RESIDUE MANAGEMENT, CROPPING SYSTMS, AND AN OVERVIEW OF NO-TILL AND CONSERVATION TILLAGE RESEARCH IN THE COASTAL PLAINS[1/]

R. B. Campbell, R. E. Sojka, and D. L. Karlen[2/]

Introduction

In 1981, 71,000 acres of field crops were planted under conservation tillage in Coastal Plain counties of South Carolina. Of this acreage, approximately 60% was planted to soybean and 36% to corn. The primary increase in conservation tillage acreage is the soybean-small grain double-crop which has followed a substantial increase in wheat acreage.

In the following discussion, we define conservation tillage to include all crop production systems that minimize tillage intensity, thereby retaining all or nearly all existing residue on the soil surface. No-till refers specifically to tillage systems that leave essentially all residues untouched and usually standing and in which a micro-seed bed is created only in close proximity to and beneath the planted seed, disturbing only a small percentage of the surface area. In this paper we discuss a variety of residue management approaches which encompass the entire spectrum of conventional, conservation tillage, and no-till systems.

Expansion of no-till or conservation tillage farming has' been slow to develop in the southeastern Coastal Plains, but this trend is not due to a lack of interest or capability in the farming community. The problem has been an inability to provide sufficient scientific manpower, answers to problems, and advice to the farming community to insure the expansion and success of conservation tillage.

Agricultural research related to conservation tillage tools and technology will continue to expand as we recognize the needs and problems that must be solved to insure successful conservation tillage farming. Some of the specialized tools developed for the management of crop residues include: in-row subsoil tools equipped with a cutting roulter ahead of the subsoiler, heavy duty planters for planting in dense surface residues, and no-till grain drills for solid seeding of various crops in previous crop residues.

1/ Contribution of the Coastal Plains Soil and Water Conservation Research Center, USDA-ARS, Florence, S.C. Presented at the 5th Annual Southeastern No-Till Systems Conference, July 15, 1982, Florence, S.C.

2/ Soil Scientist, Research Agronomist, and Soil Scientist, respectively.

Weed control is an extremely important aspect of no-till or conservation tillage farming, but a wide variety of spraying equipment has been developed ranging from common broadcast sprayers to precision shielded and directed sprayers. Every year new effective herbicides or combinations of herbicides and application techniques are being added to our compliment of weed control tools. Unfortunately, weed control will never be a routine operation since populations of easily-controlled weed species will be succeeded by populations of species that are more difficult to control. These competing weed populations, that spraying systems are least effective in controlling, are a significant threat to successful no-till or conservation tillage farming. The type and population of weeds will at times influence our choice of crop rotation or cropping system.

The challenge in no-tilling is not merely determining whether or not no-till farming is better or worse than conventional farming. The real question is "How well do we no-till"? Do we have control and are we able to manage the critical factors that control or modify yield? This paper will address soil strength and factors that control rooting and water availability in no-tillage system. The influence of standing residues, cool-season crop residues, and a few alternative double crop sequences will be discussed. Yield data for corn and soybean following a winter rye cover crop will be presented to compare no-till and conventional tillage system as influenced by standing residues and cool-season crop residues.

I. Soil Properties Affecting No-Till Farming Practices in the Coastal Plain

Research has consistently demonstrated higher yields for the major field crops due to subsoiling or deep tillage. This result provides the basic rationale for utilizing heavy tractors, tillage implements, and planting equipment in the Coastal Plains. The soils of the Coastal Plains are generally sandy at the soil surface and nay vary from well drained to poorly drained in the lower profile. The soil below the normal disking layer (8-14" deep) may either contain a tillage pan or a compact A_2 horizon which normally has a higher bulk density than either the tilled surface soil or the undisturbed B horizon (or subsoil). Tillage research has demonstrated that rooting patterns correlate very highly with soil strength. Furthermore, soil strength, because of its impact on root distribution, can restrict water availability to the plant. In soils with compact horizons, corn roots have been shown to penetrate predominantly those areas in the soil profile which are loosened by tillage tools. Consequently, corn roots remove water primarily from the soil in which rooting occurs. Capillary water movement to root systems in southeastern sandy soils becomes very slow as the soil dries beyond the 20 centibar matric potential range.

