Tillage Systems for Double-Cropped Wheat and Soybean

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Abstract. Eliminating tillage operations can improve profits, but only if the elimination of tillage does not restrict yields or result in excessive use of herbicides and other chemicals. The objective of this study, conducted at seven locations for 3 years, was to identify the least amount of tillage needed for wheat grown in a double-cropping system with soybean. Tillage treatments prior to planting wheat each year consisted of no tillage, disking, chiseling, and moldboard plowing. Two methods of soil leveling after deep tillage (chisel and moldboard plow) were dragging and disking. Tillage prior to planting soybean consisted of no tillage and in-row subsoiling. When averaged across years and soils, no tillage resulted in 23, 30, and 31% lower wheat-grain yields than disking, chiseling, and moldboard plowing, respectively. On most soils, the adverse effects of no tillage increased with years. Disk tillage resulted in adequate yield in only two of the seven soils. Except for one soil, chiseling resulted in yields equal to moldboard plowing. Yields did not vary among leveling methods after deep tillage. Deep tillage prior to planting wheat eliminated the need for in-row subsoiling at soybean planting even on soils with root restricting tillage pans. In-row subsoiling at soybean planting did not eliminate the need of deep tillage prior to planting wheat. Judging from the relationship between yields and the amount of surface soil tilled, surface soil compaction, even on silt loam soils, may restrict wheat grain yields as much if not more than tillage pans.

Introduction

For conservation tillage to gain widespread acceptance, yields with conservation tillage must be comparable to yields obtainable with multiple tillage operations. Many reports in the literature indicate that yields can be maintained with conservation tillage, but others indicate that they cannot. In studies where conservation tillage resulted in lower yields than conventional tillage, the lower yields have been attributed to many factors, including uncontrolled pests such as weeds, diseases, and insects (Burnside et al., 1980; Dick and Van Doren, 1985; Papendick and Miller, 1977), poor seed placement and/or stands (Hallauer and Colvin, 1985; Izaurralde et al., 1986), fertility stress (Kang et al., 1980), and compaction (Braim et al., 1984; Hargrove and Hardcastle, 1984).

Management technology currently available, can, in most situations, economically eliminate the adverse effects of pests, poor plant stands, and fertility stress that can exist in conservation tillage systems. Theoretically, soil compaction should be less with no tillage than conventional tillage. Organic matter levels tend to be higher with no tillage than conventional tillage (Blevins et al., 1983; Dick, 1983), and compaction and organic matter levels are inversely related (Davidson et al., 1967; Klute and Jacobs, 1949; Morachan et al., 1972). In addition, reduced machinery traffic with no tillage should result in less soil compaction. However, some reports (Douglas et al., 1980; Gantzer and Blake, 1978) have indicated that compaction can be greater as tillage is reduced.

Many of the sandy Coastal Plain soils are highly compactable (Campbell et al., 1974); and contain root restricting tillage pans 8 to 12 inches below the soil surface (Reicosky et al., 1977). These relatively thin (1 to 2 inches thick) tillage pans are created primarily by tillage implements and machinery traffic (Reicosky et al., 1977). If they are not fractured at planting, crop yields can be severely reduced, especially in dry years (Kamprath et al., 1979; Peele et al., 1974). In areas where these root restricting tillage pans are common, in-row subsoilers are used at planting. These subsoilers, which are generally attached to the planting unit, fracture the tillage pan directly under the row and permit root growth into the subsoil area (Reicosky et al., 1977; Trouse, 1983). In untilled soils, they also fracture and loosen a 6- to 12-inch strip of surface soil. Data reported by Whiteley and Dexter (1982) suggest the possibility that positive yield re-

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sponses to in-row subsoilers are due as much from fracturing the surface soil as from fracturing the tillage pan. Although these subsoilers are needed in soils with tillage pans, they create problems such as slow planting speeds, high horsepower requirements, and high initial investments. In addition, soils and or conditions in which in-row subsoilers are needed have not been well defined. These problems are one of the primary reasons for slow adaptation to conservation tillage in sandy Coastal Plain soils.

