surface soil. Moist soil is not available with narrow slot-type no-tillage planters and drills that disturb a minimum amount of soil. Residues may accumulate in covering devices. Seed covering components are used when seed slot closure components are either not used or are inadequate to completely cover the seed.

Components for seed covering (Figure 7) are as follows:

1. Single covering disk
2. Double covering disks
3. Paddles
4. Knives
5. Drag chains
   a. Loop
   b. Trailing
6. Spring tines

Seed Slot Closure and Firming

Almost all seeders use press wheels to close and/or compact the seed slot. The exceptions to this are drills that use drag chains and planters that use only seed-firming wheels and covering disks. Press wheels come in a wide variety of sizes, shapes, and configurations. Most have semipneumatic rubber coverings to prevent soil buildup. Some manufacturers offer steel press wheels for dry soil or sod planting. The method of slot closure must be compatible with the amount of soil loosened by preceding components. Dual angled wheels provide positive seed covering as well as soil firming. Some press wheels, such as the single rib and the V press wheels, are used to transmit pressure down to the buried seed to firm it in the soil. Dual ribbed or dual wheels are used on some soils to reduce surface pressure directly over the seed to reduce soil crusting. Press-wheel driven planters must have enough down force on the rear press wheel to both close the seed slot and provide a non-slipping planter drive. Slot closure and firming wheels may be either individually mounted or arranged in gangs. Ganged wheels lack individual flotation over soil surface undulations and may not align with the seed rows.

Components for seed slot closure (Figure 8) are as follows:

1. Wide semipneumatic or steel wheel
2. Single rib wheel
3. Double rib wheel
4. Narrow semipneumatic or steel wheel
   a. V-shaped
   b. Rounded
5. Dual angled semipneumatic or steel wheels
6. Split steel wheels
7. Dual wide flat wheels

Optional Functions

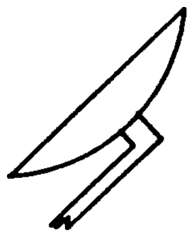
Fertilizer and some chemical incorporation attachments may require additional weight for soil penetration, and, therefore, planting machine frames must be stronger. Such attachments reduce clearance between planting machine components and may reduce machine tolerance to heavy residues. Trailing incorporators, which mix a band of material with the surface soil, may be limited to rolling types to avoid residue raking. Surface residues may reduce the incorporation effectiveness of these devices.

Putting Together The Specifications

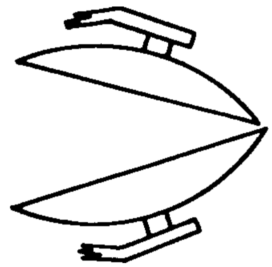
Specifications for selecting conservation planting machines are formed by following three steps: 1) Determine the crop, residue, soil, and management conditions that are going to be used with the machine; 2) Follow the descriptions of each of the seven soil-engaging planting machine functions, and select the potentially useable components for each function; and 3) Delete from further consideration all of the components that are not functionally compatible with other selected components. The result is a set of specifications for a planting machine for the anticipated usage. An example is given in Table 1 for a hypothetical situation.

Choosing From Available Machines

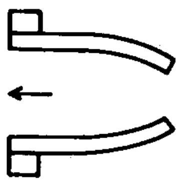
The planting machine specifications from above are matched with available machine components to iden-



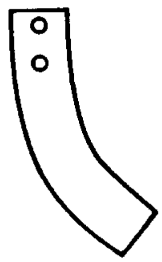
7.1. Single covering disc



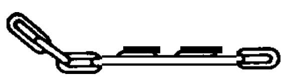
7.2. Double covering discs



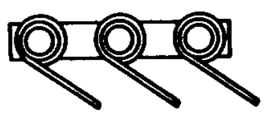
7.3. Paddles



7.4. Knives

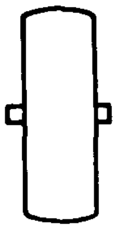


7.5. Drag chains

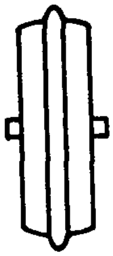


7.6. Spring tines

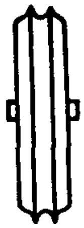
Figure 7. Component options for **seed covering.**



8.1. Wide semi-pneumatic or steel wheel

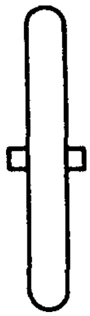


8.2. Single rib wheel

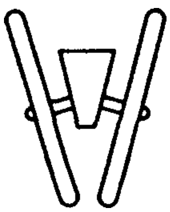


8.3. Double rib wheel

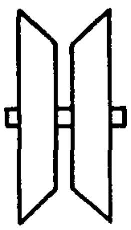
8.4.a. Narrow semi-pneumatic or steel wheel : V-shaped



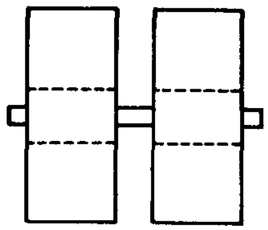
8.4.b. Narrow semi-pneumatic or steel wheel : Rounded



8.5. Dual angled semi-pneumatic or steel wheels



8.6. Split steel wheels



8.7. Dual wide flat wheels

Figure 8. Component options for seed slot closure.

TABLE 1. EXAMPLE OF GENERATION OF PLANTING MACHINE FOR SPECIFIC FARM AND CROPPING CONDITIONS

Conditions:
- Location—Henry County, Illinois
- Soil—Catlin
- Slope—4.0%
- Slope length—80 ft.
- Previous crop—wheat
- Previous crop yield—50 bu/a
- Crop being planted—corn
- Row spacing—30 in.
- Tillage system—no tillage

Predicted Soil Erosion:
- Annual soil loss—2.04 T/acre

Soil-Engaging Components Selected:

1. Soil and residue cutting
   - a. bubble coulter
   - b. powered blade or coulter
   - c. smooth coulter
   - d. rippled coulter
   - e. notched coulter
   - f. smooth coulter w/depth bands
   - g. not used
2. Row preparation
   - a. straw straightener
   - b. not used
3. Depth control
   - a. rear press wheels
   - h. side guage wheels
   - c. linked front and rear wheels
   - d. depth rings on leading coulter
   - e. depth bands on opener
4. Soil opening for seed placement
   - a. hoe opener
   - b. double disks
   - c. staggered double disks
   - d. coulter or disk w/seed boot
   - e. chisel opener w/seed boot
   - f. triple disk
   - g. powered blade wheel
   - h. stub runner
5. Seed imbedding
   - a. rubber wheel
   - h. not used
6. Seed covering
   - a. not used
7. Seed slot closure
   - a. dual angled rubber press wheels
   - h. dual angled cast or steel press wheels
   - c. steel press wheel; "V", rounded, or ribbed

New Machines Selected:'
- Case I-H800
- Deutz-Allis 385
- Fleischer Buffalo-Slot
- John Deere 7000/7100
- Kinze Double Frame
- Kinze Rear Fold
- New Idea 900/Kinze

'Mention of product names does not constitute a recommendation by the authors, USDA-ARS, or the Texas Agricultural Experiment Station over products from other sources.

tify appropriate machines for the anticipated usage. Ideally, matches can be obtained for all seven component functions.

Additional considerations for machine selection include available machine working widths, frame strength, accessories, type and accuracy of seed metering, and parts and service locations.

Modifying Machines

If it is impossible to find a manufactured machine that coincides with the selected specifications, the problem may be resolved by making modifications with components from other manufacturers to complete the machine or to custom-fabricate whole machines. There are more risks involved with machine modifications because the owner cannot take full advantage of the engineering inputs, field trials, and long-term development that is represented by whole-manufactured machines. Some made-to-fit modification kits and assemblies are low-risk possibilities for modification. Generally, machine modification risks include not achieving desired performance, not being cost-effective, and not being adequately reliable.

If an existing conventional seeder is to be converted to a conservation planting machine, then the strength of the frame must be considered. If coulters and additional weight are to be added, then frame and linkages may need reinforcement, and wheels and bearings may need to be upgraded. Caution should be used to avoid using old wide slot furrow openers or press wheels that will not be acceptable for the new conditions. Assembling new combinations of made-to-fit components is the quickest approach to obtain a specialized machine.

Discussion

Components for planters, drills, and air seeders may be selected from lists of available components to form the specifications for a specific conservation tillage planting machine for soils with surface residues. In many cases, several components may be equally effective. In such cases, the specifications will include identified alternatives.

Planting machine selection must be done with consideration of the year-to-year and field-to-field variations in planting conditions. Specific information on planting machine component adjustments are not available, and the operator must take time and gain experience to properly adjust the machine. With careful machine selection and adjustment, satisfactory planting will be accomplished.

Literature Cited

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Effect of Crop Residues on Crop Pests, Soil Water, and Soil Temperature

E.G. Krenzer Jr., R.L. Burton, F.J. Gough[1]

Much of the wheat acreage in the Southern Great Plains is in a monoculture annual wheat production system. This is very significant when planning crop management strategies, because one of the most useful pest management tools, crop rotation, is unavailable for use. Minimum tillage, or stubble mulch tillage as it was called, has been used by some farmers since the early 1940s. Research with stubble mulch tillage in the '40s and '50s in Oklahoma resulted in wheat yields slightly lower than those in clean-tillage systems. Several reasons were given, including weed control, fertilization, stand establishment, diseases, and insects. Many diseases and insects exist from one crop to the next by remaining on or in the crop residue. One classical way to reduce the prevalence of such pests is to mix the residue with the soil or bury the residue, especially with a moldboard plow.

As no-till wheat production was introduced, the alarm was sounded about increased disease and insect problems. All the residue would remain on the surface for survival of insects and diseases. In 1982, studies were initiated to quantify the severity of disease and insect problems created in no-till compared to other tillage systems. We also monitored soil moisture to a depth of at least 120 cm and soil temperature at 5 cm in these studies.

The most important wheat diseases in the Southern Great Plains are leaf rust, soil-borne mosaic virus, Septoria leaf blotch, and tan spot. Rust only occasionally overwinters in Oklahoma, and tillage practices are of no concern. Soil-borne mosaic virus survives in the soil, and tillage has little to do with its survival. The life cycle of Septoria leaf blotch fungus is not well understood; therefore, the relationship with residue levels left by different tillage systems was unknown. However, the tan spot fungus has a sexual stage which survives on the straw through the summer, matures after some cold treatment, and sporulates in early winter or spring. It was expected that tan spot would be much more damaging where residue was left on the soil surface.

TABLE 1. TILLAGE PRACTICES FOR RESIDUE MANAGEMENT SYSTEMS STUDIES

System	Residue level	Tillage practices
Plow	minimal	moldboard plow, disk as needed, harrow, mulch tread
Disk	low	disk as frequently as needed, mulch tread
Subsurface	intermediate	blade with 6-foot v-blade with treader
No-till	maximum	no tillage

Four tillage systems (Burton and Krenzer 1985) were applied to the same 15 m by 30 m plots year after year (Table 1). The tillage study was conducted at three locations. After the fourth wheat crop was planted, the residue covered 8 percent, 25 percent, 80 percent, and 90 percent of the soil surface in the plow, disk, subsurface, and no-till plots, respectively.

Greenbug

Greenbug populations (Figure 1) vary from year to year and location to location, but whenever significant numbers of greenbugs were present, we found that the more residue that was present, the lower the greenbug population (Burton and Krenzer, 1985). No other wheat-damaging insect has been present in these plots in high-enough numbers to evaluate, although two are of particular interest: the wheat curl mite and the Russian wheat aphid.

Tan Spot

Tan spot data has been variable. In some years the more residue left on the surface, the more disease, while in other years there were no differences (Table 2). Since the tan spot fungus produces both sexual (ascospores) and asexual (conidia) spores, more detailed studies were conducted. In one study, 3-m diameter circles were constructed in wheat fields containing no wheat residue. Residue rates of 0, 500, 1,000, and 3,000 kg/ha straw were spread in the circle to establish foci from which to monitor spread of the fungus. Disease development was monitored at 1, 3, 6, and 15 m from the center with the 1-m sampling area being within the residue-covered 3-m diameter circle. Early in the wheat plant development, all tan spot lesions occurred within 3 m of the center of the residue-covered areas (Figure 2). Therefore, the presence of the residue was very important in disease development. The spring of 1985 was extremely dry, and the tan spot did not develop. Gough et al. (1981) reported that significant differences between plow and reduced tillage were obtained in lesions per cm^2 leaf area at Feekes growth stage 5 but not at stage 10.4. They believed that the lack of differences was "due to lateral transmission of ascospores." Data from Figure 2 would not support this hypothesis since no lesions were present on leaves only 5-6 m from the residue. Conidia produced

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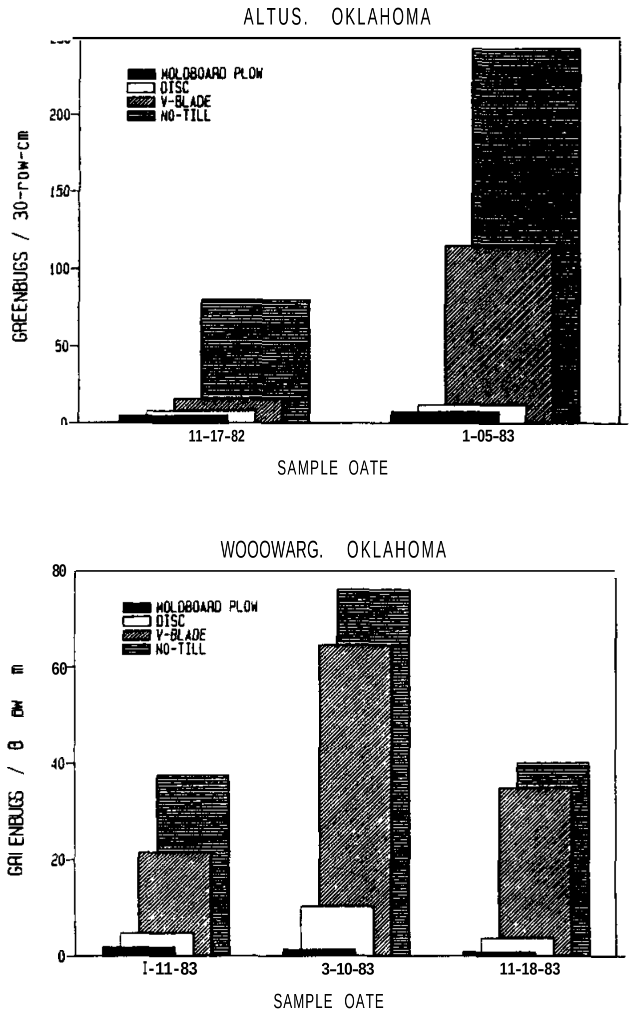

Figure 1. Effect of tillage practices in wheat plots on greenbug populations at Altus and Woodward Oklahoma. (From: Burton and Krenzer, 1985).

