A Decade of Progress in Conservation Tillage in the South Carolina Coastal Plain

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Abstract

Conservation tillage (CT) in the South Carolina Coastal Plain began in earnest with development of in-row subsoil systems capable of planting into heavy plant residues. Problems associated with this development included reducing water loss from cover crops, improving stand establishment, assessing nutrient and water management requirements, determining optimal subsoiling strategies, understanding long term effects of CT on soil properties, effects of crop residue removal, and the interaction of CT tillage systems with pests and beneficial organisms. A concerted effort was initiated to study these interactions at the Coastal Plains Soil and Water Conservation Research Center in Florence, SC since the late 1970's. The findings of these studies published to date are summarized in this paper.

Introduction

Conservation tillage (CT) will be a key component of continued southern agricultural expansion (17). In the South Carolina Coastal Plain initial adoption of CT was impeded by problems associated with root penetration of the dense eluviated (E) soil horizons (11). Furthermore, dramatic increases in water infiltration and fertilizer retention, seen with CT in the hilly Piedmont, or in states like Kentucky, did not occur in the flat, sandy Coastal Plain. Success came only after an integral in-row subsoil/planting implement was developed (16). The SuperSeeder[1] allowed planting into crop residues or living mulches that were controlled with broad spectrum herbicides (paraquat or glyphosate). With initial rooting and weed problems solved, extensive applied and basic research was initiated at the USDA-ARS Coastal Plains Research Center to extend understanding of CT principles and their applications in the region.

Review

Soil Water Content. Initial research focused on cover-crop water use because the CT system being promoted was spring planting of corn *(Zea may* L.) or soybean *(Glycine max* (L). Merr.) into a fall-planted rye *(Secale cereale* L.) cover crop. The rye, whose grain had little cash value, was often grazed in winter and the killed with paraquat at spring planting. The rye canopy abated soil loss from intense Spring rains but also severely desiccated the soil profile by evapotranspiration (ET) (9,12). This often reduced corn yield, but had no negative effect on full-season, determinate soybean yield. The occurrance of more CT problems with corn than soybean was not anticipated from research in other regions (29) but was a consistent year-to-year response in the Coastal Plain (9,12).

Initial studies attributed poor corn yield in CT plots to erratic emergence and slow early-season growth (24). The retarded plants ("corn weeds") robbed water and nutrients but remained barren. Low soil temperature caused similar problems at more northern latitudes (15), but this was not true in the Coastal Plain where temperature at 2- and 6-in depths were never more than 2° F different for conventional and CT seedbeds. Water was hypothesized as the most limiting factor because many Coastal Plain Ultisols retain less than 4 in. of plant available water per 3 ft of profile (1). Furthermore, even though surface residues can conserve several days equivalent ET by reducing soil evaporation during the growing season, this gradual benefit did not overcome early-season profile depletion and growth retardation in corn.

Determinate soybean yields were not reduced by cover cropping or CT, if full canopy cover occurred by flowering. If prolonged drought occurred in soybean during the reproductive period, CT increased yields slightly compared with conventional tillage, depending upon the timing of the dry period relative to length of the reproductive period. An effective management solution to the problem of cover crop water use was to kill the cover crop 2 to 3 wk before planting corn or soybean. This halted soil water extraction, providing an opportunity for soil profile recharge (9,12,20).

One approach to eliminating high soil strength involves managing soil water content. However, to overcome strength limitations for the high bulk densities of typical Coastal Plain soils risks maintaining water contents which limit root oxygen availability (10). Recent work with sweet corn showed that the approach can work, but only with a high level of management (7).

Subsoiling. Another applied CT study showed that for South Carolina Coastal Plain soils, in-row subsoiling and irrigation resulted in additive yield benefits for corn (6), even though water was supplied by irrigation. This occurred because sandy surface soils allowed N, K, S, and B to leach to the Bt horizon (23). Subsoiling facilitated deeper and earlier root penetration which promoted more efficient use of these nutrients from the B horizon where they occur in greater abundance, see Figure 1. In-row subsoilers were also used for direct fertilizer placement behind the subsoil shanks without requiring knives or disks on which surface trash is easily entangled (25). This produced yields equivalent to traditional 2 in. by 2 in. placement.

Energy costs in the late 1970's caused farmers to question the need for annual subsoiling. The persistence of subsoil disruption was evaluated for several deep tillage methods (4). In-row subsoiling was more effective than disking, chiseling, and mold-board plowing for reducing soil strength to the B horizon which has a higher clay content and water

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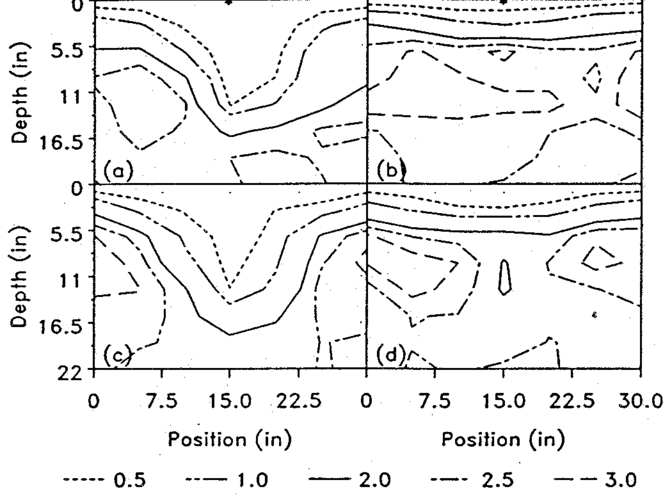

