ELSEVIER

Soil Technology 7 (1994) 197–208

SOIL TECHNOLOGY

Intensive cropping of maize in the Southeastern United States

W.J. Busscher[a,*], R.E. Sojka[b]

[a]Coastal Plains Soil, Water, and Plant Research Center, USDA-ARS, P.O. Box 3039, Florence, SC 29950-3039, USA

[b]Snake River Soil and Water Management Research Unit, USDA-ARS Route 1, Box 3793N. 3600E., Kimberly, ID 83341, USA

Abstract

The long growing season of the southeastern Coastal Plains allows planting of a second crop after spring-planted maize (*Zea mays* L.). Second crops have been shown to reduce erosion and prevent leaching of nutrients and pesticides. Maize grown with a second annual crop might also have a yield advantage over mono-cultured maize. Seven tillage/cropping systems were compared. They included disking for weed control, disking for seedbed preparation, or no disking. Double-cropped treatments included sunflower (*Helianthus annuus* L.), soybean (*Glycine max.* L.), a cover crop [crimson clover (*Trifolium incarnatum* L.)] or no double crop. Double-cropped soybean yields did not respond to irrigation. They averaged 0.63 Mg/ha over 4 years. This is less than half of the local non-double-cropped yields. Sunflower yields averaged 0.89 Mg/ha, also less than non-double-cropped yields (1.0–2.5 Mg/ha). The best continuous maize yields (7–8 Mg/ha) were from treatments with disking in some phase of the operation. Treatments with lower maize yields generally had higher plant nutrient contents. Double-cropped maize yields significantly ($P<0.10$) outyielded mono-cropped maize yields in two of the three years. In 1984, a dry year, the minimum tillage treatment had lower tensiometer readings than the conventionally tilled treatment.

Keywords: Maize, intensive cropping; Southeastern United States, maize

1. Introduction

Maize continues to be an economically attractive crop in the southeastern Coastal Plains of the United States because of known production practices and ease of marketing. Recommendations for continuous maize have been avoided because of declining yields over

*Corresponding author.

SSDI 0933-3630(94)00006-P

time without rotation, measured in other parts of the country (Havlin et al., 1990; Crookston et al., 1991; Martin et al., 1991; Johnson et al., 1992). The long growing season in the southeast, however, offers the possibility of interrupting the maize sequence with alternate crops in the same year. The effect of such a practice on the primary maize crop for these conditions is unknown. Most of the region has an average frost free growing season approaching 300 days (US Dept. of Commerce, 1968). One can harvest maize in early to mid August and can expect frost free temperatures until mid-November. Temperatures during this period range from normal daily minimums of 21 °C (70 °F) in August and 4 °C (40 °F) in November to normal daily maximums of 32 °C (90 °F) in August and 20 °C (68 °F) in November. Various fall crops have the potential for economic return (Sojka et al., 1990), for nitrogen production (Ebelhar et al., 1984), or as a conservation crop to hold soil and prevent leaching of pesticides and fertilizers (Zhu et al., 1989).

Rainfall distribution favors fall cropping with 30% of the 1100 mm coming during August to November (NOAA, 1983). Soils are generally sandy, however, and low in water holding capacity. They can retain as little as 75 mm of water per meter of soil (Beale et al., 1966). The soils may enter the second cropping sequence dry because of water extraction by the maize. Conversely, when winter tillage is not performed or when winter cover crops or weeds are not killed several weeks before maize planting, spring crops have been shown to suffer from preseason profile depletion (Campbell et al., 1984a).

One soil and water conservation practice is to reduce surface tillage. No-tillage is not feasible in many Coastal Plain soils because of a subsurface root restricting hardpan (Busscher et al., 1986). However, in-row subsoiling can disturb as little as 7 cm around the row while still breaking the hardpan enough to permit root growth through it and into the subsoil below (Busscher et al., 1988). In-row subsoiling is equally effective in disrupting the subsurface hardpan either with or without the surface tillage (Busscher and Sojka, 1987). Reduced surface tillage and increased soil cover have reduced erosion (Langdale et al., 1979) and increased infiltration (Mills et al., 1988).

This study sought to determine how production of a second crop within a growing season would effect maize compared to mono-cropping. The study included several alternative management systems some of which included disking. All management systems used their appropriate pest and weed control measures.

