Double- and Mono-cropped Corn and Soybean Response to Tillage.

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INTRODUCTION

Farmers in the Southern United States take advantage of the region's long growing season by double-cropping, with about 7 million acres double-cropped in 1990. The long growing season favors double-cropping of winter and summer crops, which spreads risks and costs and may maximize returns to land and management. Soybean *(Glycine max* L.) has been the only summer crop available to most farmers for double-cropping, and soybean acreage has dropped from 24 million acres in 1982 to 13.5 million in 1990 (USDA-NASS, 1991). Corn *(Zea mays* L.) is also an important crop in the rotation schedule for many farmers, but most of the corn varieties grown are short-season hybrids planted very early in the spring to minimize the effects of drought, heat, or high insect pressures during late summer. Development of new tropical corn hybrids which are more heat tolerant and insect resistant allow the farmer to plant corn later in the season and still have acceptable yields. Cropping systems including tropical corn will give farmers an alternative crop to soybean in double-cropping with wheat *(Triticum aestivum* L.).

Management schemes for the production of double-cropped corn and soybean must account for the limiting soil conditions of this region. In addition to a coarse surface texture and very low water-holding capacity, many of the important agricultural soils in the Southeastern Coastal Plain have a compacted layer in the E horizon, at the base of the Ap horizon. This compacted zone, caused by natural and man-induced factors such as tillage and traffic, restricts plant rooting to very shallow depths. Yields of corn and soybean grown on sandy Coastal Plain soils are frequently reduced due to the presence of hardpans which prevent root acquisition of subsoil moisture and nutrients (Simmons et al., 1989; Smittle et al., 1977). Deep tillage is needed to achieve hardpan breakage. Busscher and Sojka (1987) found that conservation tillage methods can be used to delay recompaction of the E horizon. Conventional double-cropping systems on the Atlantic Coastal Plain utilize subsoiling, but the timing of deep tillage operations and the benefits to subsequent crop growth need to be quantified.

Objectives are to evaluate: 1) the suitability of tropical corn for use in double-cropping systems; 2) the optimal type of tillage (no-till, in-row subsoiling, between-row subsoiling) for corn and soybean mono-crop and double-crop production; 3) the optimal time for deep tillage operations (at planting or at the last cultivation) for corn and soybean mono-crop and double-crop production.

METHODS

This study was conducted at the Edisto Research and Education Center of Clemson University during 1990 and 1991. Full-season corn and soybean and double-cropped tropical corn and soybean were planted using 96 cm row spacing in 12 m by 15 m plots in a randomized complete block arrangement with four replications. Each crop was analyzed separately with tillage as the treatment variable. For the soil properties, row and interrow positions were used as split-plot variables. Tillage treatments were subsoiling in-the-row at planting, subsoiling between-the-row at the last cultivation (about 5 weeks after planting), and no-tillage. In-row subsoiling was performed using a KMC subsoiler with shanks spaced 96 cm apart and

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Table 1. Corn yield response to three tillage systems.

	Grain		Stover	
Tillage	bu acre^{-1}	kg ha^{-1}	lb acre^{-1}	kg ha^{-1}
		Double-cropped Tropical Corn - 1990		
No-till	33 B*	2374 B	5804 C	6500 C
Late subsoil	40 AB	2669 AB	7504 B	8405 B
Early subsoil	60 A	4026 A	10871 A	12176 A
		Double-cropped Tropical Corn - 1991		
No-till	16 B	1030 B	1573 A	1762 A
Late subsoil	15 B	964 B	1801 A	2017 A
Early subsoil	28 A	1728 A	2199 A	2463 A
		Mono-cropped Tropical Corn - 1991		
No-till	145 A	9102 A	28150 A	31528 A
Late subsoil	153 A	9605 A	30139 A	33756 A
Early subsoil	156 A	9793 A	30260 A	33891 A

*Means in a column followed by the same letter are not significantly different according to DNMRT, $a = 0.05$.

operated 35 cm deep. Between-row subsoiling was performed using a United Farm Tools subsoiler with the shanks spaced 96 cm and operated 35 cm deep. All plots receiving deep tillage were disked prior to planting. The soil used for the study was a Dothan loamy sand (fine-loamy, siliceous, thermic Plinthic Paleudult; Rogers, 1977). All fertilizers were applied at rates based upon crop and soil test recommendations and broadcast before fall tillage, and in the spring as sidedress application as needed. Insecticides and herbicides were applied as needed according to recommended procedures (Horton, 1991).

