Tillage Intensity Effects on Corn and Grain Sorghum Growth and Productivity on a Vertisol

K. N. Potter,* J. E. Morrison, Jr., and H. A. Torbert

Sustainable production systems and conservation tillage practices are needed to control water erosion on vertisols. Five levels of tillage intensity were tested for 3 yr for effects on growth and yield of corn (*Zea mays* L.) and grain sorghum [*Sorghum bicolor* (L.) Moench.] on a Houston Black clay soil (fine montmorillonitic, thermic Udic Pellusterts). Tillage intensity treatments included: chisel plow with secondary tillage; disk only; no-till with residue rakes at planting; no-till with midseason cultivation; and no-till. Corn plant populations were greater in tilled treatments than in no-till treatments in 2 of the 3 yr. Corn above-ground biomass production was generally reduced in no-till treatments early in the growing season, but by silking differences among treatments were not significantly different. Corn yielded 840 lb/acre more on average with tillage than with no-till. Plant population differences accounted for much of the difference in corn grain yields, with low plant populations restricting yield in some years. Grain sorghum populations were not consistently affected by tillage intensity, and biomass production was less sensitive to tillage intensity than corn. Grain sorghum yields were as large or larger in no-till treatments than in tilled treatments, except in one instance where population was reduced.

Corn and grain sorghum are planted on over half of the land used for grain crops in the central Texas Blacklands, an area covering 13 million acres (Texas Agricultural Statistics Service, 1995). Soils in this region are predominantly heavy-clay vertisols which are highly erosive when exposed to heavy spring rains. Sustainable conservation tillage practices are needed to control water erosion on vertisols (Potter et al., 1995).

Use of soil-conserving management practices is complicated by the soil's large shrink/swell potential, high water holding capacity, plastic and sticky consistency when wet, great strength when dry, and a limited range of water contents when tillage may be performed. Many vertisols, including the Houston Black, are self-mulching, i.e., the surface layer has a natural tendency to granulate, which retards soil drying below the surface layers (Grant and Blackmore, 1991). This often causes the soils to be tilled at high water contents, resulting in adverse soil conditions that may strongly affect plant growth (McGarry, 1981; So et al., 1988; Hodgson and MacLeod, 1989).

Management techniques that retain a large portion of the crop residue on the surface are effective in reducing soil erosion by water (Unger, 1990; Potter et al., 1995). Morrison et al. (1990) developed a wide-bed controlled-traffic management system which retained most crop residues on the soil surface. Early evaluations indicated that vertisol properties were not adversely affected by this management system (Gerik et al., 1987). However, after 10 yr of continuous no-till, bulk density and soil strength values were increased in the surface 12 in. (Potter and Chichester, 1993).

Previous conservation tillage experiments on the Houston Black soil have been restricted to comparing no-till and chisel plowing. The effect of less extreme management options had not been explored. Therefore, the objective of this study was to determine the effect of a range of tillage intensities on the growth and grain yield of corn and grain sorghum.

MATERIALS AND METHODS

The study was conducted at the Grassland Soil and Water Research Lab at Temple, TX, on a Houston Black clay soil. Temple is located at 31° N latitude and 97° W longitude with a mean elevation of about 700 ft. The Houston Black clay soil contains 4% sand, 39% silt, and 56% clay in the surface 0 to 12 in. depth. Mean annual rainfall is 34 in. Most rain occurs between October and July, with the driest period occurring from July to September.

The study was conducted using a management system recently developed for the central Texas Blacklands which uses 5 ft wide beds with 20 in. wide furrows between beds (Morrison et al., 1990). This system restricts traffic to the furrows and provides surface drainage for the beds. Beds may be tilled out and reconstructed every year or the beds may be maintained by no-till management practices. Field plots were established in 1991 on an area which had been in continuous no-till management for 10 yr. During this period, the effect of long-term no-till management on soil properties had been established (Potter and Chichester, 1993). A portion of the area was tilled to provide for comparisons of selected levels of tillage intensity on crop establishment, growth, and productivity. A randomized block experimental design was used with five replications of tillage treatments representing five levels of tillage and residue management. The treatments consisted of complete-till, reduced-till, no-till, no-till/cult, and no-till/rake. Management operations for the five tillage systems are presented in Table 1. The complete-till involved three preplant tillage operations to provide nearly complete residue burial. The reduced-till had a single preplant disk tillage operation. No-till was a strict slot plant management system. No-till/cult was a slot-plant with a post-plant mid-season cultivation. No-till/rake was a slot plant with residue rakes attached to the planter to sweep crop residue away from the row. Corn and grain sorghum responses to tillage practices were measured in 1992, 1993, and 1994.