TABLE 2. EFFECT OF RESIDUE MANAGEMENT ON TAN SPOT PREVALENCE ON WHEAT FLAG LEAVES

	Location			
	Altus		Stillwater	
System	5/23/83	5/10/85	5/24/84	5117185
	------------lesions/gram	leaf tissue ------------		
Plow	69 a*	175 a	115a	735a
Disk	92 b	227 ab	118 a	881 ab
Subsurface	110 bc	276 ab	117 a	1364 b
No-till	117 c	327 b	143a	898 ab

***Lesion numbers followed by the same letter are** not **statistically different P = 0.05 according to either an LSD test** or **Duncan.**

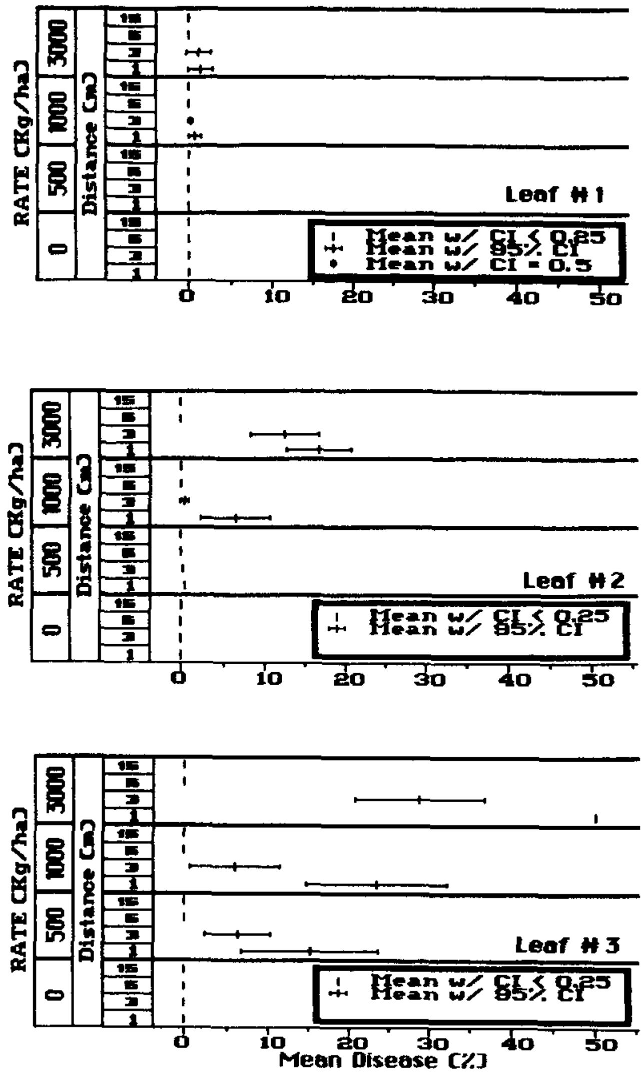

Figure 2. Tan spot lesions (12-28-85) **on wheat leaves as influenced by residue rate and distance** from **the residue.**

by the tan spot fungus are wind-borne and have been reported to move up to 50 miles (Hosford, 1976). Conidia are produced in older lesions on lower leaves and act as secondary inoculum. The presence or absence of significant numbers of conidia on older leaves may account for the variability in tillage effect upon tan spot lesions in the flag leaves. Another factor involved may be the favorableness of environment for disease development once the spores are present.

In conclusion, the severity of tan spot does seem to depend upon the presence of infected residue as a source of ascospores for early season infections, but wind-borne conidia are probably the most important later in the season. Since the number of lesions in the flag leaf are most important to wheat yield, the effect of wheat residue may be less important than formerly thought. Further research is needed to verify this.

TABLE 3. THE EFFECT OF TILLAGE SYSTEM ON SEPTORIA LEAF BLOTCH IN WHEAT

	Location				
	Altus		Stillwater		
System	2/12/84	5/10/85	5/17/83	5/14/84	5/17/85
	lesions/gram leaf tissue				
Plow	152	15	145 a*	187	92
Disk	224	12	131 ab	223	67
Subsurface	213	9	78 b	186	92
No-till	225	5	125 ab	198	93
	N.S.	N.S.		N.S.	N.S.

***Means followed by the same letter are not statistically different (LSD P=O.O5)**

Septoria blotch

The number of Septoria lesions on the flag leaves has not been statistically affected by tillage in four out of five year locations (Table 3). In the year where differences occurred, there was no trend correlating disease incidence with amount of residue on the soil surface.

Soil Temperature

Soil temperature at 5-cm depth was significantly affected by the amount of mulch left on the soil surface. During late August and early September when farmers are anxious to plant wheat to obtain maximum grazing, the no-till plots were as much as 8 o C cooler at the highest temperature than the plow plots (Figure 3). During Aug. 15-24, 1983, the plow plots did not get cooler than no-till plots. During November on hot sunny days, the plow plots were warmer during midafternoon but colder at night. In early March when regrowth is occurring, the plow plots are warmer during midday, and there were no differences in night soil temperatures (Figure 3). These soil temperature differences may be very important in disease relationships aswell asin plant growth.

Soil Water

The major effect of crop residue on soil water has been to improve the farmers' capability to plant early and obtain a good stand. In two out of six site years, the soil was so dry in August that wheat sown in plow plots did not produce a stand, whereas wheat sown in no-till plots at the same time produced a satisfactory stand. This is probably not a uniquely soil-moisture relationship but probably a combination of soil moisture and soil temperature.

Soil moisture in the rooting profile was seldom affected by tillage systems or mulch levels. This is in contrast to data published from several other states but has been consistent across three locations over four years with neutron scattering moisture monitoring being conducted at least 10 times per season.

Summary

After four years of evaluating the effects of mulch levels obtained by different tillage systems, pest relationships have not been as negative as expected. No effect of mulch level was observed in the severity of Septoria leaf blotch. On some occasions, tan spot was most Severe where high levels of mulch were present, but in other situations no difference was observed. Greenbug populations were lowest with the highest levels of mulch on the soil surface. Differences in soil temperature were observed among mulch levels, but the differences changed in magnitude and direction depending upon the time of year. Soil moisture differences occurred at planting depth at planting time, but total rooting profile soil moisture differences have Seldom occurred. Overall, the potential for reduced-tillage systems does not appear to be as negative as originally feared.

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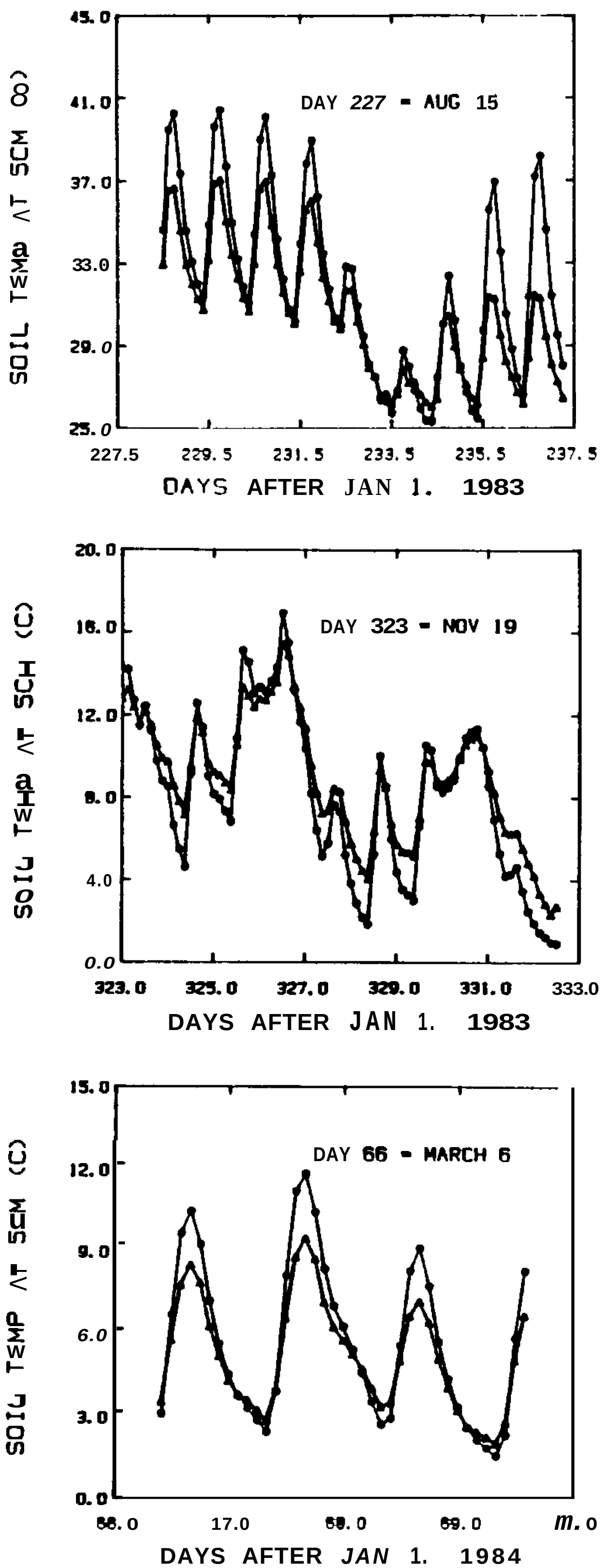

Figure 3. Effect of tillage practices and mulch on soil temperature at 5cm at different times during wheat development.

Tillage Effects on Microbiological Release of Soil Organic Nitrogen

John W. Doran[1]

Introduction

Soil tillage was an important tool of early farmers in North America to harvest the fertility of forest and prairie soils for production of grain crops. Clean tillage without supplemental fertilization, however, depleted soil organic matter reserves. Within the life span of these early farmers, net mineralization of soil N fell below that needed for sustained grain crop production (Campbell et al., 1976). Severe weather conditions in the 1930s caused accelerated soil erosion losses, economic hardship for farmers, and increased awareness of management-related degradation of soil productivity. Thus, early reduced-tillage management systems were developed to maintain residues on the soil surface to conserve water and organic matter, and reduce soil erosion losses (Unger and McCalla, 1980).

Recent shifts to conservation tillage systems have been stimulated by needs to decrease fuel and labor costs, and to enable production on land too fragile (steep, dry, sandy, etc.) for conventional tillage. Soil organic matter distribution and the cycling and availability of nutrients to crop plants can be altered greatly with reduced tillage (Baeumer and Bakermans, 1973; House et al., 1984). Increased N fertilizer requirements and/or yield reductions with no-tillage management indicate that fertility management may need to vary with tillage practice (Doran and Power, 1983; Thomas and Frye, 1984). Observed responses to management, however, are not always consistent and often vary with differences in climate, soils, cropping, and time.

Management and Soil Organic N Pools

Nitrogen cycling in soil is largely controlled by interactions between the activities of microorganisms and plants in fixation of atmospheric N and C and subsequent release of energy and N during decomposition of plant and animal residues. In this regard, resupply of N to plants depends largely on the opposing effects of mineralization and immobilization, which are closely tied to heterotrophic microbial activity (Jannson and Persson, 1982). Heterotrophic microbial activities in soil and the associated availability of soil N are largely controlled by availability of C substrates and soil environmental conditions.

Up to 99 percent of the total soil N is contained in soil organic matter. Interpretation and prediction of the effects of tillage and residue management on soil N availability to crop plants depends on understanding the unique roles played by living and non-living components of soil organic matter. The majority of soil organic matter is contained in plant and animal debris and soil humus. These non-living components determine the soil physical/chemical environment within which living organisms function. Heterotrophic soil microorganisms and fauna, a relatively small proportion of total organic matter (1 percent to 8 percent), function as important catalysts for transformation and cycling of N and other nutrients. The importance of soil microbial biomass as a significant sink/source for plant-available N has recently been emphasized.

Tillage and crop residue management practices are major determinants of soil temperature, water, and aeration regimes, and the spacial and temporal availability of energy and nutrients to microorganisms. The redistribution of organic matter and soil organisms with reduced tillage is a major factor responsible for slower recycling of N as compared with conventional tillage with the moldboard plow (Fox and Bandel, 1986; House et al., 1984). Surface soil levels of organic matter, microbial populations and biomass levels, and reserves of potentially mineralizable N (PMN) are often significantly higher with no-tillage as compared with moldboard plow tillage (Table 1). These increases in microbial biomass and activity and organic N reserves are associated with conservation of surface residues, greater total soil C and N contents, and a more optimal water status for biological activity in the surface 0 to 10 cm of redud-tillage soils (Ayanaba et al., 1976; Doran, 1987). Increased microbial biomass is also associated with increases in plant rooting activity near the surface of no-tillage soils (Carter and Rennie, 1984; Lynch and Panting, 1980).

The magnitude of management-related changes in surface soil properties and microbial responses can greatly depend on previous management, cropping, and degree of tillage. As illustrated in Table 2, the levels of N, C , and microbial biomass in surface soil of a winter wheat (Triticum aestivum L.) fallow rotation in Nebraska were inversely related to degree of soil tillage during fallow. In the previously cultivated land where initial soil organic matter levels were lower, these differences were much less pronounced than where tillage comparisons were initiated in native grass sod. Also, over an 11-year period, the total soil N content with no-tillage

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TABLE 1. AVERAGE EFFECTS OF TILLAGE ON SOIL WATER CONTENT, CHEMICAL COMPONENTS, AND SOIL MICROBIAL BIOMASS AS A FUNCTION OF SOIL DEPTH AT SIX (FOUR CONTINUOUS CORN, TWO WHEAT/FALLOW) LONG-TERM (6-13 YEAR) TILLAGE EXPERIMENTS IN THE USA.

	Ratio—No Tillage/Plow for four soil depths			
Soil Parameter[t]	0-7.5 cm	7.5-15 cm	15-30 cm	0-30 cm
Water Content	1.28*	1.08	1.08	1.13
Water Soluble C	1.47*	0.98	1.24	1.23
Total Organic Carbon	1.42*	1.00	0.94*	1.06
Total Kjeldahl N	1.29*	1.01	0.97	1.06
Potentially Mineralizable N	1.37*	0.98	0.93*	1.05
Microbial Biomass	1.54*	0.98	1.00	1.13

[†]Original data expressed on a volumetric basis

***Level of significance, $P<0.05$**

TABLE **2.** SOIL PHYSICAL CHEMICAL PROPERTIES AND MICROBIAL BIOMASS LEVELS IN THE SURFACE 0 TO 7.5 CM OF SOIL CROPPED TO WINTER WHEAT AS INFLUENCED BY PREVIOUS CROPPING AND FALLOW TILLAGE MANAGEMENT (SIDNEY, NEBRASKA, 1981)

Previous Cropping, Management	Soil Bulk Density	Soil Water Content	Total Organic C[†]	Total Kjeldahl N[†]	Microbial Biomass
	Mg/m^3 soil		%		kg C/ha
Cultivated Wheat/Fallow					
No tillage	1.30a*	0.335a	1.53a	0.156a	440a
Subtillage	1.26b	0.338a	1.34ab	0.141ab	356ab
Plow	1.25b	0.337a	1.21b	0.120b	329b
Native Sod					
Sod control	0.91d	0.303a	2.51a	0.240a	1053a
No tillage	0.99c	0.299a	2.48a	0.233ab	929b
Subtillage	1.05b	0.252b	2.15b	0.229ab	828b
Plow	1.10a	0.221c	1.76c	0.187b	669c

[†]% volumetric basis (Mg/m^3 soil × 100).

