Nitrogen Requirements of Conservation Tillage Systems[1]

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Introduction

Conservation tillage has been one of the most rapidly adopted agricultural practices of the past 15 years (CTIC, 1983). The primary impetus for conservation tillage has been decreased soil erosion; fuel, labor, and machinery costs; and increased soil water storage and yields (USDA, 1975). Conservation tillage may be broadly defined as tillage practices that reduce soil and water losses as compared with conventional tillage methods (Mannering and Fenster, 1983). The Soil Conservation Service more strictly defines conservation tillage as any system with 30 percent or greater of the previous crop's residue remaining on the soil surface following planting. Conservation tillage systems include no-till, ridge till, strip till, mulch tillage, reduced tillage, and minimum tillage. No-till is the most extreme example of conservation tillage, with the only primary soil disturbance created by coulters positioned ahead of planter units.

Tillage practices can influence soil nutrient availability. Conventionally tilled grain crops often yield greater than no-till treatments when the rate of nitrogen (N) fertilizer recommended for conventional tillage is applied to both systems (Thomas et al., 1973; Bandel et al., 1975; Blevins et al., 1977). When slightly higher N rates are added, no-till yields may be equal or superior to conventionally tilled crops. The increased N requirement for no-till may be due to several factors. Kitur et al. (1984) suggested that the large amount of surface residues associated with certain conservation tillage soils might result in considerable immobilization of surface-applied N. Conservation tillage soils may also be wetter and have larger continuous pores than conventionally tilled soils, enhancing leaching and denitrification losses (Thomas et al., 1973; Rice and Smith, 1982). Differences in fertilizer N requirements are usually most evident when comparing conventional and no-tillage systems. With increasing degrees of tillage in other reduced-tillage systems, however, differences will be less distinct.

Fertilizer N placement often is an important consideration in conservation tillage systems. Mengel et al. (1982) reported that subsurface banding of N resulted in greater no-till corn yields and suggested immobilization and volatilization as possible reasons for the reduced effectiveness of surface-applied N in high-residue systems. Nitrogen source may also influence yields in conservation tillagc systems. Surface residue accumulation is often associated with increased urease activity near the soil surface (Dick, 1984). Urea or urea-containing fertilizers applied to these soils may lose N through volatilization, resulting in decreased N efficiency and lower yields (Bandel et al., 1980).

Although several aspects of conservation tillage, including moisture storage and weed control, have been investigated in Texas (Unger, 1978, 1984, 1986; Unger and Wiese, 1979), little information is available concerning fertility requirements of conservation tillage systems within the state. Most reported research concerning fertility management with conservation tillage has been conducted in other states with corn as the primary crop (Moschler and Martens, 1975; Legg et al., 1979; Rice and Smith, 1983). Research concerning the nitrogen requirements of conservation tillage in Texas is imperative if this practice is to become a viable alternative.

NITROGEN FERTILIZATION OF CONSERVATION TILLAGE SYSTEMS

Tillage, Cropping Sequence, and N Rate Effects on Yield

A study was initiated in the fall of 1982 on a calcareous (pH 8.2) Ships clay (Udic Chromustert)-Weswood silt loam (Fluventic Ustochrept) intergrade in Burleson County to delineate the effects of tillage, cropping sequence, and N fertilizer rate on crop yields. The study consisted of five cropping sequences and two tillage treatments with variable N rates applied to all crops except soybean [*Glycine* max (L.) Merr.] (Table 1). The wheat (*Triticum aestiuum*)-soybean doublecrop produced two crops each year, while the sorghum (Sorghum *bicolor* L. Moench)-wheat-soybean sequence yielded three crops every two years. The continuous (monocropped) treatments resulted in one crop each year. Conventional tillage included three diskings after each harvest, bedding, rolling cultivation of beds, bed shaping, planting, and seasonal cultivation. Each crop was planted into the undisturbed residue of the previous crop in the no-till treatments. Fertilizers were subsurface banded in sorghum and soybean, and surface broadcast in wheat.

Grain Sorghum

Cropping sequence had no effect on sorghum yields in 1985, but a significant tillage x N interaction did occur (Figure 1). At 0 and 45 kg N ha^{-1}, conventional tillage resulted in greater yields than no-till, possibly because of decreased decomposition and mineralization associated with no-till surface residues (Dick, 1983). Yields were equivalent at the two higher N rates, however. Immobilization of applied N by surface residues should not have been a problem since all treatments were subsurface banded.

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TABLE 1. CROPPING SEQUENCE AND N RATE VARIABLES

Crop Sequence†	Applied to:	N Rate
		kg ha^{-1}
Continuous Wheat	Wheat	0, 34, 68, 102
Wheat-Soyhean	Wheat	0, 34, 68, 102
Continuous Soybean	------------	------------
Sorghum-Wheat-Soybean	Sorghum	0, 45, 90, 135
	Wheat	0, 34, 68, 102
Continuous Sorghum	Sorghum	0, 45, 90, 135

'13 kg P ha^{-1} applied to each crop.