In 1990, only double-cropped soybean and tropical corn were used for the test. Pioneer 3165 was used as the full-season corn hybrid and Pioneer 304C as the tropical corn variety. Kirby was used as the full-season and double-crop soybean variety. For double-cropped treatments, wheat was planted in mid-December immediately after disk tillage and harvested in mid-June. The wheat was grown only to plant the summer crop into, so yields were not measured. Full-season corn was planted at a rate of 48500 seed/ha in early April. Full-season soybean was planted at a rate of 110000 seed/ha in mid-May. Double-cropped soybean and tropical corn were planted after wheat harvest at rates equal to the full-season crops. In 1990, corn and soybean were planted with a John Deere 7200 MaxEmerge planter. In 1991, corn and soybean were planted with an Almaco plot planter. Due to adverse weather conditions in 1991, the tropical corn was not planted until July 9, and the late subsoiling tillage treatment was delayed due to wet conditions and resulted in damage to the tropical corn plants. Corn grain and stover were hand harvested by cutting 3 m sections of two center rows in early September. Ears were separated from stalks, weighed, and the grain yield reported at 15.5% moisture. Six randomly selected stalks were weighed, sectioned, and oven dried to adjust the stover yield data to 65% moisture. An Almaco plot combine was used to harvest 15 m sections of *two* center rows of soybean in mid-October, with soybean yield reported at 14% moisture.

Table 2. Soybean yield response to three tillage systems.

Tillage	Double Cropped Soybean bu acre^{-1}	Double Cropped Soybean kg ha^{-1}	Full Season Soybean bu acre^{-1}	Full Season Soybean kg ha^{-1}
		1990		
No-till	19 A*	1265 A	-	-
Late subsoil	17 A	1151 A	-	-
Early subsoil	20 A	1320 A	-	-
		1991		
No-till	26 A	1565 A	33 A	2005 A
Late subsoil	28 A	1720 A	33 A	1981 A
Early subsoil	30 A	1816 A	34 A	2038 A

*Means in a column followed by the same letter are not significantly different according to DNMRT, $a = 0.05$.

Undisturbed soil cores were taken at the 5 to 12 cm soil depth with Uhland sampler attached to a hydraulic coring device three times during the season: at planting, one week after the late subsoiling operation, and after harvest. The cores were slowly saturated with water and saturated hydraulic conductivity (KSAT) measured using a constant-head permeameter with a hydraulic gradient of 1.8 cm/cm (Klute and Dirksen, 1986). The cores were then oven dried and weighed for bulk density (BD) determination (Blake and Hartge, 1986). Analysis of variance procedures were performed on the data using the Statistical Analysis System (Ray, 1982).

RESULTS AND DISCUSSION

Soil Properties

For the double-cropped tropical corn plots in 1990, KSAT at planting was highest for the early subsoiled treatment at the row position, with the other treatments and depths being similar (Fig. 1). After the late subsoiling treatment. both deep tillage treatments had similar KSAT values in the row, but were significantly different at the interrow position. After harvest all treatments and positions had similar KSAT levels. Bulk density levels had an inverse relationship with KSAT (Fig. 1) Immediately after an early or late subsoil operation, BD at the position nearest the subsoil shank zone was at its lowest value with subsequent densification occurring over time. Averaged over treatments, the row position was less compacted than the interrow position, even with the obvious soil loosening of the interrow area with the late subsoiling operation.