In the southeastern USA, double-cropping wheat (*Triticum aestivum* L.) and soybean (*Glycine max* L. Merr.) is a common practice. For this practice to be successful, soybeans have to be planted immediately after wheat harvest because each 1-day delay in planting soybean after wheat harvest can reduce soybean yield an average of 0.3 bu/A (20 kg/ha) (Thurlow, 1986). To avoid delays caused by tillage, no-tillage production is frequently used. Data from a previous study (Touchton and Johnson, 1982) indicate that yield of no-tillage wheat can be reduced 8 bu/A unless deep tillage (chisel or moldboard plowing) is used prior to planting soybean or in-row subsoiling is used at soybean planting. Other studies have indicated that some form of deep tillage is needed prior to planting wheat (Hamblin and Tennant, 1971; Hargrove and Hardcastle, 1984). The interval between harvesting and planting, however, is not as critical for soybean harvest and wheat planting as it is for wheat harvest and soybean planting. Thus, for soils where some tillage is needed, it would be more opportune to till prior to planting wheat instead of after wheat harvest. Since there is no fallow period between wheat harvest and planting of double-cropped soybean, wheat root growth promoted by tillage may prevent soil recompaction and form macropores that would eliminate the need for in-row subsoiling for soybean. The objectives of these field studies were to determine tillage effects on wheat yield and if tillage prior to planting wheat would eliminate the need for in-row subsoiling at soybean planting.

Materials and Methods

These field studies were conducted for 3 years on seven soils within three geographic regions of Alabama (Table 1). At each location, double-cropping wheat and soybean is a common practice. Each of the Coastal Plain soils contained defined tillage pans 5 to 9 inches below the soil surface. On these soils, yield responses to in-row subsoiling at soybean planting is not uncommon. The Sumpter and Decatur soils generally do not contain root restricting tillage pans, and yield responses to in-row subsoiling on these soils are not common. The shrink swell characteristic of the Sumpter soil and the clay content (>35%) of the Bt horizon in the Decatur soil preclude formation of root restricting tillage pans. Treatments consisted of 6 tillage systems prior to planting wheat and 2 at soybean planting. Tillage treatments prior to planting wheat were 1) no tillage, 2) disk only, 3) chisel-disk, 4) moldboard plow-disk, 5) chisel-drag, and 6) moldboard plow-drag. The dragging implements for treatments 5 and 6 consisted of a heavy metal bar chained to the back of the tillage implement. The disk-only treatment consisted of 1 pass with an offset tandem disk. Depth of disking was 3 to 5 inches. Shank spacing on the chisel plows was 15 inches for each of the dual tool bars. The shanks on the front and back tool bars were offset so that actual distance between chisel points was 7½ inches. Actual depth of chiseling ranged between 6 and 9 inches. Turning depth with the moldboard plow for treatments 4 and 6 was 8 to 10 inches. Estimated tillage costs for tillage treatments 2–6, respectively, are $6, $12, $13, $7, and $8/A.

After wheat harvest each year, the wheat plots were split, and soybean was planted into wheat stubble with (except on the Sumpter and Decatur soils) and without in-row subsoiling. Depth of subsoiling was 10 to 12 inches. Subsoilers were attached directly in front of each planting unit. A cutting coulter was mounted in front of each subsoil shank to cut straw, and fluted coulters were mounted to the side and rear of each shank to firm and level the soil. The subsoil shank plus fluted coulters tilled a strip of soil approximately 10 inches wide at the soil surface, which tapered to a 2-inch width at the subsoil point.

