ZONE PRODUCTION SYSTEM FOR COTTON: SOIL RESPONSE

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ABSTRACT

In a three-year study, the major advantage of a zone cotton production system with controlled traffic was determined to be reduction in tractor operations for field preparation and crop management without a reduction in yield. The study indicates that tillage is required under any surface where wheels are operated to return the soil to a low impedance for root exploration and to a conductive state for water infiltration. However, the soil managed with a zone system, with no traffic or tillage after initialization, was stable with lower soil impedance and higher water infiltration than soil in tilled and trafficked plots. Adoption of these findings will reduce unit production costs.
KEYWORDS. Zone production, Cotton, Soil compaction.

INTRODUCTION

Zone systems with controlled traffic have been proposed as an improved cultural practice for field crops for many years. Carter and Colwick (1971) reported studies, conducted between 1962 and 1968, on the effect of separating the field into three zones:

Root development volume,
Water infiltration area,
Traffic support area.

The results of this work and later studies (Carter (1985), Williford (1980), Dumas (1973), and Taylor (1983)) were similar in many respects: the effect of controlled traffic upon the soil is consistent but the crop response is variable. Traction efficiency, root exploration and water use efficiency are improved; and the total energy for soil management should be significantly reduced. The first evaluations of controlled traffic and zone systems were accomplished with modified commercial equipment with traffic path spacing restricted to less than 3 m. A wide tractive research vehicle (WTRV or spanner), was obtained at Shafter in 1982, to eliminate the confounding effect of tractor and equipment wheel traffic which had been considered the greatest barrier to understanding the agronomic and soil responses. The WTRV has a span of 10 m with sufficient weight and power for all tillage, management and harvest operations for field crops.

Although several years of information from research and extension studies have been reported, few farmers have adopted or adapted a controlled traffic or zone system. A field study was designed in 1985 to evaluate the practical application of past research. This report includes only a portion of the research that is related to the stable soil state characteristics of three of the production systems that were studied.

TEST DESCRIPTION AND MANAGEMENT

The field selected for this study is located on USDA Cotton Research Station, Shafter, CA. The recent history of the field includes fallow in 1983 followed with cotton in 1984 and 1985. The soil is a coarse, loamy, mixed, nonacid, thermic, Xeric, *Torriorthents* (Entisol) in the Wasco series. The field study was laid out in the fall of 1985 and evaluated yearly through 1988.

The test consisted of three management systems (treatments): 1) broadcast system, 2) zone system, and 3) precision tillage system. The terminology 'broadcast system' is used to characterize the common farmer management system where there is no restraint on tractor or equipment wheel placement and tillage is 'uniformly' applied. The zone system concept is at the other extreme: wheels are restrained to permanent paths, and tillage varies by specific 'zones' within the field to enhance selected soil characteristics such as water infiltration, traction, root exploration, etc. The precision tillage system is an adaptation of the broadcast system in which the last primary tillage is subsoiling concurrently with bedding under the intended drill row thus creating a fractured soil zone under the bed (Carter, 1965). For this study, treatments differ only in the tillage, traffic management, and irrigation; all other management was common. No attempt was made to optimize variety, row spacing or fertility management within each treatment or system.

The zone system had the following tillage operations:

1. Cotton root and stalk disposal (once-over operation),
2. Power harrowing to a depth not exceeding 5 cm to lightly mix debris (required only to meet State of California pink-bollworm rules and incidental to the objectives of this research),
3. Bedding, and
4. Rolling cultivator prior to pre-irrigation and planting.

Original research plans specified that operations 1, 2, and 3 would be combined, however, we were unable, within the constraint of resources, to modify suitable equipment. All operations were accomplished with the WTRV, therefore no wheels were operated within the 8-row wide plot. All traction and support traffic was concentrated in the 1-m wide paths on either side of the plot.

The broadcast system management was based upon a

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survey of five farms within a 50-km radius and included the following operations:

1. Surface stalk shredding followed by a stubble disk to remove the upper portion of the root,
2. Disk harrowing in two directions,
3. Chiseling to a depth of 45 cm on 50-cm centers at an angle to the drill row,
4. Disk harrowing in two directions,
5. Bedding, and
6. Rolling cultivator prior to pre-irrigation and planting for a minimum of 10 operations.