'Treatment means within previous cropping categories followed by different letters differ significantly at $p<0.05$.

management was 9 percent greater than when croplfallow was first initiated. In converting from grassland to wheatlfallow, declines in soil organic C and N levels, regardless of tillage management, reflect decreased inputs of C and N resulting from reduced plant production and surface rooting activity. In either case, however, reduced tillage has conserved surface soil N in the organic form—likely through reducing net mineralization of crop residues and soil organic matter as compared with subtillage or plowing.

Tillage-induced differences in surface soil reserves of potentially mineralizable N and microbial biomass may vary with climate and cropping management practices (Doran, 1987). Differences in mineralizable nitrogen reserves between plow and no-tillage management at six long-term experiments across the United States ranged from 12 to 122 Kg Nlha and were highly correlated with mean annual precipitation (Figure 1). These trends likely result from increased cropping intensity and plant productivity associated with increasing rainfall. Differences between tillage management were least and values for PMN lowest for wheatlfallow production in a low rainfall region. Higher PMN levels and greater differences were observed at four locations in continuous corn *(Zea Mays* L.), especially at the most humid location where a rye cover crop was also planted.

Mineralization/Immobilization

Interactions between microbial activity and mineralization of soil organic N are often controlled by environmental factors. Predicting how changed environmental conditions in reduced-tillage soils will affect net mineralization is difficult because the contrasting effects of increased water and reduced temperatures on net mineralization may vary during the growing season and across climates (Doran and Smith, 1987; Fox and Bandel, 1986). In the early growing season, cooler and wetter soil conditions associated with reduced tillage may result in less microbial activity and mineralization compared with tilled conditions.

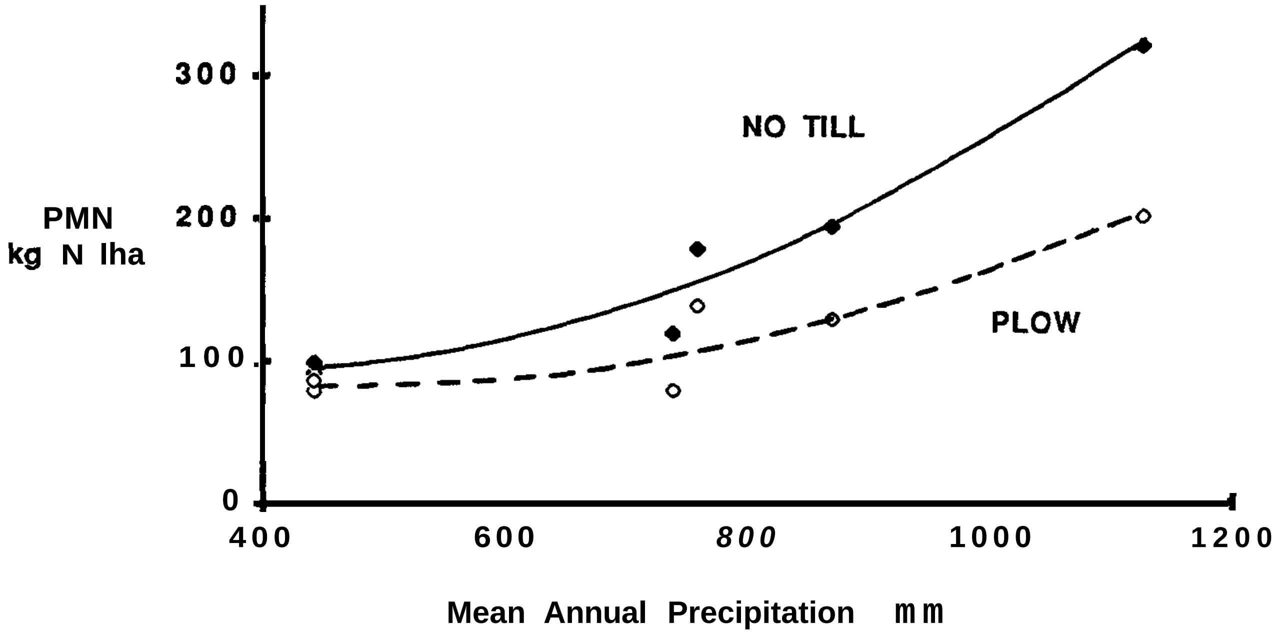

Figure 1. Surface soil (0-7.5cm) potentially mineralizable N versus mean annual precipitation at six USA locations.

Mineralization later in the growing season, when temperatures are more favorable for biological activity, may be higher with reduced tillage as a result of higher and more optimal soil water contents. Also, greater microbial biomass levels in no-tillage surface soils during the growing season can serve as a sink for immobilization of N. Higher soil microbial biomass levels in no-tillage production of wheat and corn have been related to greater immobilization of fertilizer N as compared with plowing or shallow tillage (Carter and Rennie, 1987; Rice et al., 1986).

The effectiveness of tillage in releasing the N contained in soil microbial biomass and organic N reserves is also influenced by soil type and plant rooting density. The productivity of grass pastures is often limited by reduced availability of mineral N as a result of accumulation of root and plant debris with a high C/N ratio and increased immobilization of N in microbial biomass. Periodic cultivation of grass pastures increases mineralization of soil N and stimulates grass production through changes in rooting density and mineralization of microbial and organic N reserves. In clay soils, the N mineralized by cultivation may come largely from stabilized forms of organic N, whereas in coarse-textured soils, microbial biomass may be the predominate source of mineralized N (Table 3). Changes in microbial biomass resulting from cultivation paralleling those for root biomass suggest an association between changes in rooting density and microbial biomass levels in soil.

The increased use of cover crops in reduced tillage management systems may result in pronounced changes in soil N availability. Lower yields and cover crop N

TABLE 3. EFFECT OF SOIL CULTIVATION ON TOTAL N BUDGETS FOR THE 0-30 CM SOIL DEPTH INTERVAL OF GRASS PASTURES AT TWO SITES IN QUEENSLAND, AUSTRALIA (DORAN ET AL., UNPUBLISHED DATA)

	Green Panic, Clay			Buffelgrass, Sandy Clay Loam		
Plant or Soil Component	No Tillage	Chisel Plow	Difference	No Tillage	Plow/ Resown	Difference
	--kg N/ha--					
Plant Nitrogen						
Tops	45	62	+17	28	41	+13
Roots	84	102	+18	116	94	−22
Soil Nitrogen						
$NO_3 + NH_4$	4	10	+ 6	8	7	1
Mineralizable N	945	882	−63	480	459	−21
Microbial biomass N	318	332	+14	153	116	−37
Total organic N	8143			3144		

recovery likely result from competition between plants and heterotrophic microorganisms for inorganic N and increased storage in organic N pools (Table 4). There appears to be a potential for better management of cover crop N and for using some degree of soil tillage to mineralize N for subsequent use by grain crops.

Summary

Tillage management systems affect the cycling of soil N through changes in the soil environment and supply of food sources to microorganisms and plants. Interactions between soil physical, chemical, and biological characteristics are greatly influenced by climate, soil, and soil organic matter levels. Development of alternate management strategies for the most efficient use of soil N will be enhanced by a better understanding of these interactions in the soil ecosystem.

TABLE 4. INFLUENCE OF TILLAGE AND COVER CROP ON CORN GRAIN YIELD AND RECOVERY OF COVER CROP N IN CORN GRAIN AND STOVER (AFTER VARCO ET AL., 1985)

Tillage	Cover Crop	Corn Grain Yield	Cover Crop N Recovered
		Mg/ha	%
No tillage	Vetch	6.4	16
No tillage	Rye	3.3	21
Plow	Vetch	6.9	30
Plow	Rye	5.0	31

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Integrating Irrigation and Conservation Tillage Technology

William M. Lyle and James P. Bordovsky'

There is an important relationship between conservation tillage practices and irrigation methods. The choice of a conservation tillage program may be limited by the existing irrigation system, or a change in irrigation systems could be necessary to implement a desired conservation tillage program. Traveling overhead irrigation systems lend themselves well to no-till or minimum-tillage farming operations while furrow irrigation would be of questionable use under high-residue conservation tillage conditions. An exception might be a furrow system irrigating moderate to steeply sloping no-tilled ground where the stubble and residue serve to reduce the rate of advance and runoff. A modified no-till or limited-till system could possibly be used in which furrow bottoms were cleaned and smoothed while leaving the tops of beds in a no-tilled condition. Surface or subsurface drip systems are an option for water distribution for conservation tillage but lack the capability of foliar chemigation afforded by the overhead systems. Surface drip systems require additional trips through the field for installation and removal of drip lines unless harvesting and planting can be accomplished with the lines in place. In general, the management of irrigated no-till or reduced tillage is greatly enhanced with overhead irrigation systems.

One of the primary advantages of moving overhead irrigation systems in a conservation tillage operation is the ability to apply chemicals through the system (chemigation), thus decreasing ground operations or eliminating the expense of aerial applications. Research at the Texas Agricultural Experiment Station, Halfway, is directed toward efficient chemical application through moving irrigation systems to both conservation tillage and conventionally tilled plots. Other research is focused at determining the effects of various conservation tillage treatments and crop rotations on yield and soil moisture storage under both irrigated and dryland conditions. The following is an overview of this research.

Rotation/Tillage Studies

Methods. A replicated irrigated/dryland rotation test, initiated in 1982, was expanded in 1985 to include tillage treatments in a split plot factorial experimental design. The main plots are either irrigated or dryland with irrigation being by LEPA methods. The rotation subplots consist of continuous cotton and a cotton-wheat rotation in which wheat in the rotation treatment is sown in the stalks immediately after cotton harvest. Wheat plots remain fallow during the summer until cotton is planted the next spring.

The conventional tillage treatment in the sub-subplots includes chiseling, sweeping, disking, bedding, rod weeding, and cultivation as needed. All operations are not necessarily performed each year. The alternate tillage method in the sub-subplot is no-tillage with the exception of fertilizer placement. Nitrogen and phosphorus fertilizer is placed through the side of the bed with a swept-wing applicator that bands the fertilizer about 15 cm under and 20 cm to the side of the cotton plants. This type fertilizer treatment results in minimum disturbance to the soil.

Sub-sub-subplots consist of either diked or non-diked treatments. The no-till diked treatment is referred to as a limited-till treatment with diking and dike removal being the only tillage operation other than fertilizing. The diking is confined to the bottom of the furrows with the top of the beds left undisturbed.

Results. The 1986 growing season was the first in which results were available from the added tillage treatments. Very positive response to rotation before 1986 had been observed in both irrigated and dryland tests. These data are summarized in Table 1.

The 1984 irrigated rotation cotton lint yield was 42 kg/ha greater than continuous cotton. This rotation treatment also started the year with about 4 cm more soil moisture in the soil profile than did continuous cotton. Dryland yields were increased 63 kg/ha because of the wheat rotation and had about 3 cm more water in the root zone at the beginning of the season.

The 1985 irrigated rotation treatment out-yielded the continuous treatment by only 23 kg/ha, which may have been due to similar beginning soil moisture. A large increase was measured due to the rotation in the dryland tests (114 kglha), although beginning profile moisture was only 1.6 cm higher in the rotation treatment.

The 1986 yields shown in Table 2 depict the additional subplot treatments of tillage and diking. Rotation again had a positive effect under irrigation, increasing lint yields averaged over all tillage treatments by 43 kg/ha. Rotation in 1986, however, had a detrimental effect on dryland yields, which were decreased an average of 48 kg/ha because of the wheat rotation. These yield differences were not significant at the 0.05 level. Diking also decreased yields for the first time since it was reintroduced in 1976. This was attributed to higher than normal rainfall during the growing season, which caused flooded conditions at times.

There was no difference in irrigated yields because of tillage. However, the no-till dryland treatments out-yielded the conventional tillage treatments by an average of 75 kg/ha and were significantly different (0.05).

Both rotation and no-till treatments increased the moisture content in the soil profile at the beginning of the growing season (Table 3). These values are given for

'Texas Agricultural Experiment Station Lubbock-Halfway, Texas

TABLE 1. CROP ROTATION RESULTS AT THE TEXAS AGRICULTURAL EXPERIMENT STATION, HALFWAY, TEXAS, 1984-85

	Irrigated		Dryland	
Year	Cotton Yield (kg/ha)	Beginning Soil Moisture' (cm)	Cotton Yield (kg/ha)	Beginning Soil Moisture (cm)
1984				
Cotton-Wheat Rotation	**453.3**	**48.8**	359.7*	**48.5**
Continuous Cotton	**411.6**	**44.7**	**296.4**	**45.2**
1985				
Cotton-Wheat Rotation	**463.0**	**47.8**	354.2*	**48.8**
Continuous Cotton	**440.5**	**47.5**	**239.9**	**47.2**

'Soil moisture in 1.5 m soil profile at beginning of season.
***Significantly different at 0.05 level.**

TABLE 2. EFFECT OF CROP ROTATION AND TILLAGE ON COTTON YIELD (KG LINT/HA) AT THE TEXAS AGRICULTURAL EXPERIMENT STATION, HALFWAY, TEXAS, 1986

	Irrigated			Dryland			
Tillage	Con-tinous Cotton	Cotton -Wheat Rotation	Irrigated Averages	Con-tinous Cotton	Cotton -Wheat Rotation	Dryland Averages	Overall Averages
Conventional	**924.1**	**983.1**	**953.6** a*	**622.1**	**606.3**	**614.2** bc	**783.9** ab
			920.1			**595.8**	**757.9**
Conv./Diked	**869.3**	**903.9**	**886.6** a	**612.0**	**542.8**	**577.4 c**	**732.0** b
No-Ell	940.1	**941.8**	**941.0a**	**678.0**	**694.5**	**686.3** a	**813.6** a
			926.8			**670.9**	**798.3**
Min-Till/Diked	**860.8**	**959.6**	**910.1** a	**674.5**	**636.6**	**655.6ab**	**782.9** ab
Averages	**898.6**	**947.1**	**922.8**	**645.8**	**597.6**	**633.4**	

***Numbers with the same letter behind them are not significantly different at the 0.05 probability level.**

both the 1.5-m soil profile and the top 0.6-m depth. Rotation increased beginning soil moisture by more than 2.5 cm in both irrigated and dryland treatments. No-till irrigated treatments had 2.1 cm more stored soil moisture than did the irrigated conventional, and the dryland no-till stored 3.3 cm more water than did the conventional tilled treatments.

Measured water extracted from the root zone as determined by neutron methods taken throughout the growing season is given in Table 4. There was little difference because of rotation but substantial differences because of tillage. The no-tilllnon-diked treatment stands out as superior in moisture extraction to all other treatments. This corresponds to the highest yield average also achieved by the no-till treatment.

Chemigation Research

Methods. Chemigation research is being carried out with an experimental multiple-use LEPA system that was developed for very precise chemical application through a separate nozzle system. The multifunction irrigation system (MFIS) is a linear-move irrigation system that was developed to use automated, programmable, dynamic nozzle movement and uniform constant forward movement to achieve precise and efficient water and chemical application (Lyle and Bordovsky, 1986). The system uses two independent nozzle systems (one each for water and chemical application), which are both capable of dynamic horizontal and vertical movement. The amplitude and oscillation period of the vertical dynamic nozzles are controlled by a programmable microprocessor along with the spray period and choice of independent or simultaneous span operation capability. Constant uniform movement is achieved by variable frequency A.C. control of the tower motors. A primary objective in the development of the systems was to facilitate a total no-till system.