The main effects of cropping sequence, tillage, and N rate were significant for sorghum yield in 1986, while all interactions were non-significant (Table 2). Winter and early spring 1986 were drier than normal (Table 3). Sorghum was planted in late March. Continuous sorghum emerged to an adequate population density, whereas poor germination in the sorghum-wheat-soybean sequence resulted in an inadequate density. Heavy residues in the latter sequence inhibited proper seed placement, and high winds following planting quickly depleted seed zone moisture. Sorghum in the sorghum-wheat-soybean sequence was replanted four weeks later after rainfall. Continuous sorghum experienced drought stress during early growth and development, while the replanted sorghum received above-average rainfall in late spring and early summer, resulting in higher yields for the sorghum-wheat-soybean sequence.

Conventionally tilled sorghum produced higher yields than no-till sorghum in 1986 (Table 2). Midge *(Contarina sorghicola)* populations were high and may have resulted in greater damage to the no-till sorghum, which flowered seven to 10 days later than conventional tillage sorghum. Although the tillage x N interaction was not significant in 1986, grain yields tended to be lower with no-till at low N rates as observed in 1985.

Hard Red Winter Wheat

Crop sequence x N rate and tillage x N rate interactions were significant for wheat grain yields in 1985 and 1986. In addition, the sequence x tillage interaction was significant in 1986. Continuous wheat with 0 and 34 kg N ha^{-1} produced greater yields than the other sequences in 1985, while the sorghum-wheat-soybean sequence yielded greater than the other sequences at the highest N rate (Figure 2). Wheat in the sorghum-wheat-soybean sequence receiving no N resulted in the lowest yield each year, presumably because of the nitrogen-depleting capacity of sorghum. Yield trends were similar in 1986, although yields were lower than 1985 because of drought that extended from December 1985 to May 1986. The tillage x N rate interaction for wheat yield (Figure 3) was similar to that reported for sorghum (Figure 1). No-till wheat exhibited lower yields at the

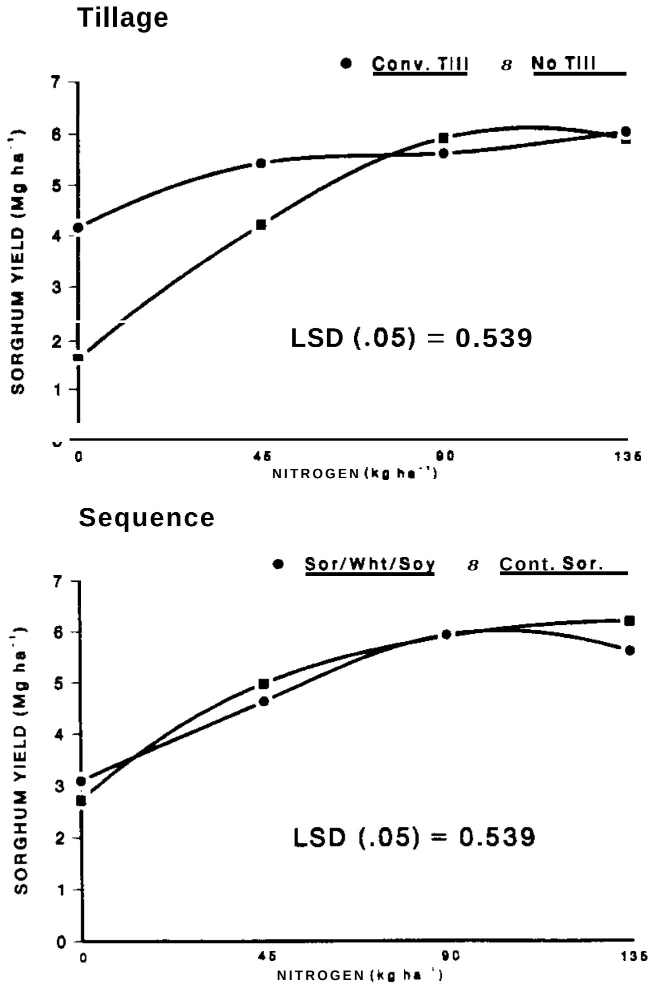

Figure 1. Effects of tillage, crop sequence, and N rate on sorghum yields, 1985.

TABLE 2. CROPPING SEQUENCE, TILLAGE AND N RATE EFFECTS ON GRAIN SORGHUM YIELD, 1986

Treatment	Grain Yield
N Rate, kg ha^{-1}	Mg ha^{-1}
0	3.55c†
45	5.08 b
90	5.68 a
135	5.68 a
Sequence	
Sorghum-wheat-soybean	5.65 a
Continuous sorghum	4.32 b
Conventional	5.36 a
No-till	4.63 b

'Means within N rate, sequence, or tillage treatments followed by the same letter are not different by LSD (0.05).