In general, many soils of the Southeast are partitioned into three zones: (1) the tillage zone, (2) a zone of compaction, either genetic or due to tillage and traffic, and (3) a subsurface horizon which is normally only slightly compacted, and into which roots are able to penetrate provided A1 concentrations are negligible. Research has shown that for a given soil type, strength can be largely explained as a function of water content and bulk density of the soil.

Figure 1 shows a family of curves obtained from a soil which is typical of the southeastern Coastal Plains (Norfolk loamy sand). The surface Ap horizon has an average bulk density of 1.58 g/cm^3 in which rooting could occur at matric potentials between –1.1 bar and –0.08 bar. Rooting is restricted at the wet limit by aeration and at the dry limit by soil strength. The A_2 horizon, however, which has an average bulk density of 1.78 g/cm^3 prevents root penetration at matric potentials dryer than –0.22 bars. After roots penetrate the tilled portion of the A_2 or permeate the A2 horizon through a root channel, they can grow ingo the B horizon which has an average bulk density of 1.48 g/cc. The E horizon does not restrict rooting due to strength until the soil reaches –0.77 bar soil rnatric potential. By utilizing these relationships we can better understand how soil strength can limit soil water use by plants.

This Norfolk loamy sand retains approximately 7.1 cm of water between the –0.05 to –1.0 bar range and to a depth of approximately 1 m. If water extraction is limited to that lateral portion of the root profile where soil strength is less than 20 kg/cm^2 of strength (within the moisture limits given above), then the effective storage volume is reduced to 6 cm to the 1-m depth. If storage is limited to only that portion of the lateral soil profile between rows which was observed to have roots under a mature corn canopy, the water retention reduces to 4 cm for the 1-m deep profile.

From these soil water retention data, one may conclude that soil strength in this soil significantly reduces the extent and development of the corn root system. With a limited root system that does not permeate the entire lateral profile between corn rows, some water may remain unused. Although some water flow from wet to dry regions within the soil profile occurs, this flow is very slow due to the sharp reduction in hydraulic conductivity as the soil water content decreases. Consequently, soils with compact root–restrictive layers must be managed to obtain maximum permeation by root systems, because limited root development influences nutrient utilization, especially in conservation tillage system where the fertilizer is not mixed into the soil by subsequent tillage operations. Incorporating in–row subsoiling into the conservation tillage program provides a partial mechanical solution to overcoming the restricted root permeation caused by the layers that are either mechanically or naturally compact.

II. Double Crop Sequences for Conservation Tillage

Conservation tillage research in the southeastern Coastal Plains has been centered on three crop sequences: (1) winter rye followed by corn, (2) winter rye followed by soybean, and (3) small grain (usually wheat) followed by soybean. Of these crop sequences, the small grain-soybean rotation is being used rather extensively under conventional and under conservation tillage. In 1981 approximately 60% of the