The third treatment, precision tillage system, differed from the broadcast only in the application of precision tillage (subsoiling to a depth of 60 cm directly under the intended drill row) following the bedding operation.

Initial field preparation consisted of leveling, subsoiling and harrowing to minimize the soil variability of prior experiments. The field was leveled to a slope of 1:1000 in the direction of furrow irrigation and to a uniform side slope consistent with topography. The field was subsoiled to a depth of 50 cm at two angles (approximately ±45°) with respect to the drill row with parabolic shanks set on 50 cm centers. The field was then uniformly harrowed twice before treatment application.

Plots were 10 m wide by 85 m long with the center 8 m used for cotton planted in rows 1 m apart. An unusual field blocking was required to allow application of the plots. Those plots that were to be managed with 'normal' tillage were surrounded by 15-m turning areas. Paths were established for each plot for the WTRV which was used exclusively for all operations on the zone plots and on other plots where a bias would have been introduced by using standard equipment such as spraying and harvesting. When the WTRV was used in non-zone plots, the appropriate tractor was run through the plots to simulate the normal traffic. In the zone plots where the WTRV was used exclusively, there was no wheel traffic applied in any area within the eight-row plot. The plots were applied in a randomized block design with six replications.

Soil penetration resistance was measured with a semi-automatic penetrometer mounted on the WTRV. All measurements were obtained at 'field capacity' soil moisture defined as three days after an irrigation exceeding 3 in. of water. The cone dimensions and speed of operation conform to ASAE standards. Twenty-one readings were obtained at 5-cm increments over a 1-m stroke. The surface of the soil was defined when a reading exceeded 0.01 bar. A sample consisted of 41 horizontal penetrometer insertions on 10 cm centers which define a profile 4 m wide by 1 m in depth that corresponded to a pattern covering four cotton rows from the center of the outside furrows. Four samples in each of six replications produced 20,664 values to characterize each treatment. This data set was analyzed as a whole for evaluation of interactions at the profile cell level and also by combining specific groups to allow comparisons of bed, major traffic furrow, minor traffic furrow and bed shoulders.

Soil bulk density was measured in the furrows using a two-probe density gauge (Model 2376, Troxler Lab.) that was described by Rawitz (1982). Soil bulk density in the beds was measured using a depth density probe (Model 504, Troxler Lab). as described by Freitag (1971). Soil moisture readings for correction of nuclear estimates of bulk density were obtained using a neutron probe. Water infiltration was measured using the basin in-flow out-flow method. Stem, leaf, plant dry matter, leaf area, and yield were determined for each treatment.

Discussion of Results

There were large, statistical differences among treatments and especially within the various interactions for the penetration resistance data (Tables 1 and 2). The average soil penetration resistance for the broadcast system was 1.75 times greater than for the zone system. Adding precision tillage to the broadcast system resulted in an intermediate average. These treatment averages illustrate

TABLE 1a. Summary of ANOVA of individual soil penetration resistance cells within a 4x1 m vertical soil profile

Class	F Value	Pr > F	LSD MPA
Treatment	54.73	0.001	0.10
Position	71.24	< 0.0001	0.04
Depth	2653.19	< 0.0001	0.02
Pos * Depth	3.20	0.0001	0.14
Treat * Pos	32.71	< 0.0001	0.05
Treat * Depth	75.04	<0.0001	0.09
Trt * Pos * Depth	1.50	0.0001	0.25

Table 1b. Summary of ANOVA of soil penetration resistance by categories†

Class	F Value	Pr > F	LSD MPA
Treatment	773.95	0.0001	0.03
Category	170.26	0.0001	0.03
Depth	370.88	< 0.0001	0.03
Treat * Cat	87.30	0.0001	0.05
Treat * Depth	12.89	0.0001	0.10
Cat * Depth	9.24	0.0001	0.10
Trt * Cat * Depth	3.50	0.0001	0.19

† Beds, furrows, and bed shoulders.