TABLE 3. RAINFALL FOR BURLESON COUNTY SITE, 1985 AND 1986

Month	1985	1986	SO-year Average	Percentage of Average 1985	1986
	-------------mm		-------------	%	
January	68.3	26.4	75.4	90.6	35.0
February	89.7	52.1	76.5	117.3	68.1
March	55.6	15.7	73.9	75.3	21.3
April	33.3	53.3	96.0	34.7	55.6
May	130.8	220.0	125.0	104.7	176.0
June	29.2	103.1	79.5	36.7	129.7
July	58.4	58.2	69.1	84.6	84.2
August	14.0	102.9	56.4	24.8	182.4
September	108.5	147.6	63.0	172.2	234.3
October	201.2	119.6	80.5	249.8	148.6
November	131.3	74.7	84.1	156.2	88.8
December	45.2	144.3	98.3	46.0	146.8

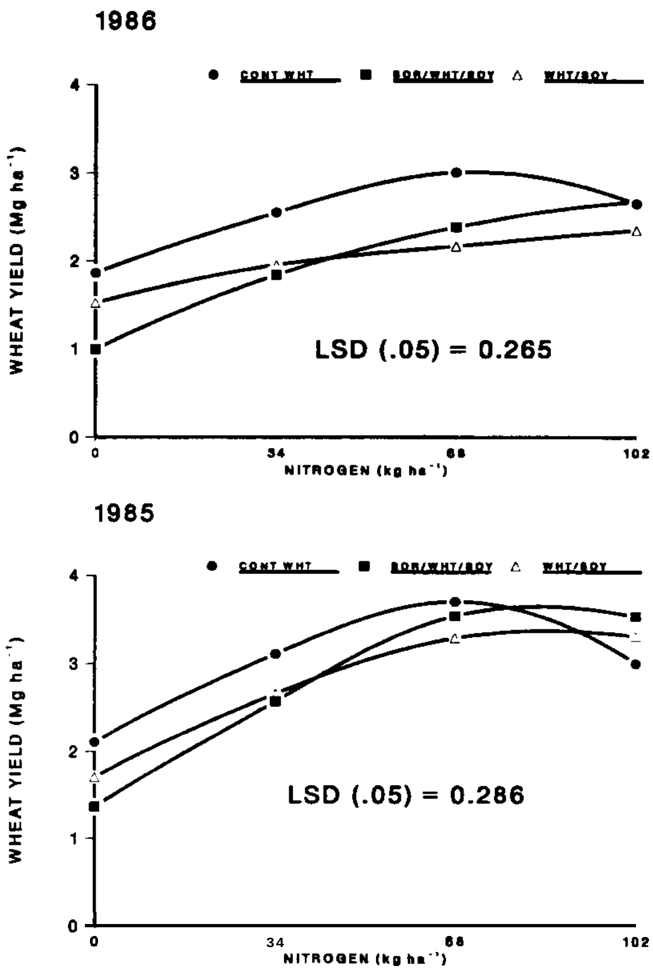

Figure 2. Cropping sequence and N rate effects on wheat grain yield, 1985 and 1986.