For the double-cropped tropical corn treatments in 1991, KSAT at planting was again highest for the early subsoiled treatment at the row position, with the other treatments and depths being similar (Fig. 1). After both deep tillage operations had been performed, the immediate area where the subsoil shank ran had the highest KSAT values. These areas also tended to have the highest KSAT values at harvest, but they were not significantly different from the other areas. Bulk density values followed a trend similar to that in 1990 (Fig. 1). In the immediate area of the subsoiling operation, BD was at the lowest level for the next two measurement periods. A gradual increase in BD over time occurred, although the no-till treatment did not change appreciably. Density levels did not reach root limiting conditions. The pattern of change in KSAT and BD for the 1990 and 1991 double-cropped

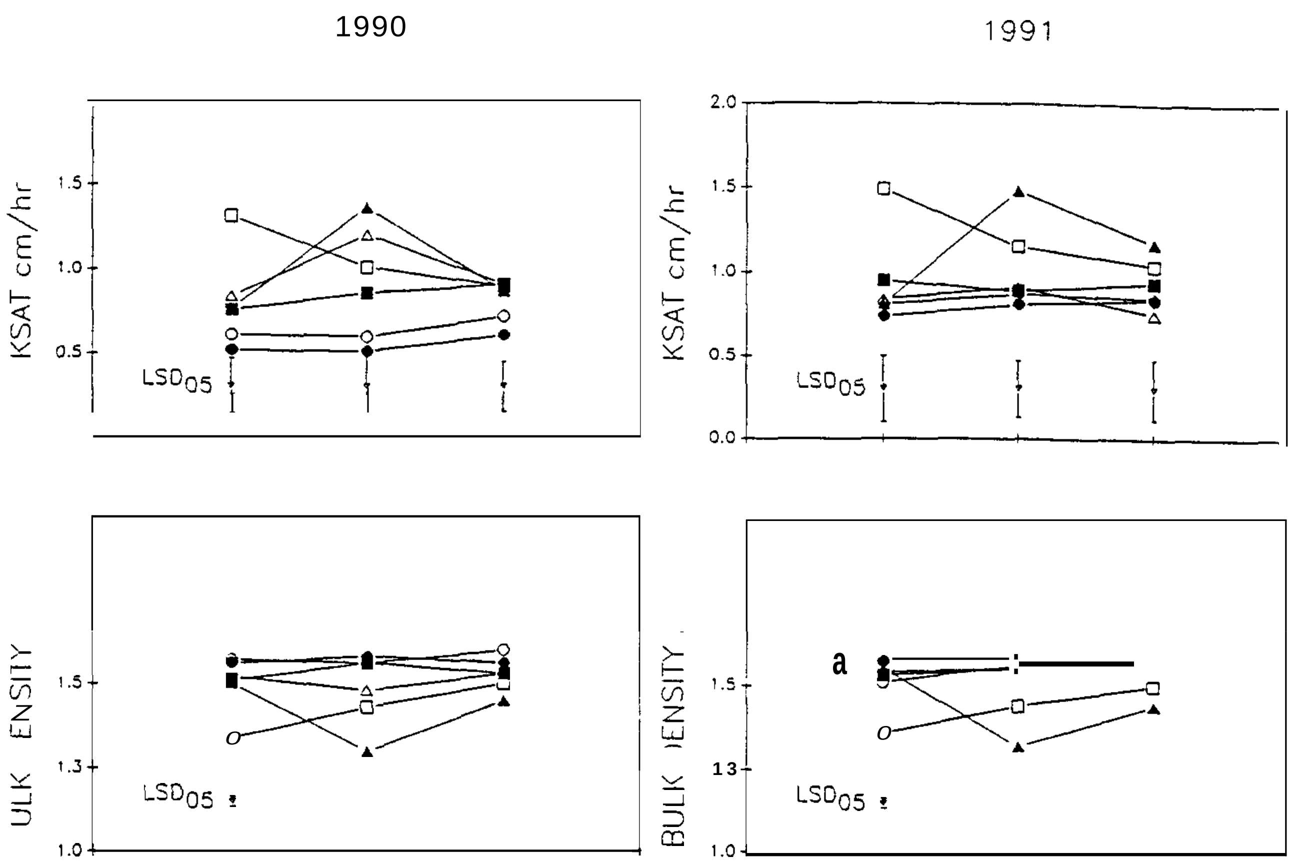

Fig. 1. Soil property response to three tillage systems for double-cropped tropical corn. KSAT = saturated hydraulic conductivity.