TABLE 2. Summary of mean soil penetration resistance

	Soil Impedance (MPa)	Increase Over Zone
Systems		
Zone	0.715	1.00
Broadcast	0.253	1.75
Precision Tillage	1.006	1.41
(LSD)	0.027	
Categories Within Systems		
Bed		
Zone	0.70	1.00
Broadcast	1.21	1.73
Precision Tillage	0.73	1.04
Major Traffic Furrow		
Zone	0.73	1.00
Broadcast	1.47	3.01
Precision Tillage	1.20	1.63
Minor Traffic Furrow		
Zone	0.72	1.00
Broadcast	1.08	1.50
Precision Tillage	1.09	1.51
Bed Shoulders		
Zone	0.75	1.00
Broadcast	1.25	1.67
Precision Tillage	1.05	1.40

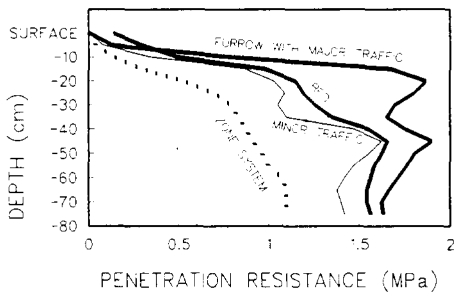

Figure 1–Average penetrometer force-displacement diagram for the broadcast system illustrating differences among bed and minor traffic and major traffic furrows as referenced to the zone system pattern.

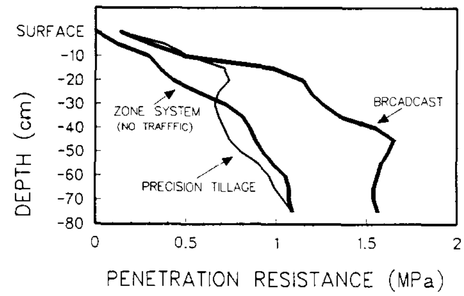

Figure 3–Average penetrometer force-displacement diagram comparing the patterns for zone, broadcast, and precision tillage systems under the beds. The difference in patterns between broadcast and precision tillage systems was a result of the single pass per year of the precision tillage operation.

that soil can be maintained at a low impedance without traffic and tillage and that precision tillage may be useful to ameliorate the high impedance of broadcast systems. However, in view of the interactions and known different soil zones, discussion should concentrate on the interactions.

The interactions can best be discussed by using different presentations of the same data. The simplest and oldest presentation method is a resistance by depth graph. The readings for the center of bed and 10 cm on each side were averaged and compared to a comparable average for the furrow that receives production wheel traffic on each operation and to one that receives only harvest traffic and incidental traffic (figs. 1 through 5). First, there were no differences within the zone system among the bed, furrow types or bed shoulder areas, which may eliminate the hypothesis that basin irrigation consolidates the soil in such a way to increase penetration resistance. For the other two treatments the average for beds and furrows and relationship with depth were quite different (fig. 1, 2). The LSD for comparison of penetrometer resistance at a given depth, determined by a combined analysis of variance, is 0.19 MPa. Where present, major traffic increased the penetration resistance by a factor of 1.5 to 3 over non-trafficked non-tilled soil. At first evaluation it was considered strange that the minor traffic furrow for the broadcast system was only slightly different than the corresponding bed (fig. 1). However, when we referred to the equipment operation records, except for harvest traffic on dry furrows, the bed and minor traffic furrow had the same tillage-traffic history. Also, it follows that any consolidation caused by irrigation had an unmeasurable effect on the impedance in this treatment. Within the precision tillage system the major and minor traffic furrows presented similar patterns (fig. 2). In this case, it must be realized that in addition to harvest traffic this treatment received heavy traffic during the precision tillage which is done after the winter rains.

Penetration resistance within the bed for precision tillage differs only at the 15-20 cm depth from the zone system while the broadcast is significantly higher at all depths (fig. 3). A second look at the traffic furrows show that the precision tillage major traffic furrow had lower penetration resistance than the broadcast furrow below 35 cm depth but that the precision tillage minor traffic furrow had higher resistance near the surface than broadcast furrow (figs. 4, 5). This is another clue that spring traffic is relatively more effective in increasing penetration resistance than comparable later season traffic.