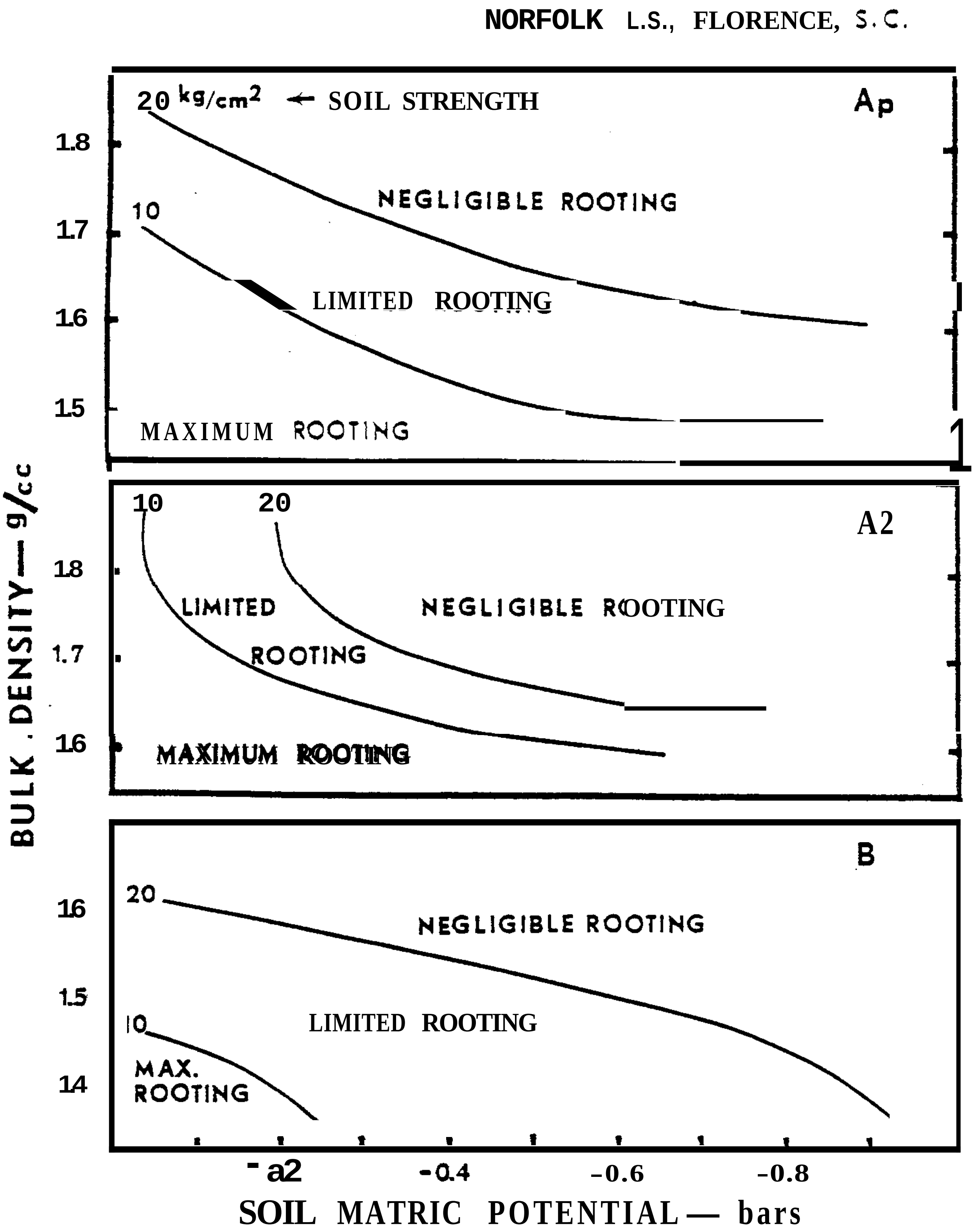

Fig. 1. Soil strength presented as a function of bulk density and matric potential (water retention) in relation to expected rooting in three soil layers, Ap, A_2, and B.

conservation-tilled acreage was planted to the small grain-soybean crop sequence. Approximately, 36% of the conservation tillage in the Coastal Plains involved corn which was planted into a cover crop or winter weeds growing in old corn or soybean residue.

Conservation tillage research in the Coastal Plains has progressed and is now in a position to consider using other cool season crops in the rotations. Economically, it is important for the cool-season crop to produce a return on the farmers investment beyond merely gaining the advantages of maintaining residue on the surface to reduce the hazard of erosion and soil loss. The use of late-season or cool-season crops may be grouped into four use categories: (1) to provide forage for grazing or hay (rye) (2) to fix nitrogen for subsequent crops (clover, vetch, or other legumes), (3) to grow oil seeds (soybean, sunflower, and rape) or (4) to grow small grains such as wheat, barley, oats, and rye. Research is underway to test the compatability of these cool-season crops with our major field crops such as corn and soybeans. At the present time, seven rotations given in Table I are being tested for compatability in conservation tillage farming.