2. Methods

In the spring of 1982 a field of Norfolk loamy sand (fine, loamy, siliceous, thermic, Typic Kandiudult) near Florence, SC, USA, was planted to maize (*Zea mays* L. cv Pioneer 3572[1]). The field design was four blocks split on water management (irrigation and rainfed). Field preparation in the spring of 1982 included three diskings of the soybean stubble (using a 2-m wide disk with 0.46-m diameter fluted coulters on the front gang and 0.53-m diameter smooth-edged coulters on the rear gang – Deere & Co., Moline, IL, USA). After disking,

[1]Mention of trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the U.S. Dept. of Agric. and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

the field was smoothed with a King Field Conditioner (King Plow Co., Atlanta, GA, USA), a tined field cultivator with rolling baskets. In the fall of 1982 we randomized seven treatments, described in Table 1, within the blocks. Maize was grown continuously, without a second crop, in conventional tillage (No. 1), reduced tillage (No. 3), and minimum tillage (No. 4) treatments (Table 1). Treatment No. 1 was disked both at maize seedbed preparation and for winter weed control. Treatment No. 3 was disked only at maize seedbed preparation. Treatment No. 4 was not disked. Subsoiling, as part of the subsoil-planting, was common to all treatments and was the only tillage applied to treatment No. 4.

Maize, hybrid Pioneer 3572, was planted in 1982 and 1983. Because of seed availability, we changed to hybrid Pioneer 3950 in 1984 and 1985. Lime (1100 kg/ha per year) and fertilizer (Table 2) were applied according to soil tests (Clemson University, 1982). Maize

Table 1
Treatment factors

Treatment	2nd Crop	Seedbed preparation		Fall/winter weed control[1]	
		2nd Crop	Maize	2nd Crop	Winter[2]
1	none	–	disking	–	disking
2	interseeded soybean	none	no-till	chemical[3]	chemical
3	none	–	disking	–	chemical
4	none	–	no-till	–	chemical
5	clover cover crop	none	no-till	–	cover crop
6	drilled soybean	none	no-till	chemical[4]	chemical
7	sunflower	disking	no-till	chemical[5]	chemical

[1]Terbufos or carbofuran banded at maize planting for all treatments.
[2]Disking/chemicals (paraquat or glyphosate) were used as needed.
[3]Acifluorfen or sethoxydim (post-emergence).
[4]Glyphosate, alachor, and metribuzin (pre-emergence).
[5]Chloramben (pre-emergence).

Table 2
Fetilizer applied (kg/ha)

Year	Application	Treatment	N	P_2O_5	K_2O
1982	Broadcast	all	200	16	35
1983	Broadcast	all	35	70	200
	Sidedressed	all	175		
	Sidedressed	7	235	85	170
1984	Broadcast	all	35	70	200
	Sidedressed	all	135		
	Sidedressed	7	235	85	170
1985	Broadcast	all	35	70	200
	Sidedressed	all	120		
	Sidedressed	7	200	85	85

was in-row subsoil-planted on 0.75-m row centers using a Brown-Harden Super Seeder (Brown Manufacturing Corp., Ozark, AL, USA). This tillage tool subsoiled about 0.45-m deep in line with and ahead of John Deere 71 flexi-planters (Deere & Co., Moline, IL, USA) in a single, integrated operation. Maize subsoil-planting for all treatments was identical. We banded insecticides terbufos (Counter 15G, 2.25 kg AI/ha) or carbofuran (Furadan 15G, 2.25 kg AI/ha) in the row above the seed at maize planting each year.

Plots were 6 rows wide by 30-m long and were randomly split into 15-m long irrigated and rainfed subplots. Subplots were irrigated with inverted microirrigation tubes placed between the rows, operated at 80 kPa pressure. In each irrigated plot we installed a gage-type tensiometer (Soilmoisture Equipment Corp., Santa Barbara, CA, USA) at 0.30-m depth and read them three times a week. When tensions in any tensiometer exceeded 40 kPa, the maize was irrigated (Table 3). In 1984 and 1985, banks of tensiometers were installed in both the irrigated and rainfed splits of treatments No. 1 and No. 4 at 0.15-m, 0.3-m, 0.6-m, 0.9-m, 1.2-m, and 1.5-m depths. Banks were installed in both in-row and mid-row positions in reps 2, 3, and 4 in 1984 and all four reps in 1985. These tensiometers were read 2 to 3 times a week for approximately fifty days from June 15, 1984 and June 7, 1985. On June 12, 1984 we took maize ear leaf samples and on May 13, 1985 whole plant samples. Plant samples were only taken from the irrigated split. The Clemson University Plant Tissue Lab analyzed the plant samples for Kjeldahl nitrogen, phosphorous, and potassium (Clemson University, 1982).