USDA-ARS, 808 East Blackland Rd., Temple, TX 76502. Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of others that may also be suitable. Received 25 Sept. 1995. *Corresponding author (potter@brcsun0.tamu.edu).

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Table 1. Summary of annual tillage treatment operations.

Operation	Season	Complete till	Reduced till	No-till/ rake	No-till/ cult	No-till
Flail chop residue	Fall	x	x			
Chisel plow	Fall	x				
Tandem disk	Fall	x	x			
Field cultivator	Fall	x				
Bed	Fall	x	x			
Herbicide	Fall	x	x	x	x	x
Fertilize	Spring	x	x	x	x	x
Plant	Spring	x	x	x†	x	x
Herbicide	Spring	x	x	x	x	x
Cultivate	Spring				x	
Harvest	Summer	x	x	x	x	x

† Residue rakes cleared the row zone during planting.

Fertilizer was applied to corn plots at a rate of 145 lb N/acre and 135 lb P_2O_5/acre prior to planting with a coulter nozzle applicator, which placed the fertilizer in the surface 2 in. of soil (Morrison and Potter, 1994). Liquid starter fertilizer (10–34–0) was applied in the furrow adjacent to the seed at planting to all tillage regimes at a rate of 5 lb N/acre and 39 lb P_2O_5/acre. Corn (cultivar Dekalb 671 in 1992, and Dekalb 689 in 1993 and 1994) was planted into soybean [*Glycine max* (L.) Merr.] residue each year at a rate of 23 800 seeds/acre in 1992 and 27 000 seeds/acre in 1993 and 1994. Planting dates were 26 Mar. 1992, 10 Mar. 1993, and 18 Mar. 1994.

Fertilizer was applied to grain sorghum plots at a rate of 120 lb N/acre and 110 lb P_2O_5/acre prior to planting. Liquid starter fertilizer, (10–34–0), was applied in the furrow adjacent to the seed at planting to all tillage regimes at a rate of 5 lb N/acre and 39 lb P_2O_5/acre. Grain sorghum (cultivar Golden Acres TEY75 in 1992 and 1993 and Dekalb 37 in 1994) was planted into corn residue, between the old corn rows, at a rate of 140 500 seeds/acre on 26 Mar. 1992, 1 Apr. 1993, and 16 Mar. 1994.

Surface residue cover from the previous crop was determined immediately after planting by an image analysis technique. In this method, the percentage of pixels falling within residue is determined on electronic photographs (Morrison et al., 1993).

The number of plants that had emerged were counted daily in a 64 sq ft area randomly located within the tillage plots from the time of first emergence until a constant number of plants was obtained. The final emergence count was considered as the final plant population.

Biomass accumulation rates were determined by sampling the above-ground biomass of six corn plants each week and eight grain sorghum plants each week from the time of final emergence-number determinations to anthesis. The plants were oven dried at 150°F to a constant weight.

Grain was harvested with a plot combine equipped with a weighing device. The net weight of grain harvested from each plot was recorded electronically. A subsample of grain was taken for moisture content determination. Reported grain yields were corrected to 15.5% moisture for corn and 15% moisture for grain sorghum.

Data were subjected to analysis of variance using a randomized block design. If the analysis of variance was significant ($P = 0.05$), Tukey's least significant difference test was used to separate mean differences. Regression analysis was used to determine population effects on grain yield (SAS, 1985).