Table 1. Potential double crop sequences for the Coastal Plains

1. Small grain followed by soybean
2. Corn followed by soybean
3. Legume followed by corn
4. Corn followed by sunflower
5. Corn followed by rape
6. Legume followed by sorghum
7. Rape followed by soybean

III. Advantages and Disadvantages of a Rye Cover

Cover crops provide many beneficial effects as well as incurring many risks in conservation tillage farming. Since cover crops are grown mostly during the cool season, they can provide forage for animals while maintaining a soil cover that stabilizes soil and reduces the hazard of soil erosion. A cover crop helps to control spring weeds (by competition) which are normally difficult or expensive to control by other means. A cover crop slightly reduce's soil temperature, but tends to increase the tilth of the soil. A cover crop provides better mechanical support for vehicles when soils are wet and hence may tend to minimize soil compaction in these instances.

There are risks and additional costs associated with conservation tillage farming in the southeastern Coastal Plain. Special considerations necessary to insure the success of conservation tillage farming with cover cropping include: (1) in-row subsoilers suited to operation in residue where subsoil compaction is a factor, (2) heavy disk-opening planters and higher seeding rates, (3) closer monitoring of insects, diseases and pests, (4) minimizing seed to residue contact to avoid phytotoxic effects of residues or exudates from plants in the weed or plant complex, and to avoid physical and disease related reductions in stand establishment of crops planted into unprepared soil, (5) adopting a fertilization strategy meeting the requirements of in-residue planted crops, (6) minimization of wheel traffic compaction arising from harvesting and other field operations that may accumulate over a period of time, increasing bulk densities and soil strength, and (7) specialized pesticide applicators for use in heavy residues.

IV. Soil and Water Management and Yield of Corn and Soybean in Conservation Tillage and No-Till Cropping Systems

Water removal by cover crops is a fundamental factor which affects crops following winter cover crops and influences the success of conservaton tillage systems. We evaluated the following winter rye residue management treatments which were established before planting corn on 16 April 1980: (1) disking the rye cover crop into the soil 20 days before planting, (2) applying a nonselective herbicide to the cover crop 20 days before planting, (3) double disking the cover crop 1 day before planting, and (4) applying a nonselective herbicide after planting, but before emergence. As the corn crop germinated and began to develop, it became obvious that in Treatment 1 (early incorporation) the corn was growing at a significantly higher rate than in tillage Treatment 4. The yield data (Table 2) show a reduction of 9-10 bu/A for Treatment 4 compared to 1. Corn yields decreased progressively, depending upon the degree to which water had been removed from the profile by the cover crop.

Table 2. Yield of corn as influenced by water extraction from soil by a winter rye cover crop-(Dargan Farm 1980)

Disposition of rye cover crop residue	Corn Yield bu/A
Incorporated 20 days before planting	102
Herbicide applied 20 days before planting	97
Incorporated 1 day before planting	92
Herbicide applied 1 day after planting	93

In a related study, corn was planted 4 April 1981. Measurements made 17 days after the crop was planted (Table 3) show that the quantity of water depleted from the soil profile reflected how the winter cover-crop had been managed. The treatments which were established prior to planting a cover crop included: (1) clean cultivation, where the soil was kept bare throughout the winter by periodic disking, (2) incorporating a rye cover crop by double-disking one day before planting, (3) applying a nonselective herbicide to the rye cover crop one day after planting, (4) applying a nonselective herbicide to the cover crop remaining after planting with a "Cole"[3/] system which buries about 50% of the previous crop residue at planting, and (5) planting with the "Cole" system, but applying no herbicide to kill the remaining cover crop.