Treatments No. 2, 5, 6, and 7 (Table 4) had a second crop: a cover crop or a double-crop. Treatment No. 5 had a crimson clover (*Trifolium incarnatum* L. cv Tibbee) cover crop seeded at 6.8 kg/ha. In 1982, 1983, and 1984 we hand planted the clover cover with a Unico (Universal Coop Products, Minneapolis, MN, USA) hand-carried rotary seed sower. In 1985 we drilled the clover cover crop with the KMC Unidrill (Kelly Manufacturing Co., Tifton, GA, USA) with disk openers. Treatment No. 2 had a maturity group VIII soybean (*Glycine max* L. cv Cobb) second crop. It was interseeded into the maize

Table 3
Rainfall/irrigation (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1982	117	119	29	104	87	151 /57	141 /25	61	105 /34	92	35	135	1176
1983	109	169	236	42	60	66 /50	97 /38	59 /25	85 /39	74	91	164	1252 /152
1984	70	102	140	90	146 /31	28 /82	343	61 /25	20 /50	30	8	37	1075 /188
1985	119	107	26	22 /50	54 /44	148	194	128	101 /38	29	170	17	1115 /132
22 Yr Mean	83	90	103	80	78	108	150	120	100	66	51	69	1098

Table 4
Planting and harvest dates (month/day)

Crop	Treatment		1982	1983	1984	1985
Maize	All	Plant	3/23	3/16	4/2	4/1
		Harvest	8/3	8/15	8/13	8/12
Soybean	2	Plant	7/27	7/20	7/19	7/16
		Harvest	11/18	1/3/84	12/10	12/10
	6	Plant	8/6	8/17	8/16	8/14
		Harvest	11/24	1/3/84	12/10	12/10
Clover	5	Plant	10/1	9/16	9/18	9/17
Sunflower	7	Plant	8/10	8/18	8/17	8/14
		Harvest	11/12	11/26	11/8	11/27

(Table 4) with the hand planter. Treatment No. 6 also had a soybean second crop. Treatment No. 7 had a sunflower (*Helianthus annuus* L. cv DO-844, MCF610, and Sheyenne 24906 in 1982, 1983, and 1984 and IS-7000 in 1985) second crop. Both treatments No. 6 and No. 7 were seeded (Table 4) using the grain drill with every other seed opener closed giving 0.33-m row spacings. Bird damage in the sunflower plots was visually estimated and data were corrected before analysis as reported in Sojka et al. (1989).

All maize and sunflower were over-planted and thinned to approximately 75000 (irrigated) and 50000 (rainfed) plants/ha 7 to 10 days after emergence in 1983, 86500 (irrigated) and 61800 (rainfed) plants/ha in 1984, and 96400 (irrigated) and 86500 (rainfed) plants/ha in 1985. Soybean treatments were planted in 0.33-m row spacings at a population of about 470000 plants/ha. Table 4 lists the planting and harvest dates for maize and for second crops.

Maize, soybean, and sunflower yields were analyzed as a randomized complete block model with no split, split, or split-split plot designs. Treatments were the main effect. Irrigation and year were the splits (Table 1). Sunflower hybrid effects were significantly different only in 1984; they were averaged before final analysis. For maize, there were year by treatment interactions but no irrigation by treatment interactions. Therefore, we reanalyzed the maize data by year. Maize nutrient content was analyzed by year with a simple analysis of variance. Tensiometer data was analyzed using treatment as the main effect and irrigation, positions (mid-row and in-row), depth, and date of measurement as splits. For all analyses, we used the GLM procedure of SAS (SAS Institute, 1990) with a least significant difference mean separation procedure. Single-degree-of-freedom contrast statements were also used to compare specific groups of treatments. We considered differences up to $P<0.10$.