Extensive spraying tests were initially conducted to evaluate chemical application with the MFIS using lithium salt solutions as tracers and analysis with atomic

TABLE 3. BEGINNING SOIL MOISTURE (CM), APRIL 9, IN THE 1.5-M SOIL PROFILE AND IN THE TOP (0.6 M) OF THE ROOT ZONE AT THE TEXAS AGRICULTURAL EXPERIMENT STATION, HALFWAY, TEXAS, 1986

Tillage	Irrigated				Dryland					
	Con-tinous Cotton	Cotton -Wheat Rotation	Irrigated Averages		Con-tinous Cotton	Cotton -Wheat Rotation	Dryland Averages		Overall Averages	
Conventional	52.3 (23.1)*	52.8 (21.8)	52.6 (22.6)		46.5 (20.1)	47.5 (20.3)	47.0 (20.2)		49.8 (21.6)	
				52.3 (22.1)				48.3 (20.1)		50.3 (21.3)
Conv./Diked	51.8 (22.4)	52.3 (21.3)	52.1 (21.8)		48.5 (19.8)	49.8 (19.6)	49.3 (19.7)		50.8 (20.8)	
No-Till	48.8 (20.6)	56.4 (23.4)	52.6 (22.1)		49.3 (20.8)	54.1 (23.6)	51.8 (22.4)		52.3 (22.4)	
				54.4 (23.1)				51.6 (22.4)		53.1 (22.8)
Min-Till/Diked	53.6 (22.9)	58.4 (24.9)	56.1 (23.9)		49.5 (21.3)	52.8 (22.9)	51.3 (22.1)		53.8 (23.1)	
Averages	51.6 (22.4)	55.1 (22.9)	53.3 (22.6)		48.5 (20.6)	51.1 (21.6)	49.8 (21.1)			

*( )—Top 0.6-m of the root zone.

TABLE 4. MEASURED WATER EXTRACTED (CM) FROM THE 1.5-M SOIL PROFILE DURING THE GROWING SEASON AT THE TEXAS AGRICULTURAL EXPERIMENT STATION, HALFWAY, TEXAS, 1986

Tillage	Irrigated				Dryland					
	Con-tinous Cotton	Cotton -Wheat Rotation	Irrigated Averages		Con-tinous Cotton	Cotton -Wheat Rotation	Dryland Averages		Overall Averages	
Conventional	13.5	12.4	13.0		14.5	13.0	13.7		13.5	
				13.0				13.3		13.2
Conv./Diked	11.7	15.2	13.0		12.4	13.2	12.9		13.0	
No-Till	16.8	17.5	17.2		14.7	16.5	15.6		16.5	
				16.8				13.7		15.4
Min-Till/Diked	16.8	16.0	16.4		11.7	11.7	11.7		14.2	
Averages	14.7	15.0	14.9		13.3	13.6	13.5			

absorption spectrophotometry. Analyses included measurement of quantity and uniformity of the chemical application by various available dynamic and stationary modes along with nozzle orientation and nozzle output. Aerial application was analyzed for comparative purposes. Data averaged over four crops (corn, cotton, sorghum, and soybeans) revealed a twofold coverage improvement for the dynamic nozzle movement over stationary application and fourfold better coverage than that obtained with aerial application.

Since initial uniformity and coverage testing, two years have been devoted to applying specific chemicals to numerous crops by both the stationary and dynamic modes. The stationary mode closely duplicates traditional chemigation from low-pressure spray nozzles.

Herbicides were applied by the MFIS to corn, sorghum, soybeans, and cotton under both minimum tillage and conventional tillage conditions. These treatments were compared to conventional spray applications with a ground rig. Water quantity with which the herbicides were applied varied between herbicides and the crop but ranged between 1.3 and 2.6 cm.

Numerous chemical and biological insecticides have been applied to corn, sorghum, and cotton by the MFIS. Replicated aerial applications were also made for comparative purposes.

Foliar fertilizer (29-7-10-4) was applied to soybeans in four and five applications during the pod-filling stages by both stationary and dynamic spraying modes. However, there was no significant response to the foliar fertilizer treatments from either spraying mode.

Other applications have included tallow applied as an antitranspirant to cotton, corn, and grain sorghum. Tallow was also applied to the soil surface as an evapora-

TABLE 5. WEED CONTROL FROM HERBICIDE APPLICATION BY CHEMIGATION AND GROUND APPLICATION (ABERNATHY ET AL., 1985; KEELING ET AL., 1986)

				Pigweed Control (Percent)			
				Chemigation		Ground Application	
Year	Crop	Herbicide	Rate (kg AI/ha)	Conventional	Min-Till	Conventional	Min-Till
1985	Corn	Dual + Propazine	1.96 + .12	100	100	100	100
		Propazine	1.12	100	100	100	100
	Sorghum	Dual + Propazine	1.96 + .12	100	100	100	100
		Propazine	1.12	100	100	100	100
	Soybeans	Dual + Lorox	2.22 + .46	95	70	100	70
		Prowl	0.78	85	65	70	55
	Cotton	Dual + Caparol	1.96 + .68	100	65	90	70
		Prowl	0.84	85	65	85	75
1986	Corn	Dual + Propazine	1.96 + 1.12	100	100	100	95
		Propazine	1.12	100	100	100	100
	Sorghum	Dual + Propazine	1.96 + 1.12	100	85	100	85
		Propazine	1.12	100	90	95	85
	Cotton	Dual + Caparol	1.96 + 1.68	100	87	100	45
		Prowl	1.40	50	80	95	90

tion suppressant. There were no significant differences in yield due to the tallow, although the trend was a yield reduction from its application to the plant as an antitranspirant.

Chemigation Results. Results of 1985 and 1986 herbicides application by chemigation and ground methods are given in Table 5. Pigweed control by chemigation was at least as effective as ground application in almost all treatments. Minimum-tillage pigweed control in cotton and soybeans, however, was not as effective as that in conventional tillage.

Pydrin insecticide was applied by various modes through the MFIS to corn for southwestern corn borer control (Bynum et al., 1986). Excellent results were obtained with three applications using a dynamic 2X spraying mode. Azodrin and Comite miticides were applied at two rates by both the dynamic and stationary spraying modes to corn. Both full and half rates gave excellent mite control when applied with dynamic nozzle movement. However, stationary overhead application that simulated traditional chemigation failed to provide control with either chemical.

A biological insecticide, Dipel, was applied to cotton along with other treatments of Dipel + Chlordimeform and Capture for bollworm control without any significant results. The bollworm infestation was late, nonuniform and not severe enough to actually warrant a control application.

Fairly extensive greenbug control tests on grain sorghum were carried out to verify the earlier results obtained with the lithium tracer tests. The data are reported in Table 6. These data verify the superiority of dynamic in-canopy chemical application over traditional chemigation and aerial application methods. Aerial application required the maximum labeled rate of Lorsban® 4E (0.57 kg [AI]/ha) to maintain effective control for two weeks. Aerial greenbug control dropped to 63 percent and 55 percent after 14 days with half and quarter the maximum labeled rate, respectively. Rates lower than these were not applied aerially. Stationary overhead chemigation remained effective at 3, 7, and 14 days following treatment with rates down to quarter the maximum registered rate (0.14 kg [AI]/ha), but effectiveness dropped drastically at rates below this. Rates of 1/16 the maximum recommended were totally ineffective. On the other hand, the MFIS dynamic treatments produced 75 percent or greater control through the two-week post-treatment period at a chemical rate of 1/16 the maximum labeled rate for Lorsban® (0.035 kg [AI]/ha).

The success of dynamic in-canopy insecticide application has led to preliminary testing of both stationary and manually adjustable in-canopy chemigation nozzles for center pivots. Three different rates of Comite were applied to corn with prototype nozzles in both every row and alternate row treatments from a continuously moving one-tower center pivot. This was compared to above-canopy traditional chemigation. Comite in previous tests had never demonstrated the ability to control mites by overhead chemigation, and this test was no exception. However, the in-canopy nozzle application gave 86 percent to 94 percent control with the recommended rate of Comite.

Summary

Conservation tillage and crop rotations are showing advantages over continuous cotton and conventional tillage in both dryland and irrigated tests. The implementation and management of irrigated no-till or conventional tillage methods is greatly facilitated by

TABLE 6. GREENBUG CONTROL ON SORGHUM WITH LORSBAN® 4E insecticide (Bynum et al., 1985; Smith et al., 1985)

Days post-treatment	Rate, kg[AI]ha	Percent control: MFIS: Dynamic nozzle movement	Percent control: MFIS: Stationary nozzle (overhead chemigation)	Percent control: Aerial application
3	0.57*	—	—	99
	0.28†	99	97	78
	0.14	99	97	83
	0.07	99	55	—
	0.035	75	−7	—
7	0.57	—	—	99
	0.28	99	99	80
	0.14	97	99	85
	0.07	96	67	—
	0.035	80	21	—
14	0.57	—	—	99
	0.28	97	98	63
	0.14	84	96	55
	0.07	81	75	—
	0.035	78	−5	—

***Maximum labeled rate of Lorsban recommended for greenbug control. Rate normally used in aerial application**

†Minimum registered rate of Lorsban for greenbug control

moving overhead irrigation systems capable of foliar chemigation. Irrigation systems that also incorporate in-canopy chemigation nozzles are being developed specifically to enhance no-till or conservation tillage irrigation and management. These systems are demonstrating distinct advantages over existing ground, aerial, and conventional chemigation techniques and look extremely promising for enhancing irrigated conservation tillage practices.

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Methods to Improve Water Infiltration on Fragile Soils[1]

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An important physical property of a soil is its infiltration rate. Infiltration rate of a soil, according to SSSA (Lutz and others, 1956), is the maximum rate at which a soil, in a given condition at a given time, can absorb rain. According to Parr and Bertrand (1960), some scientists believe that infiltration rate is governed solely by the soil mass and is largely independent of surface conditions. In contrast, Horton (1940) stated that infiltration rate is governed mainly by conditions at or near the soil surface. Duley and Russell (1939) noted that leaving crop residues on the soil surface greatly increased infiltration and reduced runoff, evaporation, and wind and water erosion.

Infiltration rate (I) of many soils is highly dependent on saturated hydraulic conductivity (Ks) of the soil surface. Research by Allison (1947), Christiansen (1944), and Poulovassilis (1972) established that Ks of soils undergoes changes with time. Gerard (1974, 1986) reported that Ks of fragile soils was a function of antecedent moisture and residue management. Time-dependent differences in Ks and I of many soils may be largely an expression of antecedent moisture and residue management and their indirect effects on soil properties and microbial activity.

Some of the conflicting ideas about factors that affect the I of soils are probably due to the failure to understand or appreciate the dynamic changes in some soils during and following rainfall. These changes and their subsequent effects on soil permeability are probably greatest on weakly structured or fragile soils. Fragile or weakly structured soils are low in organic matter, low or devoid of water-stable aggregates, and susceptible to surface sealing and crusting.

The purpose of this paper is to define the effects of antecedent moisture, residue and residue management, rainfall intensity, drying conditions, and their interactions on soil permeability and to suggest methods for improving the I of fragde soils. Studies were conducted on a fragile Miles soil. As shown in Table 1, this soil, like many in the Rolling Plains and southern U.S., is low in organic matter and devoid of 1-to 10-mm water stable aggregates considered essential for good structure (Tisdall and Oades, 1982). These conditions greatly reduce I and subject the soils to wind and water erosion.

Soils are less permeable to rainwater or water with a low level of salt than to water with significant quantities of salt. This fact was demonstrated using cores of a disturbed Miles soil that had an initial Ks of 4 to 4.5 cm h^{-1} when treated with either rainfall or water with an electrical conductivity of 0.8 dSm^{-1} and a sodium adsorption ratio of 1.5. After two wetting and drying cycles, Ks of soil to distilled water was only 2 percent of initial Ks, whereas the Ks of soil to water with an electrical conductivity of 0.8 dSm^{-1} was 20 percent of initial K_S.

Physical properties of a Miles fine sandy loam soil under different management systems described in Table 2 were measured in 1986. Data in Table 2 show measured runoff from natural precipitation and surface cover in July. As shown in Table 2, 36.8 percent of the natural rainfall ran off the bare soil compared to an average of 3.3 percent for the conservation-tilled treatments, which left half of the residue on the soil surface. Runoff averaged 11.7 percent from treatments that incorporated all the residue into the soil.

Runoff from bare soil and ryegrass treatments shows that runoff was a linear function of daily rainfall in centimeters. Calculations indicated runoff from the grass surface during a 25-mm rain amounted to about 5 mm, whereas runoff from bare surfaces amounted to almost 15 mm. The equations expressing runoff as a function of rainfall indicated that bare soil lost an average of 79 percent of the rainfall, but ryegrass lost only an average of 32.5 percent of the rainfall. Runoff on bare soil and ryegrass did not occur until 6 and 9.5 mm of rain fell on these surfaces, respectively. It should be noted that the experiment was conducted during the first year of growth for ryegrass.

Studies using collected rainfall with a rainfall simulator showed that I is high when Ks is high. The opposite is true of runoff. Ks and I from rainfall simulation are reported in Table 2. The effect of antecedent

TABLE 1. PROPERTIES OF THE TOP 150 MM OF A MILES FINE SANDY LOAM (FINE-LOAMY, MIXED, THERMIC UDIC PALEUSTALF) AND AN ABILENE SANDY LOAM SOIL (FINE, MIXED, THERMIC PACHIC ARGUISTOLL)

	Miles %	Abilene %
Sand	72.0	57.0
Silt	20.0	26.0
Clay	8.0	17.0
Organic matter	0.3	0.9
Moisture at 0.01 MPa	16.6	22.9
Moisture at 1.50 MPa	4.4	9.5
Aggregation >1 mm	0	—

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TABLE 2. RUNOFF LOSSES AND SURFACE COVER IN SPRING OF 1986 AND Ks AND INFILTRATION RATE (I) DETERMINED WITH RAINFALL SIMULATOR UNDER DIFFERENT TREATMENTS OF A MILES FINE SANDY LOAM SOIL

Treatment*	Runoff from natural rainfall***		Surface cover	—K_s****—		Ratio K_s wet/dry	—I****—		Ratio I wet/dry
				dry	wet		dry	wet	
	cm	%	%	cm h^{-1}			cm h^{-1}		
Check	7.34	36.8	0	1.05	0.68	0.65	1.28	0.93	0.73
7.5 Mg ha^{-1} straw incorporated	1.12	5.6	4	1.26	0.72	0.57	1.78	1.16	0.65
15.0 Mg ha^{-1} straw incorporated	3.52	17.7	14	1.87	0.73	0.39	2.25	0.84	0.37
7.5 Mg ha^{-1} conservation-tilled**	0.86	4.3	56	2.96	1.44	0.49	3.25	1.69	0.52
15.0 Mg ha^{-1} conservation-tilled**	0.48	2.4	96	4.57	4.42	0.97	4.60	4.50	0.98
Ryegrass	2.43	12.2	88	4.55	3.24	0.71	4.74	3.41	0.72

*Each treatment was replicated twice. Plot size was 3.3×4.0 m.