In this experiment, most of the available soil water to a depth of 24 inches had been depleted in the treatments in which the rye cover crop achieved the greatest development. The soil water data shows significant water extraction in the 18-24" depth. The importance of adequate soil water during the early development of the corn was demonstrated from these soil water data and from the corresponding yield data also presented'in Table 3. The water profile deficit-was 0.83, 1.82, 2.20, 2.31, and 2.59 inches in the 24" profile for the five residue treatments listed in Table 3.

Corn yield correlated highly with the water deficit observed 17 days after planting. In 1981, 110 bu/A yield was produced in the clean-till treatment, but there was not sufficient rain to recharge the soil root zone to make up for the effects of the initial deficit during the growing season.

Table 3. Effect of five different cover crop management techniques on gravimetric soil water content, soil water retained 17 days after planting, and corn grain yield at harvest, 1981, Florence, S.C.

Crop Management	% Soil H O by Depth (in) 0-6	6-12	12-18	18-24	% Water Capacity	Yield bu/A
Clean-tillage (no cover)	8.9	9.9	19.4	21.4	73	110
Disk cover (before planting)	5.7	6.6	15.7	19.5	41	98
No-till (herb. at planting)	5.4	5.6	13.7	18.5	29	88
50% cover (w/herbicide)	4.6	4.6	14.2	18.9	26	90
50% cover (w/o herbicide)	2.4	3.9	14.1	18.2	17	70

The effects of both dead and green plant cover on corn yield at two sites in Florence, South Carolina in 1981 are presented in Table 4. The treatment entitled "no-till in corn stover'' yielded 30% more than a clean-tilled plot. This relative yield is compared with the relative yield of corn data shown in the previous table.

3/ Mention of trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the U.S. Dept. of Agr. or the S.C. Agr. Exp. Sta. and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

Table 4. Effect of various types of plant covers on corn yield, 1981, Florence, S.C.

Site	Plant cover treatment	Yield bu/A	% Relative yield
1	Clean-tilled	99	100
1	No-till in corn stover (w/o cover crop)	129	130
2	Clean-tilled	110	100
2	Rye cover incorporated	98	89
2	No-tilled w/herbicides	88	80
2	No-tilled w/50% cover (w/herbicide)	90	82
2	No-tilled w/50% cover (w/o herbicide)	70	64

Based upon data presented in Tables 3, and 4, one may conclude (1) that to have adequate water in the soil for the early development of corn is very important, (2) that green cover crops can utilize a considerable amount of water from the soil profile, which in effect competes for the water which would have otherwise been available for the succeeding crop, and (3) that planting in old corn stover in a dry spring helped to conserve water early in the crop history which produced a 30% increase over the yield produced under clean-tillage. While competition for and changes in availability of nutrients may also play a role, clearly soil-water was the single most dominant factor.

The proper seeding rate is essential to develop a stand of corn which will result in maximum yield. Data shown in Table 5 give the percent of seeds germinated when planted in incorporated rye residue and also when planted in standing rye. The results show a reduction of 13-14% germination in the standing rye residues compared to incorporated residues. These data were obtained in the spring of 1980 which was one of the Coastal Plains most recent severe drought years. We have since found that when soil moisture conditions for seedling establishment are favorable, germination reductions in conservation tillage systems may be as low as 6%. Data shown in Table 5, however, reflect germination under conditions where the water content of the surface soil was reduced by the presence of standing residue. Table 3 shows the highest extraction occurred in the surface horizon, which is the most critical zone for seed germination and seedling establishment.

Table 5. Stand of corn obtained in incorporated and standing rye at two seeding rates, 1980, Florence, S.C.

Seeding rate	Resulting Stand in Residue			
	Incorporated		Standing	
Seeds/A	Plants/A	%	Plants/A	%
31000	26600	84	22100	71
27000	23500	87	19400	72

Yields for various corn hybrids under no-till and clean-till cropping systems, with and without irrigation are given in Table 6.

Table 6. Yield (bu/A) of rainfed and irrigated corn hybrids under no-till and clean-till systems, 1981, Florence, S.C.