3. Results and Discussion

3.1. Maize yield

In 1982, before the treatments were applied to the plots, maize yields were 12.7 Mg/ha for the irrigated and 10.1 Mg/ha for the rainfed treatments. This was 1.4 to 1.6 times greater than the yields for 1983 through 1985 (Table 5). The 1982 maize yields were generally higher than normal for the Pee Dee region of South Carolina (5.5 Mg/ha: USDA, 1990). Others (Karlen and Sojka, 1985) produced extraordinarily high yields in this area in 1982 as well. The years 1980 and 1981 were drought years. Despite soil testing, some residual fertilizer was probably available below the sampling depth following the drought years, as documented in other studies (Campbell et al., 1984a). Also, though the total annual rainfall for 1982 was not different from that for 1983 to 1985, it was more uniform during the 1982 maize growing season (Table 3). Temporal uniformity of rainfall is especially important for the Norfolk soil that is sandy and has a low water holding capacity (Beale et al., 1966).

All three years

For the years 1983 through 1985, irrigated maize yields, 7.99 Mg/ha, were significantly ($P<0.01$) higher than rainfed, 6.51 Mg/ha (Table 5). Maize yields were also significantly ($P<0.10$) different among years with 1983 having a higher mean yield than 1984 and 1985. The higher yield of 1983 was probably a result of an earlier planting date (Table 4) following a higher winter rainfall than 1984 and 1985 (Table 3). The high winter rainfall, especially the 236 mm in March of 1983, at planting, is important because the winter weeds can desiccate the low-water-holding-capacity Norfolk soil.

By year

Since there was a significant ($P<0.02$) year by treatment interaction, we reanalyzed the maize yield data by year. For the analysis by year, irrigated maize plots had 20% to 26% higher yields than rainfed plots (Table 5). This difference was significant at $P<0.01$.

Table 5
Maize yield (Mg/ha) at 15% moisture content for the seven management treatments

Treatment	1983			1984			1985		
	Irrigated[1]	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean
1	8.65ab	6.94ab	7.79a	8.32a	6.91abc	7.62a	8.26ab	7.10a	7.68a
2	8.06bc	6.86ab	7.46ab	8.21a	7.00ab	7.61a	8.51ab	6.81ab	7.66a
3	8.75ab	7.16a	7.96a	8.40a	7.02a	7.71a	7.60bc	6.27b	6.93ab
4	7.49c	6.44ab	6.97bc	8.29a	6.34cd	7.32a	6.81c	6.15b	6.48b
5	6.63d	6.74ab	6.68c	6.40c	5.69e	6.04c	7.44bc	5.01c	6.23b
6	8.99a	6.33b	7.66a	8.05ab	6.35bcd	7.20a	8.54ab	6.57ab	7.56a
7	8.26abc	6.78ab	7.52ab	7.31b	5.84de	6.58b	8.86a	6.36b	7.61a
Means[2]	8.12a	6.75b		7.85a	6.45b		8.00a	6.33b	
			7.43a			7.15b			7.16b

[1]Means with the same letter within a column are not significantly different treatments at $P \leq 0.10$ using the lsd mean separation.
[2]Means by irrigation by year and by year with the same letter within a row are not significantly different treatments at $P \leq 0.10$ using the lsd mean separation.

Disked vs. non-disked

For mono-cropped maize, the conventional tillage, No. 1, and reduced tillage, No. 3, treatments outyielded the minimum tillage treatment, No. 4. Treatments No. 1 and No. 3 were compared with No. 4 using a contrast in the analysis of variance. Treatments No. 1 and No. 3 had significantly ($P<0.05$) higher yield in 1983 and 1985. This showed a yield advantage for the disked treatments, the conventional (No. 1) and the reduced tillage treatments (No. 3), over the minimum tillage treatment (No. 4). Neither treatment No. 1 nor No. 3 were consistently higher than the other. Both treatments No. 1 and No. 3 were disked at seedbed preparation for the maize.