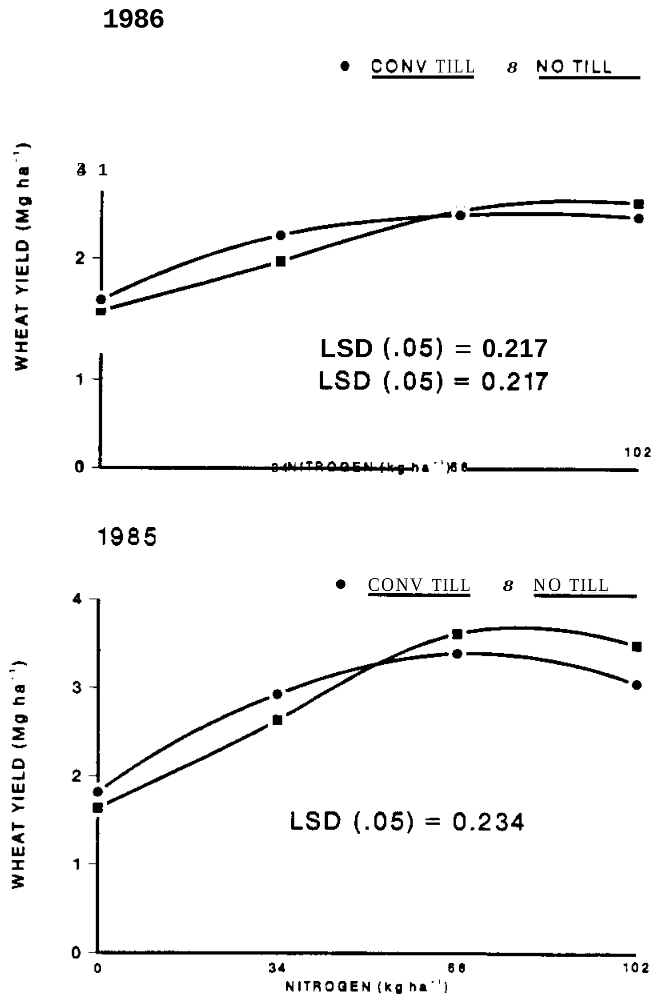

Figure 3. Tillage and N rate effects on wheat grain yield, 1985 and 1986.

lower N rates but equivalent or higher yields at the higher application rates. The sequence x tillage interaction was not significant for the sorghum-wheat-soybean rotation in 1986 but was significant for the other sequences. No-till yields were lower than with conventional tillage in continuous wheat but higher in the wheat-soybean rotation (Figure 4). The reason for the above interactions is not known, although differences in stand establishment may have had an effect.

Soybean

Soybean yields tended to be lower in 1985 than 1986 (Table 4), presumably because of extremely dry conditions from June to late September 1985. Rainfall was above average for most of the 1986 season (Table 3). No marked trends associated with tillage or sequence were evident, although yields tended to be lowest with the wheat-soybean doublecrop. The sorghum-wheat-soybean sequence produced soybean yields equal to or greater than continuous soybean, and may therefore be more economically feasible than the monocrop treatment.

TABLE 4. SEQUENCE × TILLAGE INTERACTION FOR SOYBEAN YIELDS, 1985 AND 1986

Sequence	Yield: Conventional Till	No-Till
	Mg ha^{-1}	
	1985	
Sorghum-wheat-soybean	**1.83** ab[†]	**1.79** abc
Continuous soybean	**1.97** a	**1.61** c
Wheat-soybean	**1.58** c	**1.73** bc
	1986	
Sorghum-wheat-soybean	**3.02** bc	**3.59** a
Continuous soybean	**3.22** b	**3.19** b
Wheat-soybean	**2.85** c	**2.89** c

'Means within a year followed by the same letter are not different by LSD (0.05).

Tillage and Nitrogen Placement Effects On Sorghum Yield and Fertilizer Nitrogen Uptake

Depleted $^{15}NH_4{}^{15}NO_3$ was used to measure the effects of tillage (conventional and no-till) and N fertilizer placement (surface broadcast and subsurface banded) on monocrop grain sorghum yield and fertilizer N uptake on a Weswood silt loam soil in Burleson County in 1985 and 1986. Winter wheat preceded this study so that sorghum followed wheat in 1985 and sorghum in 1986. Conventional tillage produced significantly more grain than no-till in 1985 (Table 5). Tillage had no effect on grain yield in 1986 and did not influence stover yield either year.

No-till sorghum removed more fertilizer N than conventionally tilled sorghum in 1985 (Figure 5), even though grain yields were slightly lower with no-till, suggesting that immobilization or slow N mineralization from surface wheat residue may have limited soil N availability. Nitrogen was probably not the major yield-limiting factor in no-till sorghum since the sorghum apparently was able to use fertilizer N when soil N was not available.

Dry weather during plant emergence and establishment in 1986 may account for a grain yield 16 percent lower than observed in 1985. Tillage had no effect on fertilizer N uptake in 1986 (Figure 6). Conditions that limited yields in 1986 may also have reduced crop demand, resulting in similar N uptake for both tillage systems.

Fertilizer placement had no effect on grain yield either year of the study or stover yield in 1986 (Table 6). Banding did increase stover yield in 1985, however.

Placement did not affect fertilizer N uptake at anthesis either year of the study (Figures 7 and 8). Panicle development following anthesis provided a stronger N sink, however, with subsurface banding resulting in significantly higher fertilizer N use at harvest than surface broadcasting. A greater uptake efficiency with

TABLE 5. TILLAGE EFFECTS ON SORGHUM GRAIN AND STOVER YIELDS

Tillage Treatment	Grain 1985	Grain 1986	Stover 1985	Stover 1986
	Mg ha^{-1}			
No-Ell	**5.89** b[†]	**4.80 a**	**5.20 a**	**4.43 a**
Conventional	**6.43** a	**5.31** a	**5.20** a	**4.69** a

'Means within a column followed by the same letter are not different by LSD (0.05).