RESULTS AND DISCUSSION

Corn

Corn emergence rates and final populations varied from year to year among treatments (Fig. 1). Emergence was

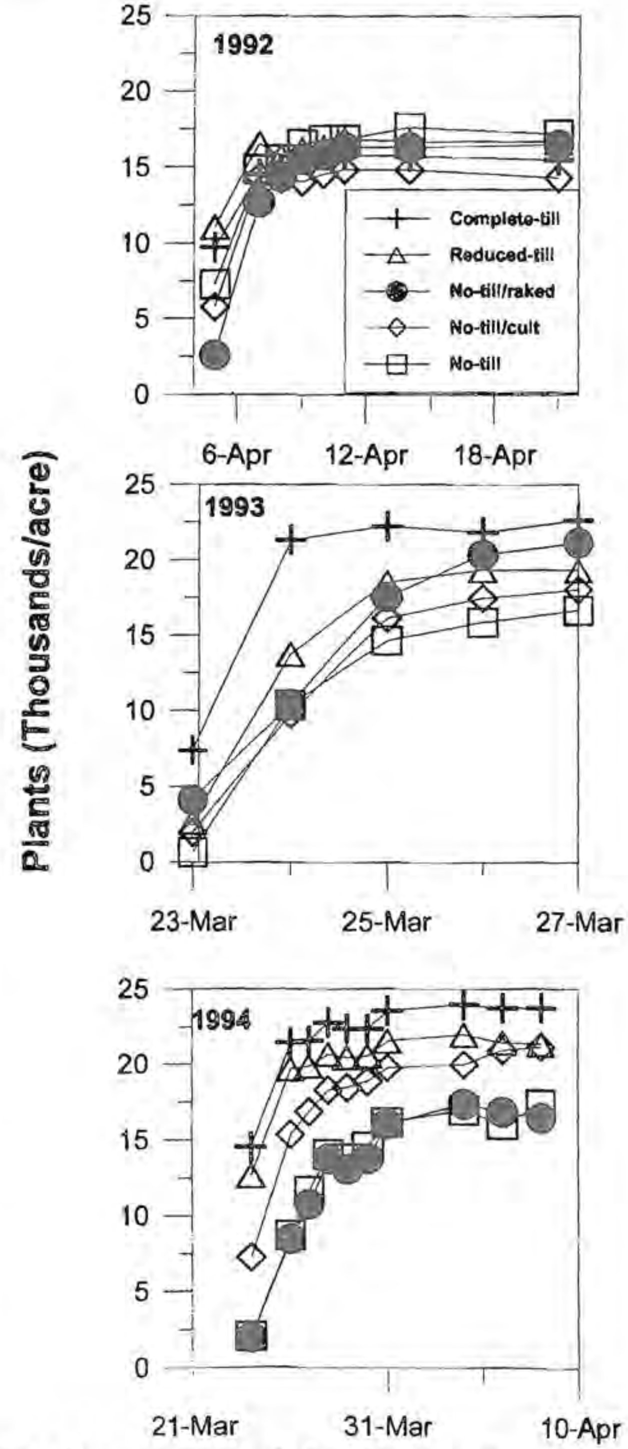

Fig. 1. Corn emergence rates for five tillage intensities.

Table 2. Emergence and growing season growing degree days (GDD)† and growing season rainfall amounts.

	Corn		Grain sorghum		
Year	Emergence period‡	Growing season	Emergence period	Growing season	Rain§
	°F				in.
1992	135	3541	135	3470	20
1993	87	3475	149	3273	19
1994	183	3417	196	3167	12

† Base temperature = 50°F.
‡ 14 d after planting.
§ February through July.

Table 3. Final corn populations for five levels of tillage intensity.

Tillage	1992	1993	1994
	plants/acre		
Complete-till	15 900	22 800	24 400
Reduced-till	17 800	20 200	22 000
No-till/raked	16 600	21 200	21 500
No-till/cult	16 100	18 200	17 700
No-till	17 800	16 900	17 800
LSD(0.05)	3 700	4 300	4 200

delayed in all treatments in 1993 compared to the other years, 17 d from planting to full emergence compared with 9 and 11 d in 1992 and 1994, respectively. This was probably because of lower temperatures in 1993 (Table 2). Differences among tillage treatments were consistent from year to year with faster emergence on the complete-till and reduced-till than in the no-till treatments. The no-till/rake was intermediate in 1993 and 1994 with the no-till/cult and no-till having the slowest emergence rate. The similarity between the no-till/cult and no-till was expected since the only difference between these treatments occurred after planting. A minor exception occurred in 1992, where initially emergence was faster in the tilled plots, but there was little difference 3 d after emergence began. The 1992 corn planting was delayed by wet soil conditions 8 to 16 d compared with the other years.