The overall advantage of disking for maize yield was partially verified by contrasting plots that had some disking in their management scheme (treatments No. 1, 3, and 7) with those without any disking (treatments No. 2, 4, 5, and 6). In 1983 and 1985, disked plots had significantly higher ($P<0.10$) maize yields. In 1984, disked plots had higher maize yields but the difference was not significant.

Yield difference between disked and non-disked treatments is usually attributed to better seed soil contact in the disked treatments and poorer stand establishment in the non-disked treatments (Campbell et al., 1984a; Karlen and Sojka, 1985). Non-disked stand counts, measured at harvest, were on the average 4.5% lower than disked stand for all three years (Table 6). Differences between treatment No. 1 (no second crop, disked) and treatment No. 4 (no second crop, not disked) were significant ($P<0.10$) for 1984 and 1985. Though not quantified, maize in residue were also less vigorous and less uniform in size. We used the same planter for all treatments. It was a conventional-tillage planter. Different planters for the different surface conditions would have complicated the experiment. However, heavier planters used in reduced tillage plots can give more uniform, more vigorous stands.

Double cropped

Among the treatments with a double crop (No. 2, 6, and 7), maize yield for treatment No. 2 (interseeded soybeans) was significantly ($P<0.10$) higher than treatment No. 7 (drilled sunflower) in 1984. However, this difference, and other differences, were not

Table 6
Maize stand count (plants/ha $\times 10^4$) at the end of the year for the seven management treatments

Treatment	1983			1984			1985		
	Irrigated[1]	Rainfed	Mean	Irrigated	Rainfed	Mean	Irrigated	Rainfed	Mean[2]
1	5.47bc	4.61a	5.04ab	7.09ab	5.76ab	6.43ab	8.61a	6.48a	7.54a
2	5.27c	4.61a	4.94b	6.82abc	6.21a	6.51a	8.23ab	6.59a	7.41ab
3	5.72bc	4.55a	5.14ab	7.19a	5.80ab	6.50a	7.29abc	6.00a	6.64ab
4	5.52bc	4.57a	5.05ab	6.09d	5.14c	5.61c	6.46c	6.32a	6.39b
5	4.30d	4.09a	4.20c	6.42cd	5.77ab	6.09abc	7.13bc	5.68a	6.40b
6	6.62a	4.38a	5.50a	6.52bcd	5.26c	5.89c	8.15ab	6.13a	7.14ab
7	5.94b	4.50a	5.22ab	6.48cd	5.41bc	5.94bc	8.10ab	6.59a	7.34ab
Means[2]	5.55a	4.47b		6.66a	5.62b		7.71a	6.26b	

[1]Means with the same letter within a column are not significantly different treatments at $P\geq 0.10$ using the lsd mean separation.
[2]Means by irrigation by year with the same letter within a row are not significantly different treatments at $P\geq 0.10$ using the lsd mean separation.

consistent over the three years. Specifically, soybean seeding method (treatments No. 2, interseeded and No. 6, drilled) did not affect maize yield.

Maize yields for the clover winter cover, treatment No. 5, were the lowest overall and were significantly ($P<0.10$) lower than for the double-cropped treatments, No. 2, 6, and 7, for the irrigated subplots in 1983. When we compared treatment No. 5 to treatments No. 2, 6, and 7 in a contrast statement, maize yields were significantly lower ($P<0.05$) for all three years for the irrigated subplots and for 1984 and 1985 for the rainfed subplots. Lower yields for fields with cover crops in this area are usually explained by plant water use of the cover crop and subsequent poor seedling growth caused in dry seedbeds (Campbell et al., 1984a, b). In treatment No. 5, maize was planted into the clover just before spraying it with paraquat. In this sandy soil, killing the cover crop early enough to allow sufficient rewetting of the profile is important for proper early season growth (Campbell et al. 1984a, b; Ewing et al., 1991). This may have caused the differences seen here. We partially verified this with maize stand count at harvest. Stand counts for treatment No. 5 were lower than the double-cropped treatments by 24% in 1983, 0.4% in 1984, and 14% in 1985, though the treatments had been thinned to the same population. These differences were only significant ($P<0.01$) in 1983.