**Consemation-tilled consisted of incorporating one-half of the straw with the soil and leaving the other half of the straw on top of the soil

***Total recorded rainfall 19.91 cm

****K_s and infiltration rate (I) of treatments were determined with a rainfall simulator at a rainfall intensitv of about **5.4** cm h^{-1}

moisture on Ks (wet vs. dry) in combination with bare soil or residue is also given in Table 2. Antecedent moisture is the moisture content of the top 25 mm of soil before determining Ks or I. When the Miles soil was dry, Ks increased with increasing residue. The effect of residue on Ks was considerably less when the soil was wet before the rainfall, especially when residue was incorporated. For a dry surface, Ks of Miles soil is a positive linear function of surface cover. In contrast, for a wet surface of a Miles soil, Ks is a curvilinear function of soil cover. High antecedent moisture reduced the benefits of surface cover, especially for surface cover greater than 60 percent.

The I as affected by treatments determined with a rainfall simulator are reported in Table 2. The ratios of Ks-wet/Ks-dry and I-wet/I-dry are probably indicative of the surface sealing after rainfall. The lower the ratio, the greater the surface sealing and the greater the reduction in the Ks or I. High surface cover by ryegrass or 15.0 Mg ha^{-1} of residues in conservation-tilled treatments reduced surface sealing and maintained soil permeability.

Runoff studies with diked furrows on Miles and Abilene soils indicated that retarding water flow by diking, especially diking every furrow, was effective in substantially reducing runoff and increasing yields (Gerard et al., 1984). On fragile soils, even on gentle slopes, the only way to prevent or substantially reduce runoff is to retard flow of water down slope by diking or by grass or residue cover. Cultivation also can reduce runoff by increasing soil surface roughness and by breaking the surface crust.

The cumulative infiltration and runoff of a Miles soil was measured at rainfall intensities of 1.3 to about 6.7 cm h^{-1} after a surface crust or seal had formed. When the soil was dry, runoff occurred only at rainfall intensities greater than 1.3 cm h^{-1}. In contrast, when surface was wet and sealed over, runoff occurred at all intensities measured. Regardless of rainfall intensity, the Ks of a dry Miles soil was almost constant at 1.35 cm h^{-1} compared to 0.5 cm h^{-1} for a wet soil. Two points are noteworthy. First, bare Miles soil sealed over as much at low rainfall intensity as at high rainfall intensity. Secondly, antecedent moisture had a significant effect on K_s.

A conservation-tilled Miles soil treated with 7.5 Mg ha^{-1} of straw was considerably more permeable to rainfall than the bare soil. Rainfall intensities had a significant effect on runoff and soil permeability. When dry and just cultivated, the residue-treated Miles had runoff at rainfall intensities of 5.5 and 6.5 cm h^{-1}, but not at rainfall intensities of 3.65 cm h^{-1}. When wet, soil subjected to rainfall intensity of 3.65 cm h^{-1} had some runoff after the second wetting and drying cycle but not at rainfall intensities greater than 3.65 cm h^{-1}. These data also showed a high Ks immediately after cultivation and a much lower Ks after the first drying cycle. Maximum drying of the surface 25 mm occurred 4 to 6 days after wetting. Ks increased about 0.3 cm h^{-1} for each day of drying and reached a maximum in 4 to 6 days.

Tisdall and Oades (1982) recently discussed the role of organic matter and water-stable aggregates in soils. They stated that g o d structure for crop growth depends on the presence of water-stable aggregates of 1-10 mm in diameter. Many soils in the southern USA are low in organic matter, weakly structured, and almost devoid of 1- to 10-mm water-stable aggregates. The status of the fine particles in these soils need to be better defined because these particles often govern the permeability of fragile soils. Questions such as "Why do fragile soils seal over and exhibit low permeability characteristics?" and "What management schemes will enhance the I of fragile soils?" need to be answered. Very little research has been concerned with measuring the status of fine particles in soils. A method to measure micro-aggregate stability from USDA Handbook No. 60 (1954) is briefly described below. The method involves measuring the concentrations of two suspensions of the same soil, one of which is dispersed by standard dispersion procedures to give total silt and clay. The other suspension, prepared by mild (end-over-end) agitation of the sample in water, gives a measure of the unaggregated silt and clay. The difference in reading with a hydrometer after 40 seconds (Bouyoucos, 1927) measures the aggregated silt and clay and after 2 hours measures the aggregated clay.

Adding residue to the Miles soil increased the stability of the silt and clay, and high antecedent moisture reduced silt and clay aggregation of the Miles soil. Clay aggregation of two Rolling Plains soils was about 100 percent for oven-dry soils but decreased with increasing antecedent moisture. At antecedent moisture suction of about 0.01 MPa, clay aggregation of Miles and Abilene soils decreased to about 0 percent and 55 percent, respectively. At high antecedent moisture, dispersed or unaggregated silt and clay particles can increase surface sealing, clog up large pores, and decrease I and Ks of fragile soils. Properties of the Miles and Abilene are compared in Table 1. These results were discussed in greater detail by Gerard (1986).

Silt and clay aggregation of oven-dried soils under crop and rangeland in the Rolling Plains ranged from 16 percent to 70 percent. Clay ranged from 9 percent to 36 percent and organic matter ranged from 0.3 percent to 1.76 percent. Stepwise regression analysis showed that aggregation of silt and clay was positively related to percent organic matter and clay but negatively related to percent sand. This is indicative of why sandy soils such as the Miles can be problem soils. Stengel et al. (1984) reported that soils high in sand and low in clay were problem soils in no-till and low-till systems.

Compaction refers to the close packing of particles. Compaction can be so severe that it stops root penetration and reduces permeability or I of soils. Traffic is the most commonly recognized cause of compaction, usually tractor or animal traffic. Soils are especially susceptible to compaction when tilled or cultivated wet. Natural compaction due to soil properties and drying conditions without mechanical forces being imposed has rarely been understood or recognized. Conservation tillage has often been referred to as tillage systems that tend to maximize residue retention on the soil surface. However, conservation tillage has contributed to soil compaction, according to Dickey et al. (1983), Hamblin et al. (1982), Whiteley and Dexter (1982), and Gerard (1986). Gerard (1986) and Taylor et al. (1966) reported that slow drying and drying, respectively, were important factors in excessive soil strength and compaction.

Many soils in Texas and the world contain high percentages of sand and low percentages of clay. Natural and induced compaction are serious problems associated with sandy soils. Natural compaction of the Miles and Abilene soils treated with residue was measured in the laboratory after three to four wetting and drying cycles at different drying conditions. Residue was mixed with the soil in cores or placed on the soil surface (mulch) of like cores. Soil cores were dried at 25°C and 35°C. Differences in bulk density were considered an estimate of natural compaction for both soils. The results of this experiment showed the following: (1) residue mixed with soils decreased bulk density, (2) slow drying (25°C) increased bulk density compared to fast drying (35°C), and (3) mulching increased bulk density. The effects of slow drying and mulching were more dramatic on the coarse-textured Miles soil than on the medium-textured Abilene soil. The Miles fine sandy loam is more of a problem soil because it is very low in organic matter and clay.

Conservation and low-till practices have created problems and yield reductions on some soils, especially soils low in organic matter and clay (Hamblin et al., 1982; Stengel et al., 1984; Whiteley and Dexter, 1982). Observations in the Rolling Plains in spring 1986 showed that wheat under conservation tillage on sandy soils had poor growth and was yellow. Strength of these soils under conservation tillage was high at the 200- to 250-mm depth. This caused some wheat to produce insufficient growth for grazing. In fact, because of poor growth some growers plowed up wheat under conservation tillage in spring 1986. This would suggest a need for scientists and growers to evaluate the strength profiles of soils when wet before adopting conservation tillage practices. Strength values of 1.5 to 2.0 MPa when wet in the upper 400- to 600-mm soil depth would suggest the need for chiseling before adopting conservation tillage systems on these soils.

Studies comparing conventional (tilled) and deep-plowed Abilene soils showed that deep plowing increased sorghum yields an average of 12 percent from 1981-1985. It is interesting to note that deep plowing increased yields an average of 22 percent on the lower part of the slope. Since water is the dominant factor for yields in the Rolling Plains, these data showed that some runoff water from the upper and middle parts of the field was captured in the lower part of the deep-plowed soil. Surface sealing probably reduced the yield increase from deep plowing on the upper and middle parts of the field to only 4 percent to 5 percent.

In conclusion, surface cover from residue in conservation tillage or grass was highly effective in increasing Ks, reducing surface sealing, and increasing the I of fragile soils. High antecedent moisture decreased the stability of fine particles. Dispersed silt and clay particles increase surface sealing and clogging of soil pores and reduce soil permeability. Slow drying or mulching can increase natural compaction. However, the adverse effects of antecedent moisture and slow drying due to conservation tillage are not as great as the beneficial effects cited above.

Compaction can be reduced by chiseling with little or no disturbance to the soil surface. Tillage sometimes can be used to increase surface roughness, break up restrictive crusts, and increase the I of soils. Practices such as furrow diking, sometimes in conjunction with straw mulching, can retard the flow of water downslope, reduce runoff, and increase water storage for crop production. Finally, the anticipated benefits from conservation or low-till systems on fragile soils may not be apparent for several years.

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Weed Control for Conservation Tillage

A.F. Wiese[1]

Introduction

Conservation tillage systems using sweep plows or field cultivators leave a high percentage of crop residues on the soil surface, which protects the soil from wind and water erosion (Johnson, 1950; Jones and Johnson, 1982; Allen and Fenster, 1986; Johnson et al., 1974). These systems have been successful in semiarid areas because meager rainfall after plowing does not allow weeds to reestablish. In wetter areas, acceptable weed control has been obtained only where weeds were uprooted or inverted with disks or plows (Davidson and Santelmann, 1973).

In conservation tillage systems for semiarid areas where soil water storage during fallow periods is essential for profitable crop production, weeds must be plowed before they are 150 mm tall or storage of soil water will be depleted compared to weed-free areas. Under the same conditions, weeds had to be sprayed with herbicides before they exceeded 50 mm (Lavake and Wiese, 1979).

No-tillage, where weeds and volunteer crops are controlled with herbicides during fallow periods, is a relatively recent innovation for maintaining crop residues on the soil surface. This technique has been successful when suitable herbicides are available that control weeds between and in crops without injuring subsequent crops in the rotation (Wiese and Staniforth, 1973). In the future, as new herbicides are developed and marketed, no-tillage will become feasible in an increasing number of cropping sequences. However, from a practical standpoint, conservation or no-tillage systems that work are not adopted unless there is an economic advantage over conventional tillage.

Texas is a large and diverse state, and, consequently, cropping sequences, weed control, and conservation tillage systems vary. Figure 1 shows locations in the state where research is being conducted on conservation tillage and cropping systems. Research information is available from the Rio Grande Valley, Coastal Bend, Northern Gulf Coast, Central Texas Peanut Production area, Southern and Northern Blacklands, Rolling Plains, and the Southern and Northern High Plains. Because of limited time, only weed control research in conservation tillage systems from the Coastal Bend, Northern Gulf Coast, Central Texas, Blacklands, Rolling Plains, and High Plains will be discussed.

Coastal Bend

The effect of tillage on crop yield in rotations has been underway for 10 years on the clay loam soil at the Texas A&M Center at Corpus Christi. Cropping sequences for which minimum and no-tillage systems have been developed follow:[2]

Continuous Corn or Grain Sorghum

In these crop sequences with corn and sorghum, minimum tillage and no-tillage were compared. With minimum tillage, soil was sweep-plowed and bedded after harvest the same as for conventional tillage, but during winter, weeds are controlled with herbicides. With normal rainfall, this required one or two sprays with paraquat during November through February. Atrazine, which controls germinating weeds, was mixed with one of the sprays at 1.7 kg ha^{-1}. In years with below-average rainfall, only one application of paraquat and atrazine was required. After planting in late March or early April, 0.8 kg ha^{-1} of atrazine is banded over the row. Sorghum or corn was cultivated once, and escape weeds were controlled with a broadcast-directed layby treatment of paraquat.

In the no-tillage system, weeds that emerged after harvest but before October 15 were sprayed with glyphosate. During the winter, one to three sprays of paraquat were required depending on rainfall. One of the paraquat sprays contained atrazine at 1.7 kg ha^{-1}. After corn or sorghum was planted in late March or early April, 0.8 kg ha' of atrazine was banded over the row. Escape weeds were controlled with a broadcast-directed application of paraquat at layby when sorghum or corn was 0.3 m tall.

Upper Gulf Coast

Preliminary research with reduced tillage has been conducted at the Texas A&M Center at Beaumont. Rice was planted in the spring on clay soil that had not been tilled since the previous fall. Weeds were controlled with either paraquat or glyphosate before planting with a no-till drill. Adequate stands were obtained, and yields from this treatment were comparable to those with conventional tillage.'

Central Texas Peanut Production

Experiments with reduced- and no-tillage systems for peanuts have been underway since 1975 at the research station at Yoakum and on farmers' fields near Pearsall. The soil at both locations is fine sandy loam. Diseases that are a problem include southern blight, which is worse where crop residue is left on the soil surface, as well as both pod and stem roots. In these studies, yields were decreased and disease incidence increased if crop residue was left on the soil surface.

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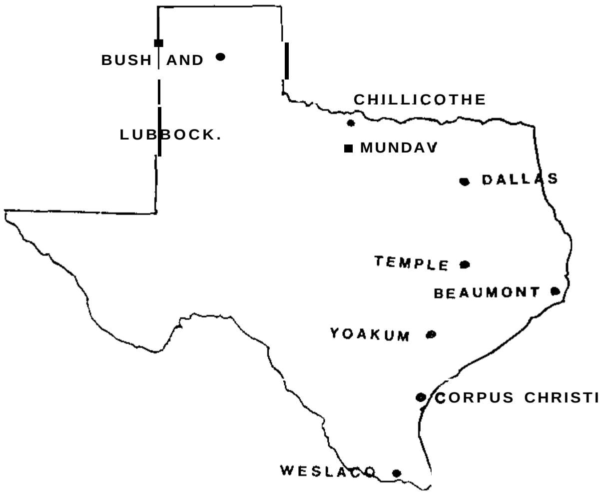

Figure 1. Locations of conservation tillage research in Texas: Weslaco, Rio Grande Valley; Corpus Christi, Coastal Bend; Beaumont, Northern Gulf Coast; Yoakum, Central Texas Peanut Area; Temple, Southern Blacklands; Dallas, Northern Blacklands; Munday and Chillicothe, Rolling Plains; Lubbock, Southern High Plains and Bushland, Northern High Plains.