Final plant populations were similar among tillage treatments in 1992 (Table 3). In 1993 and 1994, the no-till and no-till/cult treatments had lower populations than the tilled treatments. The no-till/rake treatment populations were intermediate between the tilled treatments and other no-till treatments, with differences not statistically different than either extreme except for 1993, when no-till populations were lower.

Corn populations were reduced in treatments with the greatest surface residue cover in the row (Table 4). Retaining surface residues has been shown to slow soil warming, which can delay crop emergence and may result in reduced crop populations (Erbach et al., 1986). Although mean annual temperatures are higher in Texas than in the Corn Belt, soil temperatures are similar at the time of planting because crops, corn in particular, are planted as soon as soil temperatures permit to avoid summer heat and drought (Adams, 1967).

Total above-ground biomass varied among tillage systems, especially early in the growing season (Fig. 2). In 1992 and 1994, differences in biomass occurred within the first five sample periods. As the plants approached anthesis,

Table 4. Percentage surface residue cover for corn, measured immediately after planting for five levels of tillage intensity.

Tillage	1992	1993	1994
	% surface residue cover		
Complete-till	2.3 ± 1.2†	14.8 ± 4.3	3.5 ± 0.9
Reduced-till	5.8 ± 10.7	14.2 ± 6.5	2.5 ± 0.6
No-till/raked	65.9 ± 15.7	47.6 ± 18.9	24.0 ± 11.5
No-till/cult	82.6 ± 11.8	37.8 ± 22.6	22.3 ± 7.0
No-till	82.1 ± 11.9	57.9 ± 20.2	21.5 ± 15.1

† Mean (n = 5) ± standard deviation.

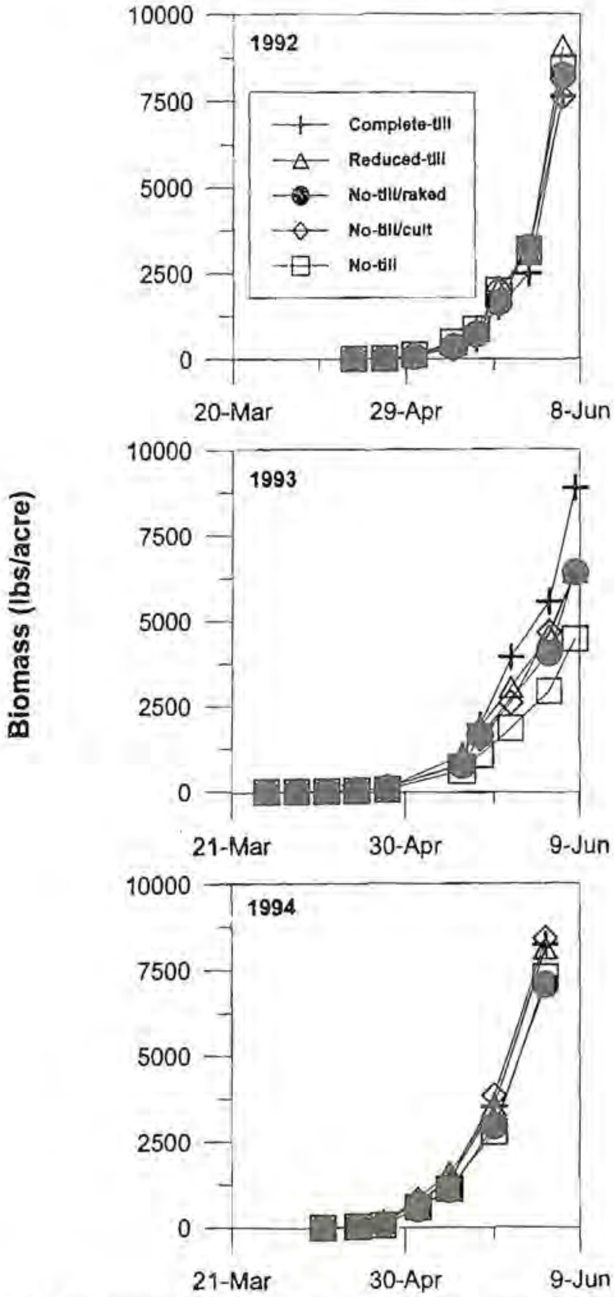

Fig. 2. Corn above-ground biomass accumulation for five tillage intensities.