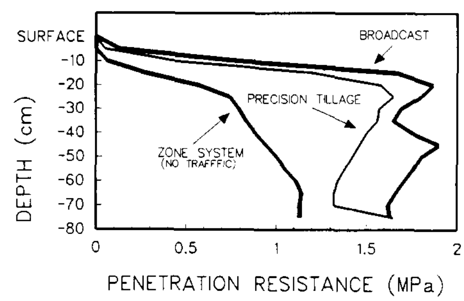

Figure 4–Average penetrometer force-displacement diagram comparing the patterns under the major traffic furrow for zone, broadcast, and precision tillage systems.

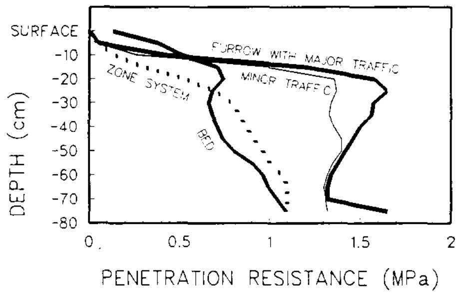

Figure 2–Average penetrometer force-displacement diagram for the precision tillage system illustrating the effect of the precision tillage operation in restoring a low impedance under the drill and the resultant increase in the minor traffic furrow relative to the major traffic furrow. The zone system pattern is included for comparison.

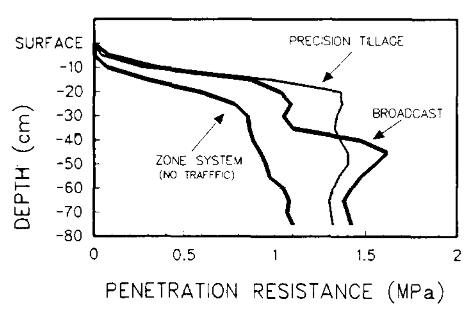

Figure 5–Average penetrometer force-displacement diagram comparing the patterns under the minor traffic furrow for zone, broadcast, and precision tillage systems.

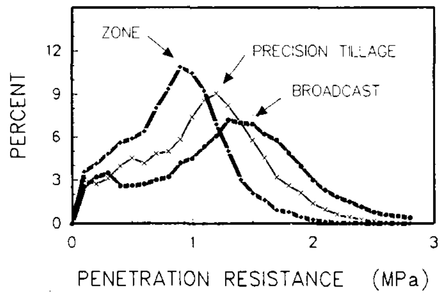

Figure 6–Frequency distribution of the impedance of 5x10 cm cells within a 4x1 m soil profiles for zone, broadcast, and precision tillage systems. The data include include all replications, samples and locations without averaging.

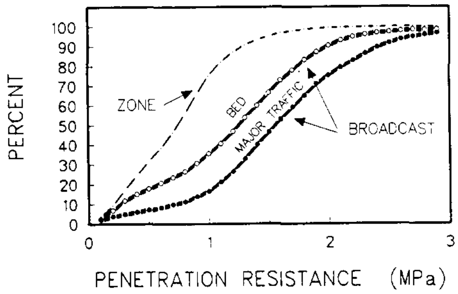

Figure 8–Cumulative frequency distribution of the impedance of 5x10 cm cells within 4x1 m soil profiles for the broadcast system illustrating the minor difference between bed and furrow patterns. The minor traffic furrow distribution would plot directly over the bed distribution and was deleted from the graph. The zone system pattern is included for reference.

Since the penetration resistance data was obtained with uniform spacing within a 4x1 m profile, each individual measurement can be considered to represent a unit volume of soil, and the aggregation of all measurements for a treatment can be combined as a frequency distribution of penetration resistance. The treatment means correspond roughly to the peaks of the distributions. The variation about the mean increases with the mean (fig. 6). The precision tillage treatment is intermediate between zone and broadcast; this point will be discussed again later. If a root has capacity to penetrate at a resistance of 1 MPa, then 69.3% of the soil is available for exploration with the zone system compared to 32.1% for the broadcast system (fig. 7). If the capacity for penetration is 1.5 MPa, then the soil volume increases to 95.6% and 64.7%. Therefore, less root internal pressure is required to deform the soil for root exploration within the zone system. Under the major traffic furrow of the broadcast system only 17.0% of the soil is available at 1 MPa (fig. 8). The minor traffic curve plots directly over the bed curve for the broadcast system (fig. 8). The bed distribution for precision tillage and the zone system cannot be distinguished as different and therefore a common line was plotted (fig. 9). Although not measured, these data would suggest that root development might be delayed or curtailed in a major traffic furrow and enhanced in a no-till-no-traffic system.