Tillage systems compared were conventional, minimum, and no-tillage. In these studies, an oat cover crop was grown over the entire experimental area during the winter to prevent erosion. Conventional tillage was shredding the cover crop, moldboard plowing, disking, bedding, bed leveling, incorporating preplant herbicides, planting, and cultivation as needed. Minimum tillage was shredding the cover crop at either 0.15 or 0.3 m, disking, bedding, bed leveling, incorporating preplant herbicides, planting, no cultivation, and postemergence herbicides as needed to control weeds. A mixture of trifluralin and vernolate were the preplant herbicides used in the conventional and minimum-tillage systems. No-tillage involved shredding the cover crop 0.15 m tall, spraying paraquat or glyphosate to kill the cover crop and weeds, planting, applying alachlor preemergence, and spraying 2,4-DB mixed with either sethoxydim or fluazifop as needed to control broadleaved weeds emerging in the crop (Boswell and Grichar, 1981a, 1981b).

Research in 1985 and 1986 indicates that yields with no-tillage were comparable to conventional tillage when Texas panicum was controlled with sethoxydim. With no-tillage, an irrigation one day before digging also increased peanut yield. Disease problems were reduced in no-tillage when weeds were adequately controlled compared to early research.[4]

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Southern Blacklands

In this area, the most troublesome weed is Johnsongrass. Until recently, attempts to reduce tillage and leave crop residue on the soil surface have failed because this weed could not be controlled. Repeated tillage and cultivation had given the best control of Johnsongrass and crop yields.

Research over the past 8 years has shown the potential for no-tillage in the Blacklands. Planters have been developed that work in wheat stubble, sorghum stubble, or bermudagrass sod (Morrison and Gerik, 1982, 1983a). The concept of controlled traffic zones and permanent beds has been developed for Blackland conditions (Morrison and Gerik, 1983b; Gerik and Morrison, 1985; Morrison et al., 1985). Sorghum yields were not affected by no-tillage (Gerik and Morrison, 1984), but wheat yield was reduced by no-tillage in dry years (Gerik and Morrison, 1985).

In a no-tillage system where grain sorghum followed winter wheat, johnsongrass, annual weeds, and volunteer were controlled between crops with 0.84 kg ha^{-1} glyphosate applied in early October. At planting, a preemergence application of propazine and paraquat, each at 2.24 kg ha^{-1}, killed existing weeds and maintained the crop free of weeds until layby. Then a directed spray of MSMA and metolachlor was applied. This was compared to six tillage operations in a conventional tillage system to destroy crop residue. In the other half of the cropping sequence, when wheat was double-cropped after grain sorghum, volunteer sorghum, Texas panicum, and johnsongrass between the crops were controlled with one or two sprays of glyphosate at 0.84 kg ha^{-1} in August and October.

In recent research (Brown, 1986) in a 3-year grain sorghum-cotton-winter wheat rotation, one crop was harvested each year because winter wheat was planted immediately after cotton harvest. No-tillage and reduced tillage were compared in that cropping sequence. Johnsongrass was controlled with herbicide treatments in the fall after harvest or in the spring before planting, depending on the crop. Reduced tillage was primary fall tillage followed by use of herbicides to control weeds in the spring. Johnsongrass was controlled before planting with glyphosate in both reduced tillage and no-tillage. The most successful fall no-tillage treatment was glyphosate and a herbicide that persisted in the soil to control winter annual weeds. This was atrazine before planting sorghum and oryzalin plus prometryn before cotton. Because wheat was double-cropped into cotton, herbicides with a long soil residual could not be used in cotton. Herbicides used just before or preemergence in row crops were propazine plus metolachlor for sorghum and prometryn and metolachlor in cotton. Fluazifop at 0.15 kg ha^{-1} was sprayed over the top of cotton, and glyphosate was sprayed after sorghum harvest. Comparisons were made using glyphosate in the fall followed by either glyphosate or paraquat in the spring. Both gave excellent control of johnsongrass and increased sorghum yields. Glyphosate or paraquat sprayed only in the spring did not control johnsongrass. Johnsongrass control and sorghum yields for 1984 through 1986 were greatest with no-tillage. Yields of cotton and control of johnsongrass were best with the system of reduced tillage.

In addition to johnsongrass, browntop panicum, and green foxtail were troublesome grass weeds. Tumble pigweed was the most prevalent broadleaf weed.

Rolling Plains

Research with conservation tillage is being conducted at the Texas Agricultural Experiment Station at Munday on Miles fine sandy loam and at Chillicothe on fine textured soil. Research at Chillicothe is primarily reduced tillage using both furrow diking and herbicides to minimize the cost of operation and greatly reduce the number of trips over the field.

Sandy Soil-Munday[5]

Sorghum to Sorghum

Using one or two sprays of paraquat, glyphosate, 2,4-D, or a mixture of 2,4-D and glyphosate to control weeds from harvest until planting has been a successful weed control practice. A residual herbicide such as terbutryn, alachlor, or metolachlor has been sprayed in February or March with a contact herbicide to control weeds until planting. Safened seed must be used with alachlor or metolachlor. During seeding, stubble on the top of the bed was removed by a sweep ahead of the planter, and, consequently, another spray of residual herbicide was needed at planting. Beds were rebuilt and weeds controlled with two cultivations in the crop. One of the cultivations in the sorghum could be eliminated with a directed spray of paraquat, or trifluralin incorporated at layby. Application of atrazine shortly after harvest eliminated one of the contact sprays during the winter and the residual herbicide ahead of planting. In a 5-year study, sorghum yields were the same with no-tillage as with conventional tillage.

Cotton to Cotton

Trifluralin at 0.8 kg ha-1 was incorporated with a rolling cultivator into undisturbed beds in early spring. This kept the crop weedfree until another application of trifluralin at 0.4 kg ha^{-1} was incorporated at layby. This system kept cotton weedfree for the entire season without cultivation or hoeing. Yields were better than with conventional tillage.

Wheat to Wheat

Weeds in wheat were controlled with 2,4-D, MCPA, bromoxynil, dicamba, chlorsulfuron, or metsulfuron-methyl. After harvest, stubble was sprayed with 18 g ha^{-1} of chlorsulfuron mixed with either glyphosate or paraquat. Grass weeds that emerged after summer rains were controlled with paraquat, glyphosate, or sweep-plowing. Weeds in no-tillage were hardest to control after harvest when they germinated in poor stands of wheat.

Fine Textured Soil, Chillicothe

Sorghum to Sorghum

Several reduced tillage systems involving diking every other row, diking all rows, and a combination of diking and subsoiling to 0.3 to 0.4 m have been compared to conventional tillage with moldboard plowing, disking, and bedding. A preemergence herbicide was applied to all systems just after planting. Yields with diking and subsoiling were better than with conventional tillage. This was especially true on the upper part of 60-m plots that had slopes from 0.1 percent to 0.4 percent (Gerard et al., 1984).

Cotton to Cotton

A comparable system of reduced tillage in cotton gave similar results, but differences were not as great. Weeds were controlled in the crop with a preemergence herbicide (Gerard et al., 1984). Lint yields on the dryland cotton were increased more than 110 kg ha^{-1} by a combination of diking and subsoiling.

Cotton-Sorghum-Cotton

In early spring following cotton harvest, beds were rebuilt, furrow dikes replaced, and propazine at 1.3 kg ha^{-1} was sprayed in one operation. Sorghum was planted in late May. Weeds in the crop are controlled with additional propazine applied preemergence. After sorghum harvest, 1.1 kg ha^{-1} trifluralin was incorporated with a disk bedder in the winter. Fertilizer was applied just before planting, and dikes were installed at this time. Yields were markedly increased over conventional tillage, which was moldboard plowing one or more diskings, herbicide incorporation, fertilizer application listing beds, rolling cultivation, and planting.[6]

Sorghum-Fallow-Wheat-Fallow

Following sorghum harvest, beds were rebuilt and furrow dikes replaced. Chlorsulfuron was sprayed in the spring at 18 g ha^{-1}, and wheat was planted in the fall. Sweep-plowing was done before planting to flatten beds and control escape weeds. Grass weeds that emerged early in summer were controlled with paraquat or glyphosate. Weeds in wheat were controlled with 2,4-D, MCPA, metsulfuron-methyl, or dicamba. After wheat harvest in June, beds were established, furrow dikes replaced, and propazine was sprayed at 2.2 kg ha^{-1} to control weeds during the fallow period before planting sorghum.

Cotton-Fallow-Wheat-Fallow[6]

Following cotton harvest, beds were rebuilt and furrow dikes installed. Chlorsulfuron was sprayed at 18 g ha^{-1} in March, and wheat was planted in the fall. Sweep-plowing ahead of planting was used to kill escape weeds and flatten beds. Weeds in wheat were controlled with 2,4-D, MCPA, bromoxynil, or dicamba. After wheat harvest, beds were established, furrow dikes replaced, and diuron (N'-(3,4-dichlorophenyl)-N,N-

5Personal communication with D.G. Bordovsky, Texas A&M Station. Route 2, Box 2E, Munday, TX 76371.

6Personal communication with D G Bordovsk), Texas A&M Station, Routc 2 Box 2E. Munday TX 76371 dimethylurea) or prometryn at 1.8 kg ha^{-1} was sprayed to control weeds until the next spring. Then fertilizer was chiseled in and trifluralin at 0.8 kg ha^{-1} was incorporated with a disk bedder before planting cotton. After planting, furrow dikes were replaced.

Wheat to Wheat

Chlorsulfuron was applied at 18 g ha^{-1} to wheat in February or early March. After harvest in late May or early June, weeds and volunteer that emerged after summer rains were controlled with glyphosate, paraquat, or sweep-plowing.

Southern High Plains

Systems of weed control are being developed for several cropping systems used in sandy soils in the vicinity of Brownfield and for loam soil at the Texas A&M Center at Lubbock.[7]

Cotton to Cotton

Excellent control of annual weeds and cotton yields were obtained from a one-pass operation of spraying trifluralin or pendimethalin and incorporating the herbicides while in the process of disk bedding. Broadleaf weeds that emerged in the crop were controlled with a directed spray of diuron or prometryn. Grass weeds in the crop were controlled with sethoxydim or fluazifop.

Sorghum to Cotton

In the spring after sorghum harvest, weeds present in the stubble were controlled with glyphosate or paraquat. After cotton planting, a preemergence spray of dipropetryn at 4.5 kg ha^{-1} controlled both pigweed and volunteer sorghum for the entire season. Fluazifop or sethoxidim controlled johnsongrass or volunteer sorghum that emerged in the cotton.

Wheat to Cotton (Double Crop)

Wheat or another small grain sown in cotton stubble to reduce erosion was killed in the spring with paraquat or glyphosate. A mixture of 2,4-D and glyphosate was used safely if applied several weeks before planting. Dipropetryn sprayed shortly thereafter prevented weed emergence before planting and in the cotton crop. If soil was sandy loam or finer texture, prometryn was used instead of dipropetryn.

Wheat-(Fallow)-Cotton

Wheat was maintained weed free with 2,4-D, MCPA, or metsulfuron-methyl. After wheat harvest, existing weeds were controlled with glyphosate or paraquat mixed with either diuron, prometryn, terbutryn, or dipropetryn. Weeds that emerged later in the summer were controlled with sprays of glyphosate or paraquat. Either dipropetryn or prometryn was applied the next spring before cotton planting. Broadleaved weeds in the cotton were controlled with directed sprays of diuron or prometryn. Annual or perennial grass weeds in the cotton were controlled with fluazifop or sethoxydim (Abernathy et al., 1985).

Wheat to Sorghum

Weeds were controlled from wheat harvest to sorghum planting on a Pullman clay loam soil with either terbutryn or atrazine mixed with 2,4-D (Baumhardt et al., 1985). Weeds in the sorghum crop were controlled with an additional preemergence spraying of terbutryn. Yields of sorghum were increased over disk tillage if mulch level on the plots was 10 tonne ha^{-1}. Sorghum yield was not increased if crop mulch on the soil surface was 1 tonne ha^{-1} or less.

Northern High Plains

Over the last 25 years, tillage methods, weed control techniques, and planting equipment for different irrigated and dryland cropping sequences have been studied at the USDA Conservation and Production Research Laboratory, Bushland, Texas (Wiese et al., 1960; Wiese et al., 1967; Jones et al., 1985). As a result, many successful minimum-tillage and no-tillage methods have been developed. The soil at the research laboratory is Pullman clay loam that contains about one-third each of sand, silt, and clay, and has a pH of 7.0 and 1.5 percent organic matter. Rainfall averages 18 inches annually. Results of many studies have been summarized into a practical guide for extension people and growers (Wiese et al., 1986).

Sorghum to Sorghum

No-tillage proved to be impractical because it was difficult and expensive to control volunteer sorghum plants. Research has shown it is best to chisel anhydrous ammonia into furrows and then rebuild beds in the spring by bed splitting or with either a disk bedder or sweep rod weeder. Weeds in sorghum were controlled with atrazine or propazine, if subsequent herbicide residue in the soil was not a problem, or with terbutryn if a short residual herbicide was needed to grow the next crop. Metolachlor and alachlor are short residual herbicides; however, sorghum seed must be treated with a safener (Allen et al., 1980; Allen, 1985).

Sorghum to Small Grain (Double Crop)

Short residual herbicides, such as terbutryn, alachlor, and metolachlor, had to be used in sorghum when wheat was planted after sorghum the same year. Wheat was planted in standing stalks or after shredding, and then watered for emergence. If nitrogen carryover was not sufficient, anhydrous ammonia was chiseled in the furrows after sorghum harvest. Dry or liquid fertilizer was top-dressed before the wheat jointed in early spring.

Corn to Small Grain (Double Crop)

A short residual herbicide or no herbicide had to be used in the corn so the double-cropped small grain was not injured. Alachlor or metolachlor were used on any soil, and cyanazine could be used on fine sandy loam or finer-textured soil. Weeds in the corn that escaped the preemergence herbicide were cultivated or controlled with directed sprays of linuron or ametryn. A postemergence spray of dicamba controlled small broadleaf

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weeds less than 25 mm tall. After corn harvest, wheat was planted in standing or shredded stalks and "watered up." If southwestern corn borer was a problem, undercutting corn stalks before wheat planting reduced overwintering borers. Fertilizer, if needed, was applied as suggested in the section for sorghum to small grain (Musick et al., 1977).

Corn to Corn

Winter annual weeds and volunteer corn plants were controlled in the spring with 2,4-D, glyphosate, a mixture of 2,4-D and glyphosate, or paraquat. Shredding stalks, chiseling in the row, or shallow sweep-plowing before March to uproot stalks helped control corn borer. Shallow rotary tillage to expose root crowns also controls corn borer. Atrazine was applied at planting for weed control, and small sweeps placed ahead of planters killed volunteer in the row. Cultivation after emergence was effective for controlling volunteer between the rows. Fertilizer was applied dry or by chiseling anhydrous ammonia into furrows during the winter in furrow-irrigated fields, or liquid fertilizer was applied through a center pivot during sprinkler irrigation of the crop. It may be necessary to rebuild beds; however, "furrowing out" to carry furrow irrigation water was usually sufficient.