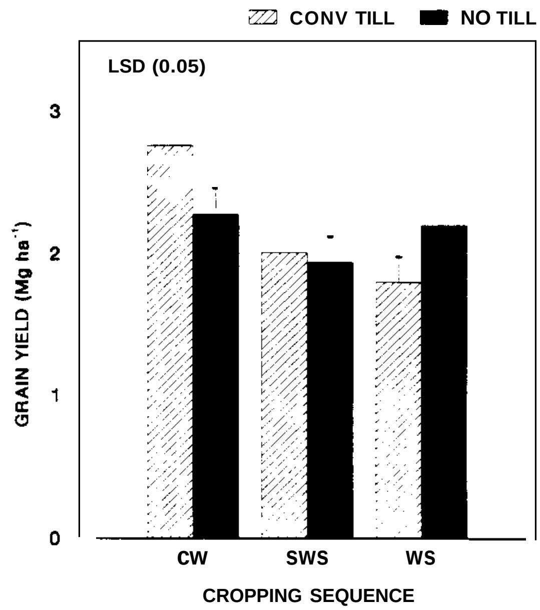

Figure 4. Sequence and tillage effects on wheat grain yield, 1986.

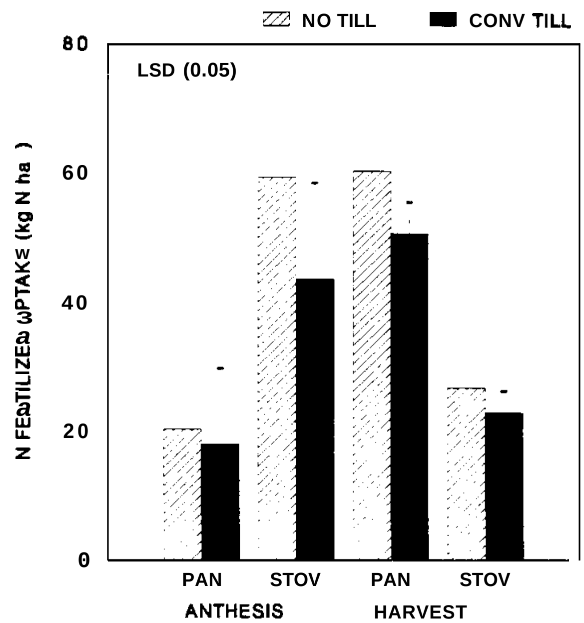

Figure 5. Tillage effect on fertilizer N uptake at anthesis and harvest, 1985. (PAN = Panicle; STOV = Stover)

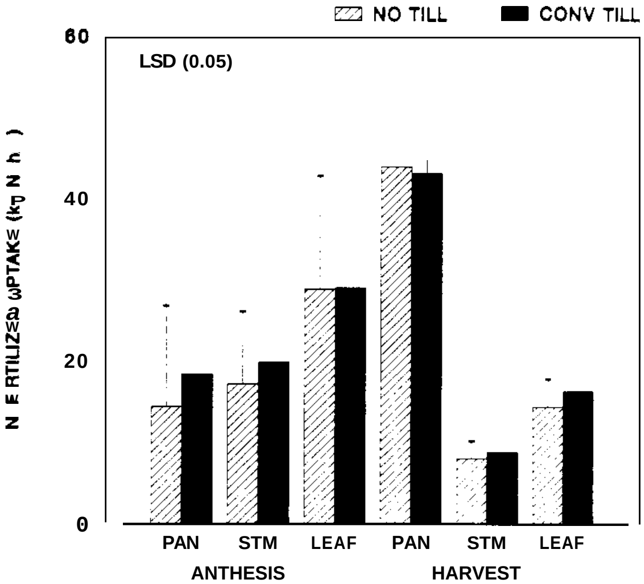

Figure 6. Tillage effect on fertilizer N uptake at anthesis and harvest, 1986. (PAN=Panicle; STM=Stem)

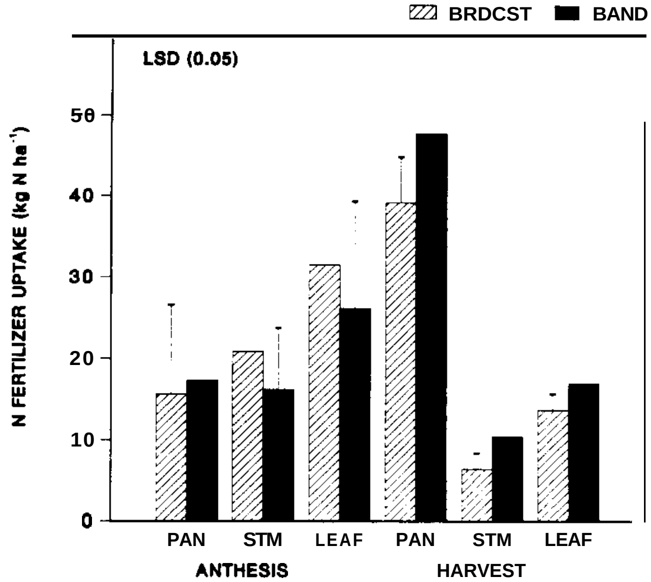

Figure 8. Placement effect on fertilizer N uptake at anthesis and harvest, 1986. PAN =Panicle; STM =Stem)