Fertilizer and lime applications were based on residual fertility levels in the upper 6 inches of soil. When needed, P, K, and lime were applied in the fall of the year. Nitrogen fertilizer (prilled ammonium nitrate) was applied only to wheat at a rate of 20 lb/A (22 kg/ha) N at planting and 60 lb/A N in late winter. For soybean, weeds were effectively controlled with a preemergence application of metribuzin and paraquat, and a post directed application of linuron or paraquat when the preemergence application did not provide adequate control. Insecticides were applied as needed to soybean. Each year wheat was planted in November and soybean was planted in late May or early June. Wheat was drilled in 6⅔-inch (9.4 cm) row widths, and soybean was planted in 36-inch (91 cm) row widths the first year and 24- to 30-inch row widths in subsequent years when the in-row subsoiler was used. When the subsoiler was not used, row widths were 18 to 24 inches depending on location. Seedling rates were 60 and 90 lb/A for soybean and wheat, respectively. Plot width was 24 ft (7.3 m) and length, which varied with location, ranged from 30 to 50 ft. Prior to harvest of each crop, a minimum of 5 ft was trimmed from the ends of each plot, and a 8- to 14-ft strip, depending on location, was combined from the center of each plot for yield determinations. Yields for both crops were adjusted to 13% moisture.

Table 1. Soil descriptions

Series	Family	Subgroup	Order	Geographic Region
Dothan	Fine-Loamy, siliceous, Thermic	Plinthic Paleudults	Ultisols	Coastal Plain
Malbis	Fine-Loamy, siliceous, Thermic	Plinthic Paleudults	Ultisols	Coastal Plain
Benndale	Coarse-Loamy, siliceous, Thermic	Typic Paleudults	Ultisols	Coastal Plain
Lucedale	Fine-Loamy, siliceous, Thermic	Rhodic Paleudults	Ultisols	Coastal Plain
Bama	Fine-Loamy, siliceous, Thermic	Typic Paleudults	Ultisols	Coastal Plain
Sumpter	Fine-silty, carbonatic, Thermic	Rendollic Eutrochrepts	Inceptisols	Prairie
Decatur	Clayey-Kaolinitic, Thermic	Rhodic Paleudults	Utisols	Limestone Valley

Data collected include yield at maturity, soil water infiltration from the middle of the soybean rows in July with the double ring infiltrometer (Bertrand, 1965), and soil bulk density in mid-July by the core method from the surface 5 inches of soil (core size was 4¼ by 5 inches) on the Dothan, Benndale, and Lucedale soils. The upper 8 inches of surface soil at all locations was sampled in July for organic matter determinations with a Leco carbon analyzer, and cation exchange capacity by summation of cations. An analysis of variance was conducted prior to the determination of protected least significant difference (FLSD) values at the 90% level of confidence.

Results and Discussion

Soil leveling methods (disking and dragging) after deep tillage had no effect on wheat or subsequent no-tillage soybean yields. Therefore, data presented for the chisel and moldboard plow treatments are averaged over leveling methods.

Although differences between years occurred and interactions between years and tillage treatments existed, the effects of tillage were consistent enough that conclusions drawn from 3-year averages did not result in substantially different conclusions than those drawn using any one year of data. No treatment resulted in higher wheat or soybean yields (Table 2) than moldboard plowing, and for comparison purposes, the moldboard plow is used as the standard treatment.

Wheat Grain Yields

No tillage resulted in lower yields than any other treatment (Table 2). When averaged across soils, no tillage resulted in 23, 30, and 31% lower wheat grain yields than disking, chiseling, and moldboard plowing, respectively. On the Lucedale and Sumpter soils, disking-only resulted in yields equal to moldboard plowing. On the Benndale, Lucedale, Bama, Sumpter, and Decatur soils, chiseling resulted in yields equal to moldboard plowing.

The increased yield with increased tillage indicates that yield-restricting surface soil compaction existed on all soils. Soils that showed greatest yield response to the amount of surface soil tilled (disking vs. chisel or moldboard plowing) were the Dothan, Benndale, and Bama soils. Since incremental increases in yields decreased as the amount and depth of surface soil tilled increased (yields averaged 31, 40, 44, and 45 bu/A (2.1, 2.7, 3.0, and 3.1 Mg/ha) for no tillage, disk, chisel, and moldboard plow, respectively), it appeared that surface soil compaction, rather than deep tillage pans, was the greatest yield restricting factor with no-tillage wheat on these soils.