soybean treatments (Fig. 2) was similar to that of the tropical corn plots. Conductivities were highest in the zone near the subsoiled slot, which was the early subsoil treatment at the row position and the late subsoil treatment at the interrow position. By harvest, all positions and treatments had similar KSAT levels. Bulk density was lowest just after the deep tillage operation at the respective row and interrow positions (Fig. 2). These BD values were still significantly different from the other four treatment/position combinations at the end of the season. Soil properties for the 1991 full season mono-cropped corn revealed the row position to have significantly higher KSAT at planting than other positions (Fig. 3). Both subsoil treatments were initially high at the row position. A significant decrease in KSAT over time was noted for the interrow position, except for the late subsoil plots. At the row position, BD was highest for the no-till treatments and least for the early subsoil treatment, with the late subsoil treatment intermediate and significantly different (Fig. 3). For the interrow location, no-till treatments also had the highest BD, the late subsoil treatment was least and the early subsoil treatment was intermediate and significantly different.

The full season mono-cropped soybean had significantly different KSAT values only at the first sampling time, with the early subsoil plot at the row position being significantly different from the other treatments (Fig. 3). At the row position, the no-till treatment had the highest BD, the early in-row subsoil plots significantly

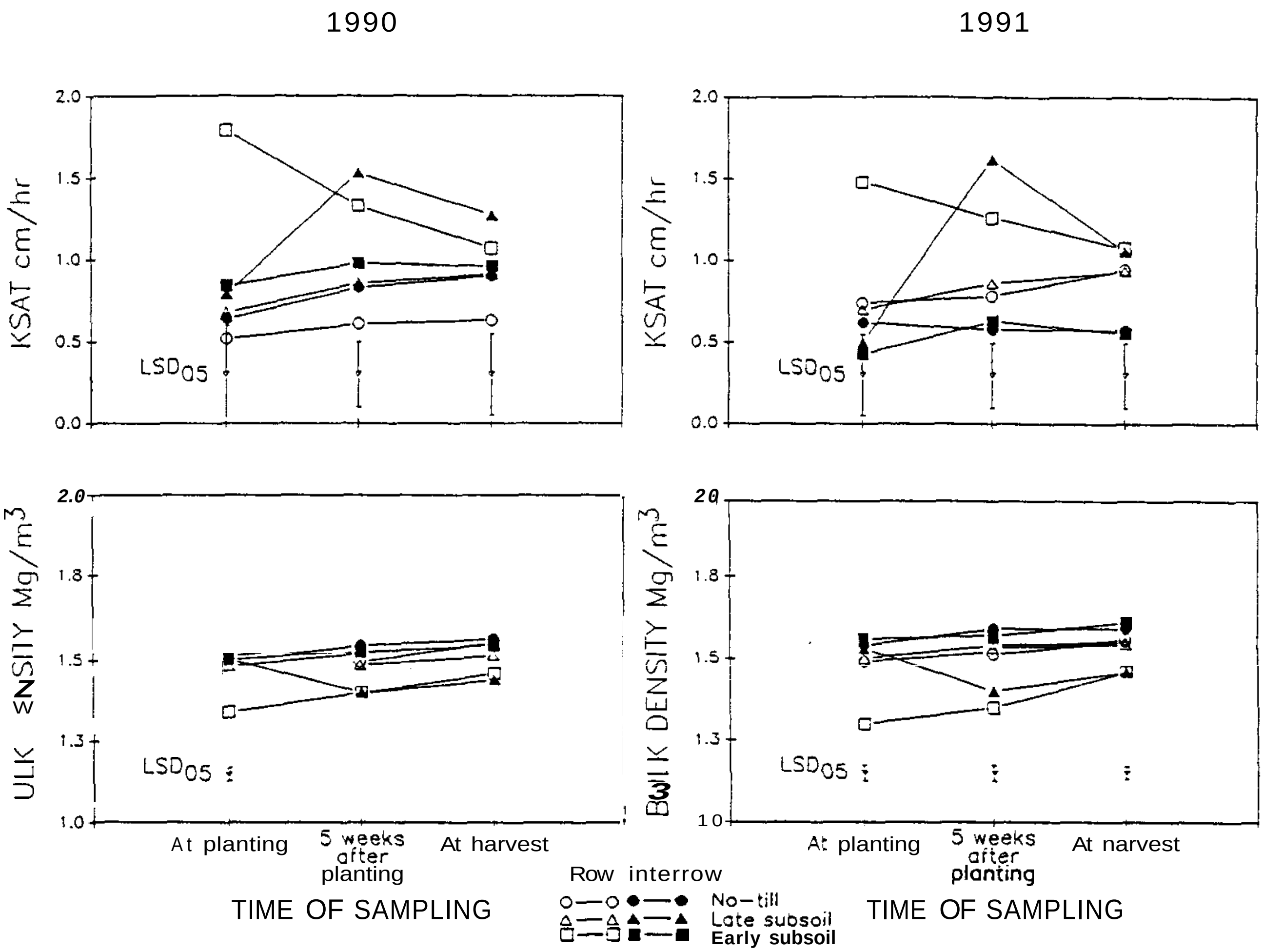

Fig. 2. Soil property response to three tillage systems for double-cropped soybean. KSAT = saturated hydraulic conductivity.

lower, and the late subsoil plots again intermediate. At the interrow position, the late subsoil treatment was significantly different than the early subsoil treatment 5 weeks after planting, but not at the other two sampling dates. Both were always significantly lower than the no-till treatment.

As mentioned, BD typically increased over the growing season due to the natural settling of the soil, with less change noted for the no-till treatment. However, KSAT values for most treatments and positions also tended to increase over time. The exceptions were the early in-row subsoil treatment at the row position and the late between-row subsoil treatment at the interrow position. These were the soil regions where the most tillage disruption occurred, and KSAT decreased with time after the tillage was performed. Root growth throughout this sandy textured soil could account for an increase in macropore flow channels and thus KSAT over time.

Crop yields

Dry weather in 1990 reduced tropical corn yields, with the early subsoiled treatment had the highest grain and stover. yields, no-till the lowest, and the late between-row subsoiled treatment was intermediate (Table 1). A late planting date reduced tropical corn yields in 1991, with the late subsoil treatment being further reduced by mechanical damage from the subsoiling operation. Due to this, the late subsoil treatment was equal to no-till in grain yield and