Mono-cropped vs. double-cropped

We contrasted mono-cropped maize, treatment No. 4, to similar double-cropped treatments, No. 2, 6, and 7. Double-cropped treatments had significantly ($P<0.03$) higher maize yields in 1983 and 1985. The differences, and the significances, were mainly for the irrigated subplots where the double-cropped treatments were 13 to 27% higher than the mono-cropped treatment. The rainfed treatments followed similar trends but were not significant in any year when they were analyzed alone.

3.2. Tensiometer readings

Tensiometers were placed in treatments No. 1 and 4 to compare water contents of conventional and minimum tillage. Tensiometer readings were always lower for the irrigated splits ($P<0.05$). There was no significant difference between the tensiometer readings at the in-row and mid-row positions. The driest part of the profile ($P<0.05$) was at about the 0.6-m to 0.9-m depths (Tables 7 and 8) for both the irrigated and rainfed splits. This corresponds to the upper part of the B horizon where roots that have grown through the subsoiled hardpan would have extracted water (Busscher et al., 1988).

Conditions were dry in 1984, except for a two-week period in July (Table 3). In 1984, the minimum tillage treatment (No. 4) was wetter than the conventional tillage treatment (No. 1). In 1985, a year of relatively uniform rainfall distribution, neither treatment was consistently wetter than the other.

3.3. Nutrient analysis

The earlier sampling date and younger plants resulted in a higher plant nutrient analysis for the whole plant samples of 1985 than for the ear leaf samples of 1984 (Table 9). Higher yielding maize treatments generally had lower nutrient analyses. Using a contrast statement,

Table 7
Tensiometer readings (kPa) for 1984. Each number is the men of three[1] reps and 21 readings from June 16 to August 8

Depth (m)	Irrigated treatment			Rainfed treatment		
	1	4	mean[2]	1	4	mean
0.15	26	23	25c	100	131	116abc
0.3	65	21	43bc	195	112	153ab
0.6	86	66	76a	139	130	135ab
0.9	83	42	63ab	195	147	171a
1.2	48	28	39c	117	80	98bc
1.5	35	19	27c	91	57	74c
mean	57a	33b		140a	109a	

[1]Rep 1 did not have tensiometers in 1984.
[2]Means within treatment with the same letter ar not different at $P<0.05$ using the lsd mean separation.

Table 8
Tensiometer readings (kPa) for 1985

Depth (m)	Irrigated treatment			Rainfed treatment		
	1	4	Mean[1]	1	4	Mean
0.15	52	54	53e	233	224	228d
0.3	137	56	96d	277	330	303bc
0.6	280	262	271a	341	415	378a
0.9	202	208	205b	341	354	348ab
1.2	150	149	149c	250	266	258cd
1.5	122	91	107d	152	174	163e
mean	157a	137a		266a	294a	

Each number is the mean of four reps and thirteen readings from June 7 to July 19.
[1]Means with treatment with the same letter are not different at $P<0.05$ using the lsd mean separation.

the higher yielding disked treatments (No. 1, 3, 7) had lower N and P in 1984 and N, P, and K in 1985 than the non-disked treatments (No. 2, 4, 6) at $P<0.03$. The same pattern was seen with the non-double cropped treatments (No. 1, 3 vs. No. 4), but differences were not significant in 1984. The lowest yielding treatment (No. 5, the clover cover crop) had higher N, P, and K in 1984 and P and K in 1985 than the other treatments though it was not always significantly higher (Table 9).

High nutrient content of the lower yielding treatments would be an indication of adequate nutrient availability with slow growth and water stress (though the treatments were the irrigated). The water stress can be partially explained by not having irrigation on the plots from the beginning of the growing season combined with the low water holding capacity of the soils. Microirrigation tubes were installed by June 14, 1983, May 23, 1984, and April 25, 1985: 3 to 13 weeks after planting.