On coarse loamy soils with well developed tillage pans, such as the Dothan and Benndale soils, depth of tillage can have a large influence on plant growth and yields. The tillage pan depth on the Dothan and Benndale soils was 8 to 9 and 5 to 6 inches, respectively. The moldboard plow (10-inch depth) penetrated the tillage pan on both soils, but the chisel plow did not penetrate the deep pan in the Dothan soil. Failure to penetrate the tillage pan in the Dothan soil may be the reason why chisel plowing resulted in inferior yields to the moldboard plow on the Dothan but not the closely related Benndale soil. This response indicates that the disruption of tillage pans may also be important for wheat production.

Yield differences between no tillage and the absolute highest yielding deep tillage treatment were greater the second than first year except on the Lucedale and Sumpter soils (Table 3). The difference continued to increase the third year on the Dothan, Malbis, Benndale, and Bama soils, which indicates that the adverse effect of continuous no tillage on wheat-grain yield can increase with time on some soils.

In-row subsoiling at soybean planting resulted in an early season visual growth response for the following wheat crop planted without tillage and with disk tillage. The wheat that was 4 to 6 inches on each side of the old subsoil track grew faster and had a darker green color than wheat in the old row middles. In-row subsoiling at soybean planting,

Table 2. Wheat grain yield as affected by tillage prior to planting wheat[a]

Tillage	Dothan	Malbis	Benndale	Lucedale	Bama	Sumpter	Decatur
	Soil						
				bu/A[b]			
No-till	32	36	19	43	26	31	32
Disk	40	42	27	51	37	40	42
Chisel	45	43	35	52	45	40	45
Moldboard	52	48	36	50	45	39	48
FLSD 0.10	3.5	2.7	2.6	3.0	3.5	2.6	2.4

[a] Yields are averaged over 3 years and planting methods for double-cropped soybeans.
[b] bu/A × 67.2 = kg/ha.

Table 3. Wheat grain yield reductions with no tillage compared to the highest yielding deep tillage treatment[a]

Tillage	Dothan		Malbis		Benndale		Lucedale		Bama		Sumpter		Decatur	
	Soil													
	(%)	(bu/A)	(%)	(bu/A)	(%)	(bu/A)	(%)	(bu/A)	(%)	(bu/A)	(%)	(bu/A)	(%)	(bu/A)
1	32	16	6	4	37	18	20	12	22	15	22	14	6	3
2	34	18	15	9	42	21	20	10	30	15	15	5	63	34
3	58	29	69	27	71	12	12	6	84	26	28	11	40	21

[a] bu/A × 67.2 = kg/ha.

however, resulted in higher wheat grain yield in only one year and only on the Dothan (6 bu/A) and Benndale (8 bu/A) soils. Improved wheat yields form in-row subsoiling for soybean, however, did not result in yields equal to those obtained with deep tillage (chisel or moldboard plow) prior to planting wheat at any location.

Soybean Yield

Tillage prior to planting wheat did not have an effect on soybean yields except on the Dothan and Benndale soils (Table 4). Within years, the response to tillage occurred in 2 of the 3 years on the Dothan soil and each year on the Benndale soil. At the five locations where in-row subsoiling at soybean planting was a treatment, it improved yields only on the Dothan and Benndale soils. These were the same soils in which tillage prior to planting wheat influenced soybean yields. On all soils, however, in-row subsoiling resulted in greater early season growth and larger plants at maturity than when in-row subsoilers were not used (data not shown). In-row subsoiling improved yields only when deep tillage was not used prior to planting wheat, which indicates that deep tillage prior to planting wheat can eliminate the need for expensive in-row subsoilers for no-tillage soybean when soybean are planted in relatively narrow rows (18 to 24 inches). If wider rows (30 to 36 inches) had been used, however, the increased plant growth from in-row subsoiling would probably have resulted in yield increases over smaller plants in nonsubsoiled rows.

Soil Properties

During the 3-year test period, significant differences in bulk densities, organic matter contents, and cation exchange capacities were not found. Water infiltration rates, however, were influenced by tillage treatments. Differences in water infiltration varied among years and soils (Table 5). Although differences in bulk densities were not detected, differences in infiltration rates indicate that soil physical characteristics were affected by tillage.