Wheat to Sorghum (Double Crop)

Sorghum was planted directly into heavy wheat stubble with unit planters and coulters, or a grain drill could be used if the wheat stubble residue was not over 2.8 tonne ha^{-1}. Because the soil was usually very dry at this time, sorghum has to be irrigated for emergence. Weeds and volunteer wheat were controlled with 2.2 kg ha^{-1} of atrazine sprayed post-emergence in an oil-water emulsion carrier. Anhydrous ammonia was knifed into furrows after the crop emerged. Wheat could not be double-cropped back immediately after the sorghum crop was harvested because of atrazine residue in the soil. Wheat could be planted the next season. (Allen et al., 1975).

Wheat-(Fallow)-Sorghum

Dry atrazine formulations were applied at 3.3 kg ha^{-1} to wheat stubble immediately after wheat harvest before weeds emerged. Weeds in wheat must be controlled with 2,4-D, MCPA, dicamba, or metsulfuron-methyl. Broadleaf weeds in wheat stubble were controlled with either 2,4-D or dicamba mixed with the atrazine. If both broadleaf and annual grass weeds were present in the stubble, they had to be controlled by mixing paraquat with atrazine, using a separate spray with glyphosate, or a 2,4-D-glyphosate mixture. If annual grasses emerged after treatment, a sweep-plowing or spraying with paraquat or glyphosate was necessary. Terbutryn or propazine applied in March or April assured a weed-free sorghum crop. Sorghum grain yields were increased about 1,100 kg ha^{-1} (Unger et al., 1977; Wiese and Unger, 1983; Unger and Wiese, 1979).

Wheat-(Fallow)-Corn

After wheat harvest, atrazine mixed with 2,4-D at 3.3 and 1.1 kg ha^{-1} was sprayed on the stubble to control existing weeds, volunteer wheat, and any weeds that may germinate during the 11-month fallow period. Annual grass weeds that may emerge after treatment with atrazine have to be controlled with sweep-plowing or a spray with either paraquat or glyphosate. In the spring before planting corn, another herbicide with residual in the soil must be sprayed to control weeds until planting and in the crop (Unger, 1986).

Sorghum-(Fallow)-Wheat

In early April, following sorghum harvest the previous fall, chlorsulfuron, metsulfuron-methyl, terbutryn, or cyanazine were applied to reduce the number of tillage operations in the summer before planting wheat in the fall. Existing weeds were controlled with 2,4-D, glyphosate or paraquat. A practical limited-tillage system during the spring following sorghum harvest was disk bedding followed by deep injection of anhydrous ammonia with chisels or sweeps in the middles so beds were not destroyed. Weeds were controlled for the remainder of the fallow period with a heavy duty sweep-rod weeder or rolling cultivator (Wiese and Lavake, 1984).

Wheat to Wheat

Applying chlorsulfuron at 24 g ha' in March to growing wheat controlled broadleaf weeds late into the summer. Weeds and volunteer that emerge in midsummer were controlled with glyphosate, a mixture of 2,4-D and glyphosate, paraquat, or sweep-plowing. Another possibility was using cyanazine and terbutryn after wheat harvest along with paraquat or glyphosate to kill existing weeds. Volunteer wheat had to be controlled or wheat-streak mosaic infected the new crop. If stubble was not loosened by sweeps or other tillage operations, a regular drill passed through standing stubble without trouble. Fertilizer was chiseled into the furrows before rebuilding beds (Allen et al., 1976). Using this system of no-tillage, wheat yields were increased about 300 kg ha^{-1}.

Wheat-(Fallow)-Wheat

Applying 24 g ha^{-1} of chlorsulfuron or metsulfuron-methyl to growing wheat in March controlled weeds in the crop and in the stubble up to when volunteer wheat emerged after harvest. Volunteer wheat and other weeds that emerged during the summer and fall were controlled with paraquat or glyphosate. Applying chlorsulfuron to fallow soil the next April reduced the number of weeds emerging the summer before wheat planting. Those that emerged had to be controlled with contact herbicides or shallow sweep-plowing.

Cotton to Sorghum

In the spring before planting sorghum, a minimum of tillage and fuel was used if old cotton beds were not destroyed but rebuilt with a disk bedder or sweep-rod weeder. A preplant application of propazine at 1.7 kg ha' was incorporated with a rolling cultivator. Additional terbutryn was applied at planting for weed control in the sorghum. If safened seed was used, alachlor, metolachlor, or a propazine-metolachlor mixture could be used also. If beds did not need rebuilding, winter annual mustard, kochia, and Russian thistle emerging in March were controlled in early April with 2,4-D. Glyphosate or paraquat controlled weeds before planting sorghum, and terbutryn applied preemergence controlled weeds in the crop. Using single-row cotton and double-row sorghum reduced planting problems (Valliant, 1973).

Sorghum to Cotton

In the spring before planting cotton, 2,4-D mixed with prometryn was applied in late March or early April to kill mustard (Descurainia spp.), kochia *[Kochia scoparia* (L.) Schrad.], and Russian thistle *(Salsola iberica* Sennan & Pau). This kept beds weed-free until planting. If weeds were a problem before planting, they were killed with paraquat or glyphosate.

The cotton was treated with a preemergence application of either prometryn, alachlor, or metolachlor. Weeds would be controlled also when old beds were rebuilt with a disk bedder or sweep-rod weeder before planting cotton. Sorghum stalks may need to be shredded or chopped before rebuilding beds. Trifluralin or pendimethalin was incorporated with a rolling cultivator as beds were being rebuilt. Broadleaf weeds in the crops were controlled with directed sprays of duiron or prometryn. Grass weeds could be controlled with sethoxydim or fluazifop. Using double-row sorghum and single-row cotton facilitates planting (Valliant, 1972; Wiese et al., 1967).

Cotton to Cotton

A minimum of tillage and energy was used when old beds were not destroyed, and trifluralin or pendimethaliin was preplant incorporated with a rolling cultivator in March before winter weeds became established. This controlled weeds before planting and throughout the season. A no-tillage system was developed for flat land or where beds were not rebuilt. Winter annual mustard, kochia, or Russian thistle that emerge in March were economically controlled with 2,4-D in late March or early April. Paraquat or glyphosate were used to kill existing weeds before planting. Theni prometryn, alachlor, or metolachlor were used preemergence in the crop. Broadleaf weeds in the crop were controlled with directed sprays of diuron or prometryn.

Wheat (Fallow) Cotton

Weeds in wheat stubble were controlled with glyphosate, paraquat, a mixture of 2,4-D and glyphosate, or dicamba. Residual weed control was achieved with fluometuron at 2.2 kg ha^{-1}, or atrazine or propazine each at 1.4 kg ha^{-1}. The next April, existing winter annual broadleaf weeds such as mustards, kochia, and Russian thistle were controlled with a mixture of 2,4-D and prometryn. The rate of prometryn was about 0.5 kg ha' above that recommended for the soil type to have enough herbicide to keep cotton weed-free (Wiese and Harman, 1982, 1983, 1985).

Cotton (Fallow) Wheat

In mid-April following cotton harvest, chlorsulfuron at 24 g ha^{-1} mixed with 2,4-D controlled winter annual broadleaf weeds. If winter annual grasses were growing, paraquat, a mixture of 2,4-D and glyphosate, or glyphosate was mixed with the chlorsulfuron. Grassy weeds that emerged during late summer were controlled with paraquat or glyphosate. These weeds would also be controlled during bed rebuilding operations required for furrow irrigation of wheat. Herbicides that were used in the wheat crop must not injure the following crop of cotton (Wiese and Harman, 1985).

NOTE!

In all cases, herbicides and rates of application must be in accordance with labels and soil types. Cropping sequence restrictions for herbicides must be observed.

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Abstracts of Concurrent Presentations

Factors Influencing Successful Sod Seeding of Winter Annuals Into Perennial Grass Sods in Texas

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Overseeding cool season annual forage species into perennial grass sods can provide high-quality forage during fall, winter, and spring months. Overseeding cool season annual legumes can provide nitrogen for use by sod the following season.

Tests have been conducted on seeding rate, date of seeding, row width, fertilization, and other cultural practices. Timely incorporation of practices that affect optimum growth are discussed.

Conservation Tillage Systems for Maximizing Profitability On The Texas Souther High Plains

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Conservation tillage systems offer potential for reducing production costs, increasing yields, reducing risks, and providing a means for satisfying conservation compliances provisions for the highly erodible soils of the Texas Southern High Plains. Cropping systems plots were established in 1985 at Lubbock and Halfway and in Terry County in 1986 to evaluate various conservation tillage/crop rotation systems under irrigated and dryland conditions. New weed control programs are being developed using preemergence and post-emergence applications to replace traditional preplant herbicide applications and tillage operations.

Systems being evaluated include continuous cotton and sorghum, cotton-sorghum, cotton-sudangrass, cotton-wheat, and sorghum-wheat conservation tillage systems, which are compared to conventional cotton and sorghum production. In 1986, yields were increased 13 percent and net returns increased 30 percent with conservation tillage systems for cotton at Lubbock. At Halfway, cotton yields were increased 12 percent and returns 43 percent when compared to conventional cotton production. Sorghum yields were increased 25 percent and net returns increased 100 percent at Lubbock, while yields were increased 34 percent and net returns by 80 percent at Halfway when compared to conventional sorghum production.

Relay Planted Soybeans: An Alternative Doublecropping System

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A soybean-wheat doublecropping study was conducted in 1984-86 to evaluate tractor wheel track width and soybean relay planting date effect on wheat and soybean yield. Soybeans were planted in 16- and 32-inch wide rows with two 24-, 28-, and 32-inch wide spaces per 20-foot planter width for tractor wheel tracks. Soybeans were planted as a monocrop in mid-May, between 16-inch wide wheat rows in a relay planting system in mid- and late May, and in wheat stubble in mid-June and early July. Wheat yield from soybeans relay-planted into wheat with 28- and 32-inch wide wheel tracks was 10 percent greater than the 24-inch wide wheel track in 1985 but not in 1986. But these yields were equal to 24-, 28-, and 32-inch wheel track wheat treatments harvested before soybean planting in 1985 and 1986. The three-year average wheat yield for the relay double-cropping system was 88 percent of the monocrop wheat in 7-inch rows. Relay-planted soybean two-year (1984-85) average yields were not different from monocrop soybeans. But yields were 11 percent and 214 percent greater than soybeans planted in wheat stubble about June 19 and July 2, respectively.

Grain Sorphum, a No-Till Crop in Mississippi

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A 3-year (1983-85) study was conducted on Catalpa silty clay and Ora fine sandy loam soils to evalute grain sorghum response to tillage systems (conventional and no-till) and nitrogen rates (0,40, 80, and 120). Conventional tillage consisted of chisel plowing 6-8 inches deep followed by disking in the spring and then harrowing before planting. Nitrogen was broadcast on the soil surface within 25 days after sorghum emergence. Three-year average grain sorghum yield on both soils indicated no difference due to tillage system. However, average yield was 23 percent greater on the fine sandy loam than on the silty clay. Nitrogen rates and tillage had no effect on sorghum plant population and grain test weight on either soil. Grain sorghum on the fine sandy loam soil showed little response to nitrogen rates. However, grain sorghum showed a yield response up to 80 lb N/a on the silty clay. Results on these two soil types indicate no-till grain sorghum can be grown successfully in Mississippi.

Tillage Effects on Fertilizer Rate and Placement Requirements of Dryland Grain Sorghum

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Reduced-tillage and no-till systems of crop production have encouraged either shallow banding or broadcast applications of fertilizer nutrients. Nutrient-use efficiency may be significantly affected by these alternate fertilization techniques. Studies evaluating fertilization methods included starter and pop-up fertilizers, broadcast and knife placements as well as sidedress applications. Fertilization rates included soil test recommendation and 1.5X recommended rates. Reduced, conventional, and chiselbedder systems of tillage were compared as major plots (main effects) while fertilization techniques were studied in split plot design within each tillage system. Grain yields averaged across all fertility rates in the first season of the three-year study showed the chiselbedder system produced significantly more than the reduced-tillage system. This was primarily because of low yields from the broadcast fertilizer treatment with reduced tillage. Reduction in the yields because of broadcasting was less severe in the second and third years when plant stress for moisture was not a problem. In 1984-85, tillage treatment effects were non-significant. However, grain maturity measured by a moisture test at harvest showed that reduced tillage delayed maturity in 1984. Although grain yields were substantially higher in 1985 because of optimum soil moisture conditions, tillage effects were non-significant. Substantial response to low rates of fertilizer were measured in all seasons. Splitting band applications of fertilizer into 2/3 preplant and 1/3 as either starter or sidedress had only slight effects on grain yields and maturity. Yield data indicate that tillage methods used in seedbed preparation will have minimal impact on grain sorghum response to fertilizer nutrients when materials are knifed in a preplant application.

Effect of Different Tillage Practices on Surface Residue and Soil Physical Properties

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An experiment was conducted to determine the effects of continuous cropping of corn, sorghum, and cotton under three different tillage systems (conventional, minimum, and no-till). The study was conducted in the Coastal Bend region of South Texas on an Orelia sandy clay loam. A split plot design with four replications, tillage systems in the whole plots, and crops in the split plots was used. Plots were generally planted in early to mid-March and harvested in early August. After harvest, conventional and minimum tillage plots were generally shredded and disked. The conventional tillage plots were bedded and rebedded with middlebusters. Middles and beds were rerun three to four times during the fallow period to control weeds. Weeds were controlled on the minimum tillage and no-till plots using periodic herbicide applications. The conventional and minimum tillage plots have been sustained for 10 years, while the no-till plots have been in place for eight years. Surface penetrometer readings indicate that decreased tillage has resulted in higher bulk densities. Little difference in surface residue can be observed between the conventional and minimum tillage treatments. However, the use of no-till has resulted in large increases in surface residue compared to the conventional tillage plots. Data will be presented describing the effect of treatments on aggregate size distribution, aggregate stability, and water infiltration.

Cover Crops in Conservation Tillage: Benefits and Liabilities

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Several of the benefits of conservation tillage are derived from the presence of a vegetative mulch cover on the soil surface. One of the most effective ways to ensure a mulch cover is to use a winter cover crop that can be chemically killed in the spring at or before grain planting. Along with the benefits derived from the mulch, such aserosion control, soil water conservation, and nitrogen fixation (if a legume), there are definite liabilities associated with a cover crop and its subsequent mulch. Perhaps the most important, potentially yield-limiting effect that we have identified in our studies is depletion of stored soil water.

Cover crops depleted soil water to at least 24 inches depth before corn planting. However, a water conservation effect of killed cover crops was obvious with no-tillage two weeks after planting corn. Greater soil water content was present at planting where the cover crop was chemically killed three weeks before planting corn than where it was allowed to grow until the corn was planted. The additional water used by the late-killed cover crop appeared to be more important than the additional tonnage of mulch produced in the case of a non-legume cover crop.

A hairy vetch cover crop gave the offsetting advantage of providing biologically fixed nitrogen to the corn. This was estimated by yield comparisons to be equivalent to about 80 to 90 Ibs/acre of fertilizer nitrogen. Over a five-year period, average corn yields increased at a rate of about 8 bushels/acre/year with the hairy vetch cover crop treatment when compared to corn residue alone. At least part of the increase in potential yield appeared to result from some unidentified factor or factors that were additional to increased nitrogen.