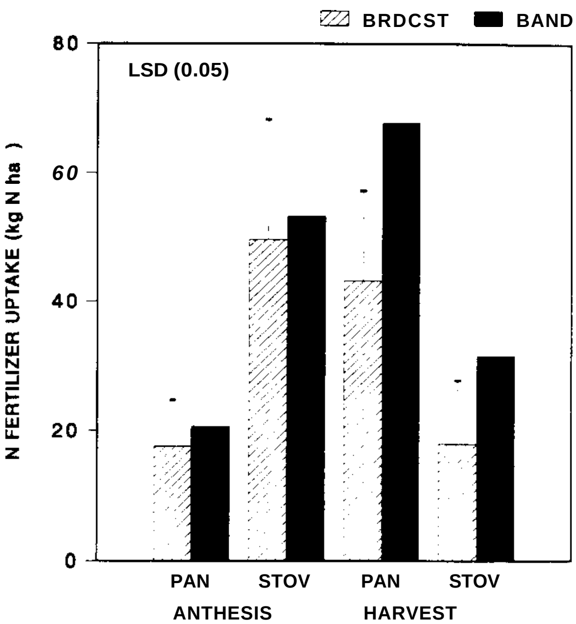

Figure 7. Placement effect on fertilizer N uptake at anthesis and harvest, 1985. (PAN= Panicle; STOV= Stover)

TABLE 6. FERTILIZER NITROGEN PLACEMENT EFFECT ON SORGHUM GRAIN AND STOVER YIELD

	Grain		Stover	
Placement	1985	1986	1985	1986
	Mg ha^{-1}			
Broadcasted	5.95 a[†]	5.00 a	4.97 a	4.44 **a**
Banded	6.38 **a**	5.11 a	5.43 b	4.68 a

[†]Means within a column followed by the **same** letter are not different **by LSD *(0.05)*.**

banding was observed with both tillage systems, implying that surface broadcasted N was probably less positionally available, especially during periods of dry surface soil conditions. Some surface broadcasted N may also have been volatilized or immobilized.

Tillage and Starter Nitrogen Effects on Corn Yield

Starter N was applied at planting in Burleson County in 1986 to determine its interactive effect with tillage (conventional and no-till) on corn *(Zea mays* L.) grain yield. All plots received 150 kg N ha^{-1} plus the appropriate rate of starter N. Corn exhibited no yield response to starter N with either tillage system (Table 7). Conventional tillage produced higher yields than no-till, however, possibly because of a decreased population density with no-till.

Tillage and Furrow Diking Effects on Yield and Nitrogen Response of Corn

The effects of factorial combinations of tillage (minimum or conventional), furrow diking (all rows diked or undiked), and N rate on corn yield were evaluated on a Ships clay-Weswood silt loam intergrade in Burleson County in 1986. The conventional tillage treatment included shredding, three diskings, bedding, bed shaping, planting, and two growing season cultivations. Minimum tillage consisted of no-till planting followed by two growing season cultivations. Dikes were established with a paddle diker in both tillage regimes following the second cultivation. Late April, May, and June were much wetter than normal (Table 3), with no observed water stress occuring during pollination or grain fill. As a result, neither tillage nor furrow diking influenced corn yield in 1986 (Figure 9). Applied N did

TABLE 7. TILLAGE AND STARTER N EFFECTS ON CORN GRAIN YIELD, 1986

Tillage Treatment	Starter N	Grain Yield
	kg N ha^{-1}	Mg ha^{-1}
Conventional	0	10.35ab[1]
	4	10.53 a
	8	10.64 a
	12	10.47 a
No-till	0	9.43 bc
	4	9.12 *c*
	8	9.40 bc
	12	10.06 ab

[1]Means followed by the same letter **are** not different **by** LSD (0.05)

affect yield, with production significantly increased by N addition up to 150 kg N ha^{-1}.