Table 5. Corn grain yields for years 1992 to 1994 with five levels of tillage intensity.

Tillage	1992	1993	1994
		lb/acre	
Complete-till	6030	7620	6860
Reduced-till	6410	7720	5240
No-till/raked	6230	6800	4760
No-till/cult	5130	6670	5480
No-till	5850	6570	4800
LSD(0.05)	575	348	1180

the differences in above-ground biomass among tillage regimes diminished. In 1993, the differences in total above-ground biomass persisted up to anthesis. The complete-till treatment had the greatest amount of biomass and no- till treatment had the lowest. Other tillage treatments were grouped between the two extremes.

Corn grain yields varied among tillage regimes and years, but several consistent trends occurred (Table 5). The complete-till and reduced-till treatment grain yields were either larger or similar to the yields of the other tillage regimes. Complete-till yields were greater than the three no-till treatments in 1993 and 1994. Complete-till and no-till treatment yields were similar in 1992, except for the no-till/cult. The reduced-till treatment yields were not statistically different from the complete-till treatment in 1992 and 1993. In 1994, the reduced-till grain yield was similar to that of the three no-till treatments but less than the complete-till.

A midseason cultivation (no-till/cult) did not improve grain yields compared with other no-till management systems. The no-till/cult treatment resulted in similar mean yields as the no-till in 1993 and 1994, but reduced yields in 1992.

Plant population had a significant positive correlation with corn grain yields in 1993 and 1994, in which there were differences in populations among tillage treatments.

In 1993:

Yield (lb/acre) = 4560 + 130 × plants (thousands/acre): $r^2 = 0.45$

In 1994:

Yield (lb/acre) = 1000 + 200 × plants (thousands/acre): $r^2 = 0.47$

Plant population alone could account for nearly half of the variation in corn grain yields among plots.

Grain Sorghum

Grain sorghum emergence rates followed the same general trends as corn, with complete-till having the most rapid emergence each year (Fig. 3). The reduced-till emergence rates were similar to those of the no-till treatments in 1992 and 1993 and similar to those of the complete-till treatment in 1994. The no-till/rake treatment had little or no advantage compared with the other no-till treatments. Final grain sorghum populations varied among treatments (Table 6), but there were no consistent trends over years. The complete-till treatment usually had the greatest final populations and the other treatments were usually similar. In 1992, the no-till/cult treatment had a much lower final population than the other treatments. The reason for this is unknown, especially since management procedures were similar to the no-till treatment until the midseason cultivation. Surface residue cover (Table 7) did not have as much effect on grain sorghum emergence as in corn. This may have been because the grain sorghum was planted in the interrow area between the old corn rows and was not affected by the crown roots. The planter was able to sweep away the unanchored corn residue from the crop row.

Biomass accumulation rates were more consistent with grain sorghum than with corn. Some differences occurred