Effect of Tillage, Water Quality, and Gypsum on Infiltration and Water Storage

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Improved water conservation practices are needed in the Texas High Plains because of the variable rainfall and declining water table. The first step in conserving water applied to the soil is to increase infiltration. In this study, the effect of tillage, water quality, and gypsum on the infiltration of simulated rainfall, water storage, and soil density were evaluated on Paleustoll soils. In a lab experiment, gypsum was mixed with soil at 0 or 3 Mg/m3, packed into columns (0.5 m long x 0.3 m wide x 0.15 m deep) to a density of 1.0 Mg/m3, placed on a turntable, and exposed to simulated rainfall (intensity = 5 0 mmlhr) using water with SARs of 0.0, 0.487, or 4.217. Gypsum did not change the amount of infiltration; however, water treatments with SARs of 0.0 or 4.217 had lower infiltration. In field experiments, rainfall was simulated (intensity = 65 mm/hr) over a 1.2 m2 area on both crusted or uncrusted soil that had been disk- or chisel-disk tilled with or without furrow dikes, and on soil that had been cropped to continuous cotton or sorghum under conventional or reduced tillage, wheat, or fallow. Infiltration was reduced by the surface crust and the absence of furrow dikes. Tillage treatments, including less costly reduced tillage systems, did not affect infiltration, water storage, or soil density. Less soil water was stored where wheat was growing in the spring. The data indicate that cumulative infiltration can be limited by water quality and the soil surface conditions regardless of the amount of tillage.

Rating Long-Term Soil Productivity

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There is documented evidence that long-term cropland soil productivity declines under certain management systems. A combination of factors, including excessive wind and water erosion, loss of soil organic matter, and deterioration of soil structure, can affect this decline. Tools are available to predict erosion (Universal Soil Loss Equation and Wind Erosion Equation). A tool is needed to rate the effect of other components of a cropland management system. Using these tools, one can predict the trend and comparative rate of improvement or degradation in long-term soil productivity. Soil condition rating indices offer a useful and usable approach to rating long-term productivity under alternative cropland management systems.

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Influence of Cover Crops On Fertilizer-N Requirements of No-Till Corn and Grain Sorghum

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The objective of this study was to determine the influence of cover crops such as winter legumes or small grains on the fertilizer-N requirement of subsequent crops of corn (*Zea mays* L.) or grain sorghum (*Sorghum bicolor* L. Moench). Five cover crop treatments (three legumes, wheat, and no cover crop) were studied on two soil types (Rome loam and Greenville sandy clay loam) in Georgia. Five fertilizer-N rates (0, 28, 56, 112, and 224 kg ha' for corn and 0, 22, 45, 90, and 180 kg ha' for grain sorghum) were superimposed on each cover crop treatment. Corn or grain sorghum were no-till planted following desiccation of the cover crops in 1985 and 1986. Results show that optimum fertilizer-N rates for corn were 67, 89, 92, 184, and 188 kg ha^{-1} following hairy vetch (*Vicia villosa* L. Roth), crimson clover (*Trifolium* incarnatum L.), winter pea (*Pisum sativum),* fallow, and wheat (*Triticum aestivum* L.), respectively. For grain sorghum, optimum fertilizer-N rates were 0, 0, 48, 72, and 109 kg ha^{-1} following hairy vetch, crimson clover, berseem clover (*Trifolium alexandrinum* L.), fallow, and wheat, respectively. Mean grain yields at the optimum N rates for each cover crop treatment were 10.25 and 5.37 Mg ha^{-1} for corn and grain sorghum, respectively. We conclude that a well-adapted legume can replace as much as 120 kg of fertilizer-N ha^{-1}, while corn or sorghum following a non-leguminous cover crop may require 20 to 40 kg ha^{-1} more N than no cover crop.

Conservation Tillage: Corn, Grain Sorghum, and Wheat in Dallas County, Texas

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Conservation tillage is a practice that will cut production expenses and control erosion. Conservation tillage corn is being grown, but systems using wheat and grain sorghum need to be developed for North Texas Blackland Prairies.

A study was initiated comparing conservation tillage to conventional tillage with corn, wheat, and grain sorghum. The comparison evaluated stand establishment, grain yield, and production costs. A no-till drill was used to plant the crops in about 8,000 pounds of residue.

Conservation tillage corn yielded 10 percent to 15 percent higher than conventional tillage with $15 to $20 per acre less production cost. Wheat yields have not been obtained to date, but plant stand and growth was good. Conservation tillage wheat production costs are 30 percent less than conventional tillage wheat. Conservation tillage grain sorghum production costs are significantly reduced compared to conventional tillage. Conservation tillage farming appears to work well in the North Texas Blackland Prairies.

Growth of Conservation Tillage in Blacklands

Bob Kral

Despite problems encountered with tough, sticky soils, farmers in the Blackland Prairie region of Texas are gradually using conservation tillage on more acres each year. Reduced expenses of production is the chief incentive for changing from conventional tillage to conservation tillage, with reduced time input and reduced soil loss also being factors. All major crops of the region (grain sorghum, cotton, wheat, and corn) are being successfully produced with conservation tillage. Specifically, mulch tillage or reduced tillage are the conservation tillage methods used most with no-till being used on a relatively minor acreage.

In past years, resistance to change from traditional tillage methods may have prevented many farmers from using conservation tillage. Today, however, farmers are more likely to hesitate changing to conservation tillage because of the expense of purchasing a different kind of planter. Other factors limiting greater use of conservation tillage include concerns about adequate weed control or how to place fertilizer into crop root zones without destroying surface residues. While no rapid or dramatic shift to conservation tillage is anticipated, the steady increase experienced in the past 10-15 years is expected to continue.

Measuring Yield Difference and Stand Establishment As It Relates to Percent Ground Cover

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The Blacklands of Texas are capable of producing large amounts of crop residue ranging from 30 percent to 100 percent ground cover at planting. Farmers have reported difficulty with planting ability and stand establishment in heavy residues. A system was designed to measure stand establishment and yield differences as it relates to percent ground cover. Three residue management treatments using three soil insecticides were evaluated on seven 1-acre plots.

Treatments were evaluated for required break-even yields. Conclusions were that total yields exceeded all break-even yields on conservation tillage plots. The amount of residue had little effect on stand establishment. This study shows the greater the amount of residue, the greater the yields, primarily because of available moisture at grain filling.

GRAMOXON® SUPER Herbicide in a Conservation Tillage System

Milton A. Sprague and Glover B. Triplett[1]

With the discovery of paraquat in the late 50's, the implementation of a successful conservation tillage system was greatly increased. With the ability to kill existing vegetation and plant directly into it, soil conservation was realized.

According to Sprague and Triplett (1986), “Stand Establishment is regarded as the single most important stage of growth in the life cycle of a crop.”' The use of paraquat, now known as GRAMOXONE SUPER, as a preplant or preemergence contact herbicide allows the seed to be planted directly into a cover crop. The cover crop is then noncompetitive, the soil basically undisturbed, and moisture is retained. This is in an excellent environment for stand establishment.

GRAMOXONE SUPER can be fit into virtually every type of conservation tillage program. This versatiligy allows GRAMOXONE SUPER to be used alone as a burndown herbicide or in tank mixes with residual herbicides to give both contact and residual control of competitive weeds.

Recent data indicate that often better weed control of tough annuals and some perennial weeds is achieved through the addition of certain residual herbicides. The residual herbicides, such as the triazines and metalachlor, in addition to their residual control, act as photosynthetic inhibitors. Since GRAMOXONE SUPER requires active photosynthesis to be activated, these inhibitors slow the activity of the GRAMOXONE SUPER without shutting it down completely since they do not cause a 100% plant shutdown. This reduction in photosynthesis allows a localized translocation of the paraquation to increase the active area. The tank mix of the two products, therefore, gives a synergized effect: 1 + 1 = 3 .

Along with the versatility of GRAMOXONE SUPER for various cropping programs, new burndown and residual products from ICI that fit into conservation tillage programs include the following:

SUREFIRE™ herbicide for corn, cotton, wheat and orchard crops.
COLONEL® herbicide for corn and grain sorghum.
PRELUDE® herbicide for sorghum and soybean.
GFU 477B, an experimental for corn, trees and vines and alfalfa.

So whether it is conservation tillage, no-till, or CRP or other government programs, products from ICI fill the need for total weed control.

'No-Tillage and Surface Tillage Agriculture: The Tillage Revolution, John Wile). & Sons, Publisher. New York, New York.

Insecticidal Performance of Terbufos In Continuous and Noncontinuous use Cornfields

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In 1985, a study of 28 cornfields in Illinois, Iowa, Nebraska, and Wisconsin was conducted to examine the performance of COUNTER systemic insecticide-nematicide (turbufos), Twenty-one of these fields had a history of terbufos use; seven fields with non-terbufos use served as controls. This study was repeated in 1986. Fourteen of the original 21 history fields were included again in the second year. Again, seven fields with non-terbufos use served as controls. The performance and rate of degradation of the insecticide was examined throughout the season.

Residue analyses and rootworm bioassays were performed on soils collected prior to treatment and at 0, 30, 60, and 90 days after treatment. Root ratings (1-6 scale) were made in the field to measure performance. Root protection provided by terbufos in terbufos history fields was similar to those in the control fields. The degradation rate of terbufos in history fields was similar to the control fields. Bioassays revealed high corn rootworm mortality through the 90-day sampling period. In summary, banded and in-furrow application data indicate no evidence of enhanced microbial degradation of terbufos.

No-Till Corn and Sorghum Production in Texas Blacklands

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In recent years many crop producers across the country have considered the reduction of tillage as a means of reducing production costs. The Texas Blacklands is an extensively cropped area of the state. The following question has been frequently asked by producers: “Will No-Ti11 work with corn and sorghum in the Blacklands?”.

A replicated tillage study was begun in the Fall of 1983. This study included crop rotation sequence of corn-sorghum-wheat on 51 foot wide strips (16-38”rows). The tillage treatments used were (1) No-till and (2) conventional tillage.

The results show that over the first 3 years of the study crop stand establishment has been the major factor affecting the relative advantage of the tillage treatments. Another factor of interest of this crop rotation was the killing of sorghum plants after harvest. Essentially the same herbicides were used to control weeds on both tillage treatments for the respective crops.

Soil compaction in no-till plots is an important factor in crop stand establishment and may impact crop performance and yield. Therefore, an evaluation of this problem needs to be made.

An interesting observation has been that in 1985 and 1987 the greenbug population on the sorghum in the conventionally-tilled plots were sufficient to merit insecticide applications for control, while the greenbug presence was near zero in the no-till plots.

PROWL: A Perfect Fit for Conservation Tillage

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The chemical properties of PROWL Herbicide fit into the conservation tillage practices for cotton on the High Plains of Texas. PROWL Herbicide provides excellent weed control utilizing two pass incorporation techniques with field cultivators and rolling cultivators.

PROWL Herbicide applied pre-emergence to cotton through a center pivot provided excellent control of Pigweed and Watergrass in 1986. The pre-plant application of PROWL through the center pivot irrigation system provided good to excellent control of Pigweed and Crabgrass in cotton in 1987.

Agitation of the PROWL solution in the nurse tank is required. The addition of an emulsifier to the PROWL solution is recommended when applying PROWL through the center pivot.

Ratoon Grain Sorghum: An Alternative Cropping System for Conservation Tillage

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SORKAM, a dynamic grain sorghum growth and development model, was used to evaluate the potential of dryland ratoon grain sorghum production in Texas. Eleven independent data sets from Georgia and Texas were used to determine the model’s accuracy. Simulated grain yield estimates were within 25 percent of the observed yield (RMSE = 877 kg/ha) for the cultivars that consistently produced the highest yields at each location. This level of accuracy is similar to that experienced by simulations of grain yield for the first or “plant” growth phase of sorghum with SORKAM. Results of multiple-year (10-30) simulation of ratoon grain yields from 14 locations in Texas using location-specific meteorological data indicated that ratoon sorghum (grain yields of more than 1,500 kg/ha) could be profitable more than 50 percent of the time in East Central and East Texas (College Station, Temple, Dallas, Beeville, Angleton, Columbus, Center, Corpus Christi, and Beaumont). The probability of obtaining profitable ratoon yields increases to more than 80 percent for areas on the coastal plain. Although soil water was the primary factor limiting ratoon grain yield, rainfall during the late fall, winter, and spring months usually replenished the soil profile to that normally obtained without ratoon cropping. Simulated estimates of grain moisture at the harvest of the ratoon crop indicate that supplemental drying facilities would be required to augment natural grain drying, thus increasing related expenses. The area best suited for ratoon cropping sorghum is south and east of a line running from west of Corpus Christi to Beeville to College Station to west of Center. About 1 million to 1.2 million hectares of land currently under cultivation would fall into this zone. If ratoon grain sorghum were grown on 20 percent of this total area and produced grain yields of 3,000 kg/ha (at $4/cwt), about $32 million could be added to the agricultural economy of the state.

Interaction of Tillage on Corn Yield and Quality of the Runoff Water

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An inherent part of conservation tillage (CT) is the presence of residue and the reduction or complete lack of tillage. Fundamental soil physical properties such as bulk density, temperature, and moisture are influenced along with important chemical and biological properties. Thus, the first step in making CT work is selecting the specific system to fit individual soil type. Corn yields from long-term tillage studies on benchmark soils of Wisconsin are summarized. Generally, no-till works well on soils that are droughty, such as sands, with the yield advantage being attributed to increased moisture. On heavy textured, poorly drained soils, the increased moisture coupled with the reduction in temperature common under no-till results in decreased yields. However, systems such as the chisel plow evidence no yield reduction under these conditions when compared to the conventional system. Because the environment under CT differs from that of the conventional system, traditional fertilizer management techniques also differ. The importance of corrective and maintenance P and K will be emphasized with particular attention being paid to starter fertilizer response. Water quality implications of CT are presented. Simulated rainfall studies indicated that CT systems reduce erosion by 80 percent to 90 percent when compared to conventional. The quality of the runoff water under CT is generally higher, especially with respect to dissolved P loadings. While all CT systems resulted in increased pesticide concentration in the runoff water, total loads were comparable to conventional because of decreased runoff from CT.

No-till Winter Wheat Production in the Texas Blackland Prairie

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The Blackland Prairie of Central Texas is an extensive area of productive soils with a diverse cropping mixture including wheat, sorghum, corn, cotton, and oats. Much of this production region is characterized by rolling land, which under clean tillage is subject to considerable erosion during heavy rains.

No-till wheat offers an attractive alternative to wheat planted in conventionally prepared seedbeds in the Blacklands of Texas due to reduced soil erosion, increased soil water storage, and reduced labor and land preparation costs. Higher herbicide costs in no-till, particularly as wheat follows sorghum, offset savings associated with reduced land preparation costs. No-till wheat exhibited more symptoms of nitrogen deficiency than wheat in tilled plots, but yields were not correspondingly reduced. In the 1984-85 crop year, no-till wheat averaged three to five days earlier in maturity and exhibited considerably less lodging than wheat in tilled plots. A cultivar with a stronger straw was used in 1985-86, and no difference in maturity or lodging was observed. No difference in yield was measured over the three-year study between no-till and wheat planted in a prepared seedbed. Attempts at double-cropping sorghum after wheat failed because of inadequate rain.