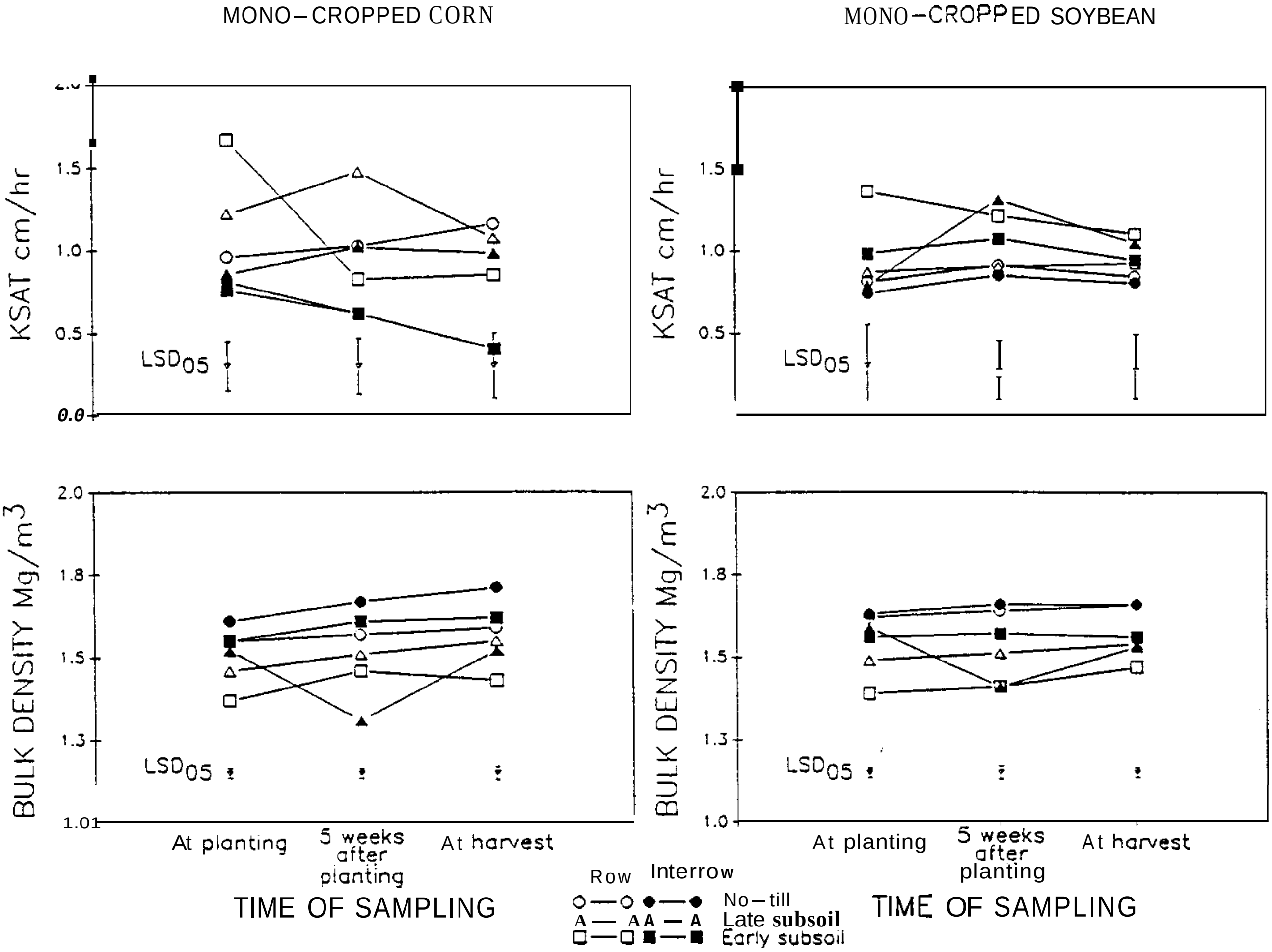

Fig. 3. Soil property response to three tillage systems for full season mono-cropped corn and soybean. KSAT = saturated hydraulic conductivity.

lower than the early subsoil treatment. Stover yields were not significantly different among treatments. With excellent rainfall distribution in 1991, all tillage treatments for full season mono-cropped corn produced similar grain and stover yields (Table 1).

Double-cropped soybean yields in 1990 were similar for all treatments, with very dry weather responsible for the low yields (Table 2). In 1991, though not significantly different, the early subsoil treatment was highest followed by the late subsoil and the no-till treatments. Mono-cropped full season soybean yields were slightly higher than the double cropped soybean, but again the tillage treatments were not significantly different from each other (Table 2). As with the 1991 corn yields, this effect was probably due to the adequate rainfall distribution throughout the growing season.

On this Coastal Plain soil deep tillage will generally benefit crop yields. In normal to wet years the bulk density and conductivity of the soil, as measured in this test, will not be restrictive to root growth and plant development. The restrictive soil density levels will change with changes in soil moisture, and was most obvious in 1990 with the reduced plant growth in the no-till treatment. Even in an adequate soil moisture year (1991) the no-till yields were slightly reduced, with increased soil bulk densities at least partially responsible. Preliminary observation of root growth patterns indicated the least root growth expansion below the hardpan in the no-till areas. Subsoiling between the rows five weeks after planting did damage some root systems, but the majority of roots were directly under or near the plant row. Thus, this treatment did not generally reduce crop yields. In cropping systems utilizing irrigation, the late subsoiling operation may benefit infiltration later in the season when the crop would need supplemental water to avoid drought stress during the silking and tasseling growth stages. Reducing the amount of trips over the field after any deep tillage operation, or limiting traffic to specific paths, such as done in this small-scale test, would also reduce compaction and benefit subsequent water infiltration, root growth and crop yield.

ACKNOWLEDGMENTS

We would like to thank United Farm Tools, Inc., South Carolina Land Resources Conservation Commission, and Pioneer Hi-Bred International, Inc. for support of this project.

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