In contrasts, the irrigated double-cropped treatments (No. 2, 6, and 7) had higher maize yields than irrigated mono-cropped maize treatment No. 4 in 1985. However, maize N, P,

Table 9
Nutrient analysis (g/Kg) of the irrigated subplots for June 12, 1984 (ear leaf samples) and May 13, 1985 (whole plant samples)

Treatment	1984			1985		
	N	P	K	N	P	K
1	26.1a[1]	2.72c	30.6ab	33.3b	2.91c	52.0cd
2	25.8a	3.08bc	28.9bc	39.6a	3.80a	59.0ab
3	25.9a	3.00bc	28.8bc	33.5b	3.19bc	51.6d
4	26.1a	3.15ab	28.9bc	38.9a	3.69a	57.8ab
5	27.8a	3.45a	31.5a	40.1a	3.90a	61.0a
6	26.6a	3.05bc	27.4c	40.5a	3.64a	59.1ab
7	23.5b	3.10ab	28.4bc	34.8b	3.56ab	56.0bc

[1]Means with the same letter within the column are not signficantly different treatments at $P \geq 0.05$ using the lsd mean separation.

and K values were not significantly different; they were similar (Table 9). This would be consistent with recent findings by Johnson et al. (1992) that soil fungi in monoculture are detrimental to the uptake of nutrients but not in rotations. They found that soil micorrhizal fungi were negatively correlated with yield and tissue mineral concentration of continuous maize. They suggested that the buildup of fungi, to the detriment of maize nutrient uptake, caused a yield decrease.

Treatments No. 5 and 6 (clover cover crop and drilled soybean) had the highest N contents in 1984 and 1985. This is consistent with their ability to fix soil nitrogen. To further verify this, a contrast of legume treatments No. 2, 5, and 6 vs. non-legume treatments showed significantly ($P < 0.05$) higher N in both 1984 and 1985.

3.4. Double-crop yields

Table 10 lists the yields for the double crops, soybean and sunflower. Neither the soybean nor the sunflower had yields that were consistently high enough to be on a par with mono-cropped culture. Soybean yield averaged 0.63 Mg/ha over 4 y and sunflower yields averaged 0.89 Mg/ha.

Soybean yields did not differ between the drilled and interseeded treatments or between irrigated and rainfed treatments. There were yield differences among years. In 1985, soybean yield was higher ($P < 0.05$) because of an especially wet late summer and early fall (Table 3). In that year, soybeans yields, averaging 1.19 Mg/ha, were comparable to county average full-season yields of 1.3 Mg/ha (USDA, 1990). Net sunflower yields in 1982 and 1984 were toward the bottom of the range of mono-cropped production, 1.0 to 2.5 Mg/ha (Sojka *et al.*, 1990). This is at least partly attributed to sunflower high fertilizer requirement (Table 2).

Table 10
Double crop yield (kg/ha) for soybean at 13% moisture content and for sunflower at 9% moisture content

Crop	Treatment[1]		1982	1983	1984	1985
Soybean	2	I	265	573	457	959
		N	450	852	281	793
	6	I	638	420	450	1678
		N	418	359	230	1334
	2&6	Mean	443bc	551b	354c	1191a
Sunflower	7	I	1193	253	1006	815
		N	1144	349	1178	1178
		Mean	1168a	301c	1092ab	997b

[1]I = irrigated, N = Rainfed, treatment means in the same row with the same letter are not statistically significant different at $P < 0.05$ using the lsd mean separation.

4. Conclusion

Of the seven management treatments in the experiment, those with disking in some phase of the management had best maize yields. Better seed-soil contact of heavier new improved planters could improve the non-disked stand and yield. Averaged over the four years neither second crop produced yields that were on a par with the full season yields. However, including a second crop increased maize yields for two of the three years. Lower yielding treatments generally had higher plant nutrient contents. In 1985, maize yields for the double-cropped treatments were higher than mono-cropped maize yields but nutrient concentrations were not significantly lower. This is consistent with recent findings by Johnson et al. (1992) that soil fungi in monoculture are detrimental to the uptake of nutrients but not in rotations. Successful adaptation of this system in this or other areas would depend on the system's ability to improve maize and double-crop production and on the conservation aspects of the double crop.

References

Beale, O.W., Peele, T.C. and Lesesne, F.F., 1966. Infiltration rates of South Carolina soils during simulated rainfall. S.C. Agricultural Experiment Station Technical Bulletin 1022.

Busscher, W.J. and Sojka, R.E., 1987. Enhancement of subsoiling effect on soil strength by conservation tillage. Trans. ASAE, 30: 888–892.

Busscher, W.J., Sojka, R.E. and Doty, C.W., 1986. Residual effects of tillage on Coastal Plain soil strength. Soil Sci., 141: 144–148.