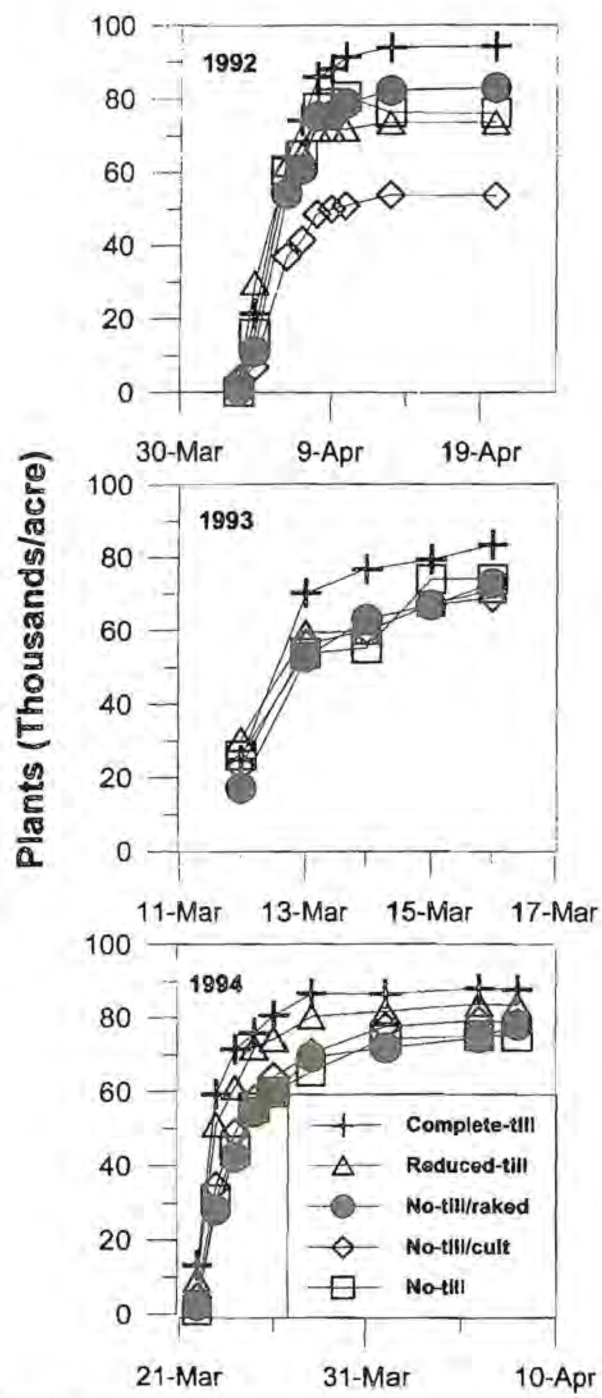

Fig. 3. Grain sorghum emergence rates.

Table 6. Final grain sorghum populations for five levels of tillage intensity.

Tillage	1992	1993	1994
	plants/acre		
Complete-till	95 100	83 800	90 000
Reduced-till	74 500	73 400	84 600
No-till/raked	83 700	73 200	78 600
No-till/cult	55 300	70 100	80 100
No-till	81 800	75 200	77 200
LSD(0.05)	13 800	6 400	5 400

Table 7. Percentage surface residue cover for grain sorghum, measured immediately after planting for five levels of tillage intensity.

Tillage	1992	1993	1994
	% surface residue cover		
Complete-till	9.8 ± 1.9†	32.6 ± 13.2	18.0 ± 2.4
Reduced-till	21.9 ± 13.0	9.3 ± 3.5	9.5 ± 5.1
No-till/raked	32.2 ± 12.2	67.5 ± 12.5	12.2 ± 5.4
No-till/cult	58.7 ± 17.1	78.2 ± 4.8	25.0 ± 17.5
No-till	30.1 ± 9.0	78.4 ± 12.3	26.1 ± 5.8

† Mean (n = 5) ± standard deviation.

Table 8. Grain sorghum yields for 1992 to 1994 for five levels of tillage intensity.

Tillage	1992	1993	1994
	lb/acre		
Complete-till	5752	5011	5108
Reduced-till	4643	5068	4823
No-till/raked	5471	5037	5323
No-till/cult	2756	5277	5533
No-till	5149	5279	5423
LSD(0.05)	1230	1270	300

among treatments early in the growing season, but trends were not consistent over years (Fig. 4). Differences in biomass accumulation among treatments were most pronounced in 1992, but did not appear to be related to the amount of soil disturbance. Population differences were large enough to affect the total biomass accumulation. Plant compensation, such as tillering, did not offset the effects of low populations, which occurred in some treatments.

Grain yields were not significantly correlated with plant population in grain sorghum. Yields in the no-till treatments were as large or larger than yields in the complete-till and reduced-till treatments (Table 8). The exception was the no-till/cult treatment in 1992, where grain yields were limited by the low plant populations. The no-till/rake and no-till/cult treatments yields were similar to those of the simpler no-till treatment in 1993 and 1994.