Figure 1. Soil strength contours that show breaking up of the 6- to 14 in deep E horizon by the Superseeder in April (1) soon after the deep tillage and in August (c), compared to disked plots in April (b) and August (d). Some remanats of deep tillage from previous years can be seen in the disked plot. * indicates the row position.

holding capacity. Although, using a penetrometer, the location of a subsoiling operation was identifiable after 2 yr, none of these implements maintained cone indices below recognized limits to rooting for more than one year (31). Furthermore, without precise traffic control, planting over the previous season's subsoiling was not possible. Another study showed that rather than alleviating physical and nutrient problems, complete mixing of the A and B horizon exacerbated both of these problems because of the acidity, nutrition, and void ratio of the resulting media. (8).

As in-row subsoiling became more universally adopted in the Coastal Plain, several implements became available for use in CT. Though the deep disruption patterns for the Brown-Harden Superseeder, the Tye Paratill, and the Kelly No-till System and their draft requirements varied (T.H. Garner, personal communication), they all shattered the E horizon to non restricting cone indices. Despite differences in the overall soil profile strengths (see Table 1), yield differences among plots treated with the implements were not significant (2). Another promising tool was described which slits shallow tillage pans (13). Here, a thin blade cuts a 0.15 in wide slit (about the size of a macropore) through the hard layer. Crop roots stabilize the slit and maintain it for several years. Where the layer of high strength is deeper, this blade is attached to the bottom of a short subsoil shank, using less horsepower than unaided deeper shanks. These slits have been found 3 yr after they were cut. Plots that were annually slit outyielded standard in-row subsoiled plots after 2 yr of slitting (22).

Soil Strength. Establishing CT has been difficult in areas where soils easily compact. Coarse textured ultisols with low organic matter required less compactive force to produce high bulk densities and high probe resistances (5,30). Relating strength to bulk density and water content also depends on texture and organic matter. Making field strength com-

Table 1. Mean profile soil strengths for disked and minimum tillage plots subsoiled with the Superseeder (SS), Paratill (PT), and Kelly (KE).

Residue Mngmt	Implement SS	PT	KE	Mean
	(MPa)			
Disked	6.18	5.68	5.22	5.69
Mintill	5.48	5.58	5.40	5.49
Mean	5.83	5.63	5.31	

parisons is complicated by water content and bulk density variability, requiring mathematical techniques to assess absolute strength differences. Sophisticated statistical and mathematical techniques were developed to make these comparisons (3,28), reducing treatment confounding effects such as strength dependence on measurement date, treatment location, or water regime. These techniques were utilized to show that in-row subsoiling was more effective than conventional tillage when combined with CT (3).

Soil Biota. In addition to physical, chemical, and environmental aspects of CT pest management techniques were also unknown. Crop residue removal and tillage affected four nematode species (*Meloidogyne incognita, Scutellonema brachyurum, Pratylenchus scribneri,* and *Paratrichodorus christiei*) differently (14). *Meloidogyne incognita* and *P. christiei* populations were not significantly affected by tillage, but *S. brachyurum* populations were highest in CT treatments where crop residue was not removed. In contrast, *S. brachyurum* populations were lowest in CT plots where 90% of the crop residues were removed or incorporated. In insect studies emergence of *Heliothis* species was reduced by tillage. Compaction without tillage stabilized insect burrows; compaction after tillage sealed the burrows and damaged the pupae (26,27). Therefore, less intensive tillage treatments had greater emergence.

Conservation tillage also affects the environment of beneficial organisms. The success of soybean depends greatly on providing a suitable environment for the symbiotic interaction of soybean and Bradyrhizobium japonicum. Despite subtle tillage x strain x cultivar interactions that affected nodular occupancy and N_2 fixation by specific cultivar and strain combinations, yield was not affected (19). In a related greenhouse experiment in which understory surfaces were varied independently from soil properties, early stem growth was greater for a straw-covered surface than for a bare surface, but nodulation was unaffected (18).

For sandy Coastal Plain soils, increased organic matter can improve both water and nutrient retention, enhancing productivity. Long-term effects of CT on several soil-test parameters were examined after eight years. In the upper 8 in, there was a trend toward, but not a significant increase of, CT Mehlich I soil test values over disked treatments. There was, however, an increase of organic carbon over the eight years from 0.5 to 1.0% for the disked treatment and from 0.5 to 1.2% for CT (21).

Conclusion

The Coastal Plains Soil and Water Conservation Research Center in Florence, SC exerted a concentrated effort at understanding the advantages and shortcomings of CT for that region of the country. This included the interaction of CT with water loss from cover crops, stand establishment, water and nutrient management, soil strength management through deep tillage or intensively managed irrigation, crop residue removal, long term effects on soil properties, and pests and beneficial organisms. Understanding these effects on conservation tillage has helped make CT a more viable management alternative in the SC Coastal Plain.

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