Legume Nitrogen for Grain Sorghum Production

Nitrogen fertilization of non-leguminous crops represents one of the major costs of production. The use of winter annual legumes as a surface mulch or green manure double-cropped with non-legumes may reduce or eliminate the need for fertilizer N (Fleming et al., 1981). However, reduced N mineralization associated with no-till legume residues remaining on the soil surface and soil water depletion by preceding legumes may create difficulties for a following crop. The effects of tillage, annual clover, and N fertilization on grain sorghum yield were determined in 1985 and 1986 in Burleson County on a Weswood silt loam soil. Tillage systems included conventional, no-tillage and a green manure treatment. Clover plots that were to be green manure treatments were disked twice and rebedded before sorghum planting. Mt. Barker *(Trifolium subterraneum)* and Bigbee berseem *(Trifolium alexandrinum)* clovers were used in 1985 and 1986, respectively. Clovers in no-till treatments were desiccated with paraquat (1,1'dimethyl-4,4'-bipyridinium ion) two weeks before sorghum planting. Clovers were not included in conventional tillage treatments.

Clover dry matter and N yields were considerably greater in 1986 than 1985 (Table 8) because of berseem clover's better adaptation to the soils and climate of the area. Treatments with clover (no-till and green manure) but no supplemental N yielded more grain than conventionally tilled sorghum without added N in 1986 (Figure 10). The green manure treatment without additional N also produced considerably more grain than no-till both years of the study. The results suggested that incorporation of the clover as a green manure promoted more rapid decomposition and mineralization of tissue N as compared to the surface mulch. The tillage events may also have enhanced mineralization of residual organic soil N. One problem with an annual clover-grain sorghum doublecrop in this region is the early sorghum planting date (late March to early April) required to avoid sorghum midge damage. The early planting date may reduce clover biomass production and subsequent clover N yield.

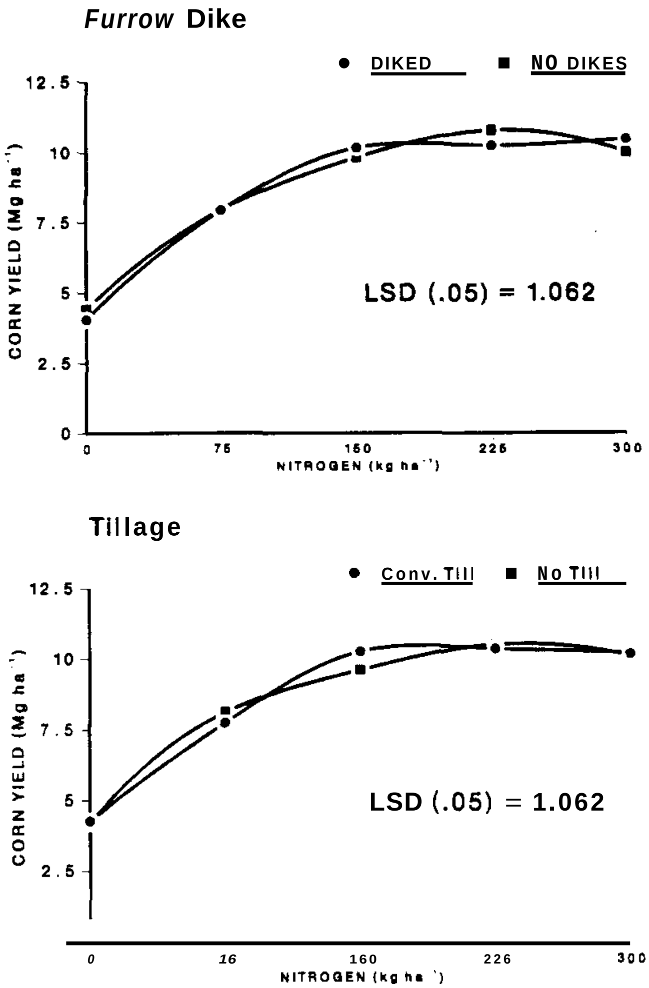

Figure 9. Tillage, furrow diking, and applied **N** effects on corn grain yield, **1986.**

Tillage Effects on Phosphorus and Potassium Availability

Surface application of phosphorus (P) and potassium (K) with reduced tillage could result in decreased positional availability of these nutrients. Several researchers in the southeastern U.S. have demonstrated, however, that P and K surface-applied under no-till conditions were as available as when subsurface banded, presumably because of greater near-surface rooting activity and higher soil water contents associated with no-tillage (Hargrove, 1985; Evangelou and Blevins, 1985). Limited research has been conducted with P and K in conservation tillage systems in Texas because of the relatively high concentrations of these elements in soils where much of the tillage research has been accomplished. Because of dry surface soil conditions often encountered in Texas, even with no-till, further studies are needed to compare surface-applied and knifed P and K under conservation tillage systems.

TABLE 8. CLOVER DRY MATTER PRODUCTION, N CONCENTRATION, AND TOTAL N CONTENT OF ABOVEGROUND TISSUE

Year’	Dry Matter	N Concentration	Total N
	$Mg\ ha^{-1}$	$g\ kg^{-1}$	$kg\ ha^{-1}$
1985	**0.89** b[2]	**32.3** a	**27.6** h
1986	**4.30** a	**28.0** b	**120.3** a

‘Mt. Barker subterranean and Bighee berseem clovers used in 1985 and 1986, respectively.