SUMMARY AND CONCLUSIONS

Tillage intensity effects on corn and grain sorghum growth and yield were tested for 3 yr on a Houston Black clay soil. Corn responded favorably to soil tillage, with increased plant populations, larger early season growth, and higher yields with some tillage as compared with no-till. A reduced tillage regime (disk only) had similar grain yields as a more intensive management system (chisel-plow, disk, and field cultivator) in 2 of the 3 yr of the study. Differences in corn grain yield were related to plant population differences among treatments.

Grain sorghum plant populations and grain yields were not consistently related to tillage regime. Grain sorghum biomass accumulation was not affected by the treatments imposed in this study. Grain sorghum yields, in contrast to the corn yields, were as large or larger in the no-till systems as in the more intensive tillage regimes.

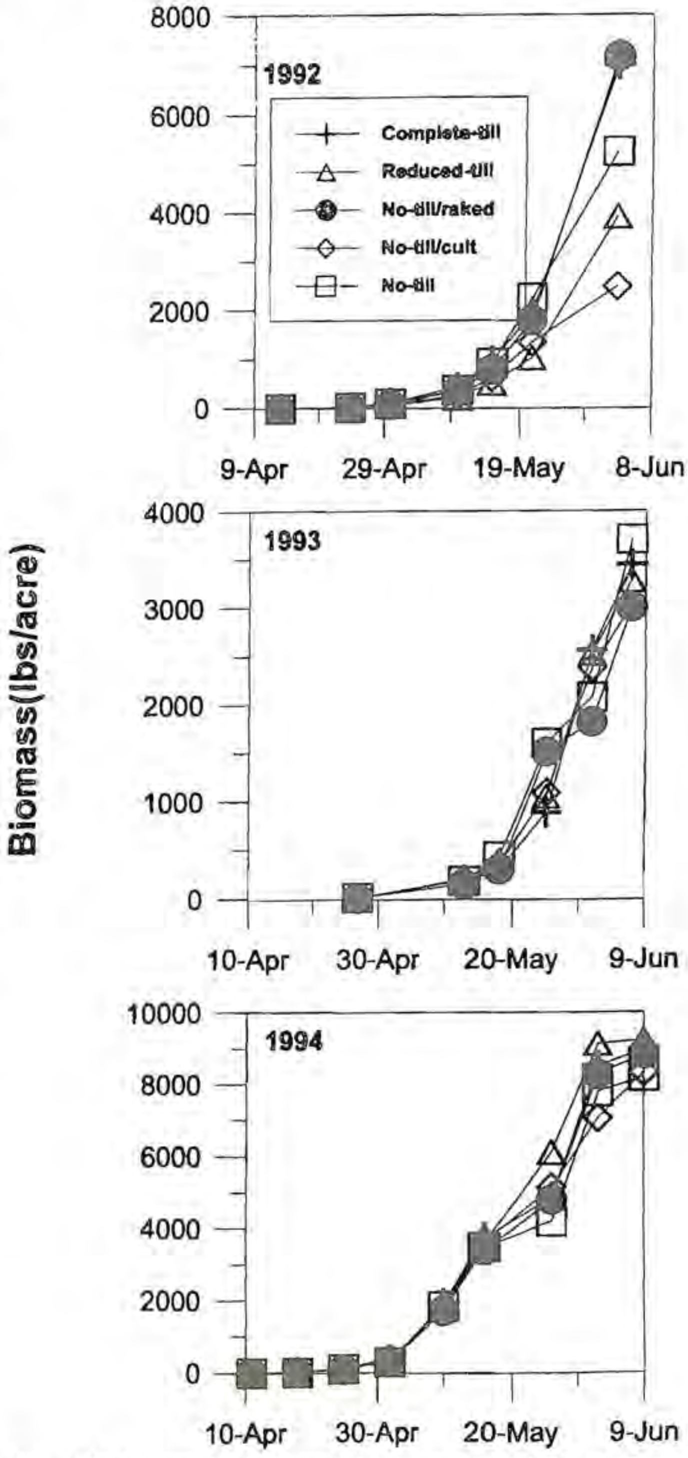

Fig. 4. Grain sorghum above-ground biomass accumulation for five tillage intensities.

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