Busscher, W.J., Karlen,D.L., Sojka, R.E. and Burnham, K.P., 1988. Soil and plant response to three subsoiling implements. Soil Sci. Soc. Am. J., 52: 804–809.

Campbell, R.B., Karlen, D.L. and Sojka, R.E., 1984a. Conservation tillage for maize production in the U.S. southeastern Coastal Plain. Soil Till., 4: 511–529.

Campbell, R.B., Sojka, R.E. and Karlen, D.L., 1984b. Conservation tillage for soybeans in the U.S. southeastern Coastal Plain. Soil Till., 4: 531–541.

Campbell, R.B., Busscher, W.J., Beale, O.W. and Sojka, R.E., 1988. Soil profile modification and cotton production. Beltwide Cotton Prod. Res. Conf. Proc. Jan. 3–8, 1988, pp. 505–509.

Clemson University., 1982. Lime and fertilizer recommendations based upon soil test results. Cooperative Extension Service Cir. No. 476, Clemson, SC, USA

Crookston, R.K., Kurle, J.E., Copeland, P.J., Ford, J.H. and Lueschen, W.E., 1991. Rotational cropping sequence affects yield of corn and soybean. Agron. J., 83: 108–113.

Ebelhar, S.A.., Frye, W.W., Blevins, R.L., 1984. Nitrogen from legume cover crops for no tillage corn. Agron. J., 76: 51–55.

Ewing, R.P., Wagger, M.G. and Denton, H.P., 1991. Tillage and cover crop management effects on soil water and corn yield. Soil Sci. Soc. Am. J., 55: 1081–1085.

Havlin, J.L., Kissel, D.E., Maddux, L.D., Claassen, M.M. and Long, J.H., 1990. Crop rotation and tillage effects on soil organic carbon and nitrogen. Soil Sci. Soc. Am. J., 54: 448–452.

Johnson, N.C., Copeland, P.J., Crookston, R.K. and Pfleger, F.L., 1992. Mycorrhizae: Possible explanation for yield decline with continuous corn and soybean. Agro. J., 84: 387–390.

Karlen, D.L. and Sojka, R.E., 1985. Hybrid and irrigation effects on conservation tillage corn in the Coastal Plain. Agron. J., 77: 561–567.

Langdale, G.W., Barnett, A.P., Leonard, R.A. and Fleming, W.G., 1979. Reduction of soil erosion by the no-till system in the southern Piedmont. Trans. ASAE, 22: 82–86.

Martin, M.A., Schreiber, M.M., Riepe, J.R. and Bahr, J.R., 1991. The economics of alternative tillage systems, crop rotations and herbicide use on three representative East-Central Corn Belt farms. Weed Sci., 39: 299–307.

Mills, W.C., Thomas, A.W. and Langdale, G.W., 1988. Rainfall retention probabilities computed for different cropping-tillage systems. Agric. Water Management, 15: 61–71.

NOAA, U.S. Dept. of Commerce., 1983. Climatic Atlas of the United States, National Climatic Data Center, Federal Building, Ashville, NC 28801, USA.

SAS Institute., 1990. SAS/STAT Users Guide, Version 6, Fourth Edition, SAS Institute, Inc., Cary, NC, USA.

Sojka, R.E., Arnold, F.B., Morrison III, W.H. and Busscher, W.J., 1989. Effects of early and late planting on sunflower performance in the Southeastern United States. Appl. Agric. Res., 4: 37–46.

Sojka, R.E., Busscher, W.J. Gooden, D.T. and Morrison, W.H., 1990. Subsoiling for sunflower production in the Southeast Coastal Plains. Soil Sci. Soc. Am. J., 54: 1107–1112.

US Department of Agriculture, 1990. South Carolina crop, livestock, and poultry statistics, County Bulletin, June 1990, National Agricultural Statistics Service, Columbia, SC, USA.

US Department of Commerce, 1968. Climatic atlas of the United States. National Climatic data Center, Ashville, NC, USA

Zhu, J.C., Gantzer, C.J., Anderson, S.H., Alberts, E.E. and Beuselinck, P.R., 1989. Runoff, soil and dissolved nutrient losses for no-till soybeans with cover crops. Soil Sci. Soc. Am. J., 53: 1206–1210.