Generally, deep tillage resulted in more water infiltration during the 30-minute period than disk or no tillage. There were no differences ($P = 0.10$) in infiltration rates between no tillage and disk tillage. No tillage and disk tillage resulted in less infiltration (up to 3 inches in 30 min) than moldboard plowing in five of the nine comparisons. No tillage and disk tillage resulted in less infiltration than chiseling in four of the nine comparisons. Chisel plowing resulted in less infiltration than moldboard plowing (up to 2.2 inches) in only three of the nine comparisons. Although interactions between soil types and tillage systems existed, definite trends in

Table 4. Yield of no-tillage soybean (3-year average) as affected by in-row subsoiling at planting and tillage prior to planting wheat

Wheat tillage	Dothan SS[a]	Dothan NS	Malbis SS	Malbis NS	Benndale SS	Benndale NS	Lucedale SS	Lucedale NS	Bama SS	Bama NS	Sumpter	Decatur
							bu/A[c]					
No-till	43	40	52	49	46	30	32	35	31	28	35	33
Disk	45	40	49	47	49	36	37	36	29	24	30	30
Chisel[b]	46	44	49	49	48	43	38	35	31	27	33	31
Moldboard	43	44	50	52	49	45	37	36	30	28	31	28
FLSD (0.10)	3		ns		5		ns		ns		ns	ns

[a] SS is in-row subsoiling and NS is no subsoiling. Subsoiling was not a treatment variable on the Sumpter and Decatur Soils.
[b] Yields from chisel and turn treatments are averaged over leveling methods.
[c] bu/A × 67.2 = kg/ha.

Table 5. Water infiltration over 30 minutes as affected by tillage prior to planting wheat, soil type, and years

Soil	Year	No-till	Disk	Chisel	Moldboard	FLSD (0.10)
				(infiltration, in./30 min)[a]		
Dotahn	1981	2.2	1.7	2.2	2.4	0.6
	1982	1.3	1.6	1.5	1.7	0.2
	1983	2.2	2.0	2.8	5.1	0.6
Lucedale	1981	2.0	2.4	4.7	5.2	0.7
	1982	1.5	2.0	3.5	3.8	0.6
	1983	1.4	1.2	1.5	1.6	NS
Benndale	1981	0.7	1.0	0.9	2.4	0.7
	1982	0.5	0.2	1.1	1.0	0.3
	1983	2.9	2.2	3.0	3.2	0.6

[a] in. × 2.54 = cm.

infiltration between soil types and tillage were not distinguishable among years.

Differences in grain yield among tillage systems could possibly have been due to changes in soil physical characteristics. Deep tillage prior to planting wheat resulted in highest yields at locations where water infiltration rates were measured, and this treatment generally resulted in the greatest infiltration rates. Since soils are generally wet during the winter months, yield improvements associated with increased water infiltration were probably a result of better internal drainage than increased soil moisture levels. Differences in infiltration rates are commensurate to yield differences between deep tillage and disk or no tillage only. Yield differences between no tillage and disk tillage were common, but infiltration differences between these tillage systems were infrequent.

Summary and Conclusions

As expected, method of leveling the soil after deep tillage had no effect on yields. Therefore, when leveling is needed, a drag bar attached to the tillage implement would be more economical than a separate leveling operation. When yields of both crops are considered, the highest yielding system would be no-tillage soybean with deep tillage prior to planting wheat on soils with physical characteristics similar to the Dothan, Malbis, Benndale, Bama, or Decatur soils. On soils with physical characteristics similar to the Lucedale or Sumpter soils, disking prior to planting wheat would be the most economical tillage system. However, it is not easy to separate the Lucedale from the Dothan, Malbis, or Bama soils on the basis of soil characteristics. If the presence of a root restricting tillage pan cannot be determined, the best option would be to chisel plow prior to planting wheat. On soils with root restricting tillage pans, deep tillage prior to planting wheat can eliminate the need for expensive in-row subsoilers in conservation-tillage soybean production. Although in-row subsoiling at soybean planting can have some residual effect on yield on the subsequent wheat crop, it will not compensate for deep tillage prior to planting wheat. Deep tillage can be accomplished and some conservation practices can be maintained by using a chisel plow instead of a moldboard plow prior to planting wheat.

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