Hybrid	Monirrigated		Irrigated	
	Clean-Till	No-Till	Clean-Till	No-Till
Coker 21	95	111	159.	165
DeKalb XL71	116	141	169	178
Northrup-King PX74	92	145	182	151
Pioneer 3382	103	140	168	159
Ring-Around 1502	88	109	193	181
Mean	99	129	174	167

The mean yield in the clean-till, nonirrigated system was 99 bu/A as compared to 129 bu/A mean yield in the no-till treatment which was planted in corn-stover with winter-weed residue. This yield increase appears to be due to the conservation of water by the stover cover on the soil surface. Under irrigated conditions, the clean-tilled treatment yielded 174 bu/A vs. 167 bu/A under the no-till system. Differences in yields among five corn hybrids within any tillage system under irrigated and nonirrigated conditions showed a wide range of response. This experiment is being continued in an effort to establish consistent differences between corn hybrids planted in the various types of tillage systems.

These data indicate that Northrup-King PX74 gave the highest yield under the nonirrigated no-till treatment, whereas Ring-Around 1502 gave the highest yield under the irrigated no-till treatment. This result is of special interest since Ring-Around 1502 gave the lowest yield of the five varieties in the nonirrigated no-till treatment. These data indicate that intensive screening of corn hybrids under no-till conditions would significantly improve corn production in no-till cropping systems.

Soybean has shown marked responses to drought stress during the germination, seedling development, and full canopy development. In 1980, data from Dargan Field #2 showed a reduction in seedling size at the 4-leaf stage in the no-till planting which continued throughout the growing season. Yet, as seen from the yield data in Table 7, the yield from the no-till soybean planted in rye residue was 30.9 bu/A as compared to 28.2 bu/A when rye cover was incorporated two weeks before planting. Soybean yields from several replicated large-scale incorporated vs. no-till plantings in winter rye cover are shown in Table 7. The average yield for several experiments conducted between 1978 and 1980 reflect a slight increase in yield in no-till planting behind a rye cover crop. The average yield for conventional tillage was 29.3 vs. 31.4 bu/A for the no-till in rye residue plantings. These data suggest that southern, determinate soybean is not as sensitive as corn to early-season growth reductions in no-till systems.

Table 7. Soybean yields for large-scale replicated conventional and no-till plantings in production fields with a winter-grown rye cover crop (bu/A).

Year	Field	Yield: Incorporated	Yield: No-till
-1978	Dargan 1	20.2	27.6
1979	Dargan 1	28.1	28.6
1979	Dargan 2	41.8	41.0
1979	Dargan 3	34.6	37.6
1979	Williamson	22.2	22.9
1980	Dargan 2	28.2	30.9
Average		29.3	31.4

In 1980 and 1981 a more comprehensive tillage-regime soybean test involving various methods of managing residues further supports this conclusion. The treatments compared were (1) clean-tillage where the field was disked periodically during the winter to control weeds, (2) disk-incorporated rye residue, 20 days before planting, (3) disk-incorporation just before planting; and two other treatments where a non-selective herbicide was applied (4) 20 days before planting, and (5) immediately after planting as a pre-emergent chemical (in the usual no-till manner).

Data from this experiment demonstrate effects of row spacing within these five tillage regimes. The mean yields (Table 8) show an increase for the 30" row in 1980 and an increase with a 38" row in 1981. These results indicate that row spacing interacts with the time and duration of drought. In 1981 severe drought occurred late in the

Table 8. Effect of row spacing on soybean yield for five tillage regimes (bu/A), 1980 and 1981, Florence, S.C.

Tillage System	30" Row Spacing 1980	30" Row Spacing 1981	38" Row Spacing 1980	38" Row Spacing 1981
Clean-till	17.1	27.2	14.0	29.7
Disk-early	14.7	29.6	14.4	28.8
Disk-late	15.8	31.0	14.9	31.0
Herb-early	15.5	24.4	12.9	29.4
Herb-late	14.0	29.4	14.7	29.4
Average	15.4	28.7	14.2	29.7

crop cycle, consequently soybeans which were slowest to develop a closed canopy survived the drought best by conserving more moisture for the reproductive growth phase, thus producing the highest yields. Determinate soybean grown with adequate water, planted to a 30" row spacing normally produce slightly higher yields compared to 38" rows in full season crops.