[2]**Means within a column followed by the same letter are not different by LSD (0.05).**

Summary

Cropping sequence, tillage treatment, and applied nitrogen can interact to affect crop yield and fertilizer nitrogen uptake. No-tillage with grain sorghum and wheat produced equivalent or greater yields at higher nitrogen rates than conventional tillage, but exhibited lower yields than conventional tillage at less optimal addition rates. Cropping sequence had little influence on grain sorghum or soybean yield, while monoculture wheat tended to yield more than other wheat sequences, especially in dry years.

Subsurface banding of fertilizer nitrogen with grain sorghum resulted in greater fertilizer nitrogen uptake efficiency than surface broadcasting under both conventional and no-till practices. Dry surface soil conditions, even with no-till, may have resulted in decreased positional availability of the broadcast treatment. Improved fertilizer uptake efficiency can potentially improve yields and decrease nitrogen pollution.

Starter nitrogen applications had no effect on corn yields under conventional and no-tillage systems. Soil temperatures in the study locations are generally warmer than those reported in more northern regions of the U.S. and may partially explain the lack of starter response, even with no-till.

Furrow diking and tillage treatments had no effect on corn grain yields in 1986. Diking may he beneficial in years of below-average rainfall, however. Corn responded to nitrogen up to rates of 150 kg N ha’with both coventional and no-tillage systems.

Cool season annual legumes double-cropped with grain sorghum may provide a portion of the sorghum’s nitrogen requirement. Incorporation of the legume before sorghum planting tended to increase yields relative to no-till, possibly because of more rapid clover nitrogen mineralization following disturbance.

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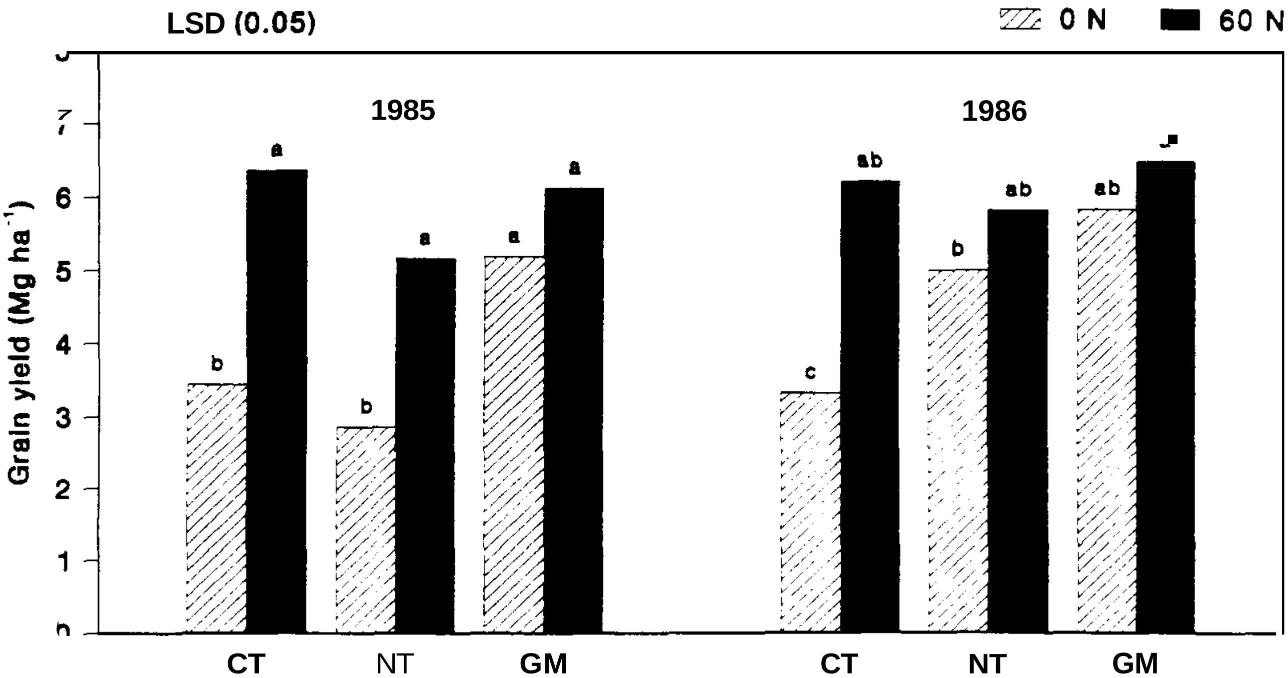

Figure **10. Tillage and clover effects on the yield** of double-**cropped grain sorghum. (CT = Conventional** Till; NT = No-Till; **GM = Green Manure)**

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