The effect of variety on soybean yield within the five tillage regimes is shown in Table 9. In this experiment, Coker 338 produced a lower 2-year mean yield than the Bragg and Ransom. Water stress occurred in the later part of the production cycle for soybean in both 1980 and 1981, although late stress was more pronounced in 1981. Hence, the later varieties were affected more severely by drought than the earlier varieties of soybean.

Table 9. Effect of variety on soybean yield for five tillage regimes (bu/A).

Tillage System	Coker 338		Bragg		Ransom	
	1980	1981	1980	1981	1980	1981
Clean-till	14.3	28.5	15.6	28.3	16.8	29.1
Disk-early	14.8	29.2	14.5	28.3	15.6	30.1
Disk-late	13.6	29.4	16.0	30.6	16.5	33.1
Herb-early	13.2	26.0	13.9	28.7	15.5	27.9
Herb-late	15.4	28.4	13.3	29.2	14.4	30.6
Yearly Avg.	14.0	28.3	14.7	29.2	15.8	30.2
Variety Avg.	21.2		22.0		23.0	

The effect of tillage regime on soybean yield is presented in Table 10.

Table 10. Effect of tillage regime on soybean yield.

Tillage System	Yield (bu/A)	
	1980	1981
Clean-till	15.6	28.7
Disk-early	14.5	29.2
Disk-late	15.4	31.0
Herb-early	14.2	27.4
Herb-late	14.3	29.4

In 1981, yields were highest where the cover crop was undisturbed until shortly before planting. This occurred because a drier seedbed in the treatments where the cover crop was controlled late, slowed the early vegetative development of the soybean crop, conserving water for use in that year's late-season drought. Thus, under severe late drought, the disk-late and herbicide-late tillage treatments produced yields higher than conventional tillage and early cover crop control with herbicides or tillage. These data show that differences in water use and conservation by various canopy and residue conditions can result in water stress during the crop cycle itself or may experience stress due to water use by the preceding cover crop. Consequently, the time of water stress influences the effectiveness of row spacing and soybean varietal selection.

V. Summary and Conclusions

The results of conservation tillage research show that it is not a question of whether or not conventional tillage or no-tillage is better or worse than the other. The real question is how much do we know about the management factors that affect the various yield components within the various tillage systems and how well can these yield components be managed. Critical aspects of conservation-tillage and multi-cropping include the following considerations: (1) the timeliness of operations because one crop always follows another crop, (2) maintaining a favorable plant water status either by deep tillage and/or irrigation, (3) managing cool season crops to give an economic return on investment such as: pasture, oil-seed crops, legumes for nitrogen production, or small grains, (4) preventing disease and insect pests which are always a threat, (5) managing cool-season crops or spring weeds to conserve water, (6) achieving weed control through proper timing of the herbicide application, (7) developing long-term fertilization programs for no-till farming which have yet to be tested and recommended, and (8) selecting and developing cultivars which are best suited to a conservation-tillage planting environment.

No-till research in the Southeastern Coastal Plains is progressing, but is still in its infancy. Consequently, many cropping systems are being tested. Long-term effects of no-till cropping systems on Coastal Plain soils are only now being established and must continue to be studied, particularly in relation to disease and insect infestation and the synthesis of phytotoxic substances. Equipment and tools for no-tilling have been greatly improved and adapted to local farming conditions, but reduction in power requirements, seed placement, and residue displacement need improvement. Methods of managing and marketing the crops will continue to have the same kinds of problems associated with them under conventional tillage. No-tilling is destined to become a farming practice that will assure the success of double-cropping and multi-cropping programs in southern agriculture and will probably be the best method by which wind and water erosion can be controlled.