When the penetrometer data are averaged over samples and replications for each cell location within each treatment an iso-impedance profile for a 4-m wide by 1-m deep soil section can be constructed which is useful for illustrating the differences among treatments. Since this data presentation method eliminates the tails of the distribution curves by averaging, the profiles appear to be more uniform than in reality. With this caution in mind, the zone production system maintains a soil environment that is relatively uniform laterally and increases uniformly with depth to values no higher than 1 MPa (fig. 10; note values are in bars where 1 MPa = 10 bars). The zero impedance curve indicates the soil surface topography showing furrows beds and furrows. Within the broadcast system profile the 0.2 to 1.2 MPa iso-impedance lines are horizontal indicating uniform surface compacting across beds and furrows alike (fig. 11). Higher closed areas of impedance are located under the major traffic furrow. The effect of traffic extends below the sampling depth, thus the penetration resistance of a volume of soil about 50 cm wide by an unknown depth has been increased by traffic from 1.0 to greater than 2.0 MPa.

The advantage, and associated problems, of the precision tillage system are illustrated in figure 12. With precision tillage the soil beneath the bed approximates that under the zone system, however the wheels of the precision tillage tractor operation dramatically affect the minor traffic furrow as indicated on the graph at the 0, 200, and 400 cm locations when compared to the broadcast system.

The combined effects of preparation tillage and traffic and production traffic can be easily viewed by subtracting the zone profile from the broadcast profile. The whole profile was increased by preparation traffic/tillage by 0.2 to 0.8 MPa. The production wheel traffic (centered at 100 and 300 cm in the profile) increase was greater than 1 MPa to a depth greater than that sampled (fig. 13). The effect of

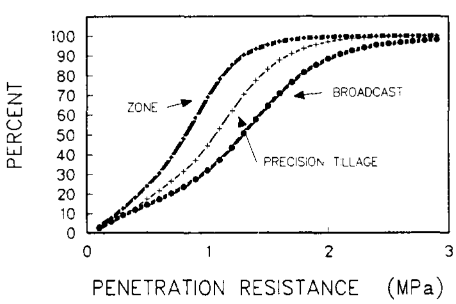

Figure 7–Cumulative frequency distribution of the impedance of 5x10 cm cells within 4x1 m soil profiles for zone, broadcast, and precision tillage systems. Some data as figure 6 re-drawn to illustrate increased soil available for root exploration within each system at a given resistance.

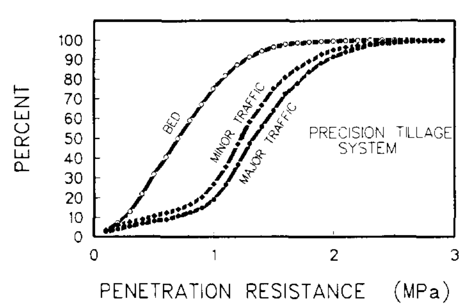

Figure 9–Cumulative frequency distribution of the impedance of 5x10 cm cells within 4x1 m soil profiles for the precision tillage system illustrating common distribution for major and minor traffic.

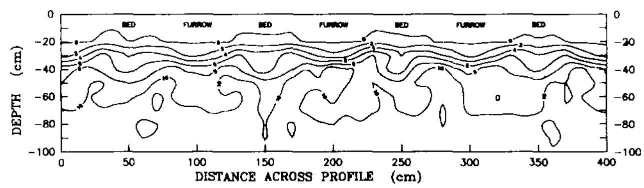

Figure 10–Iso-impedance profiles for zone system. Penetration resistance in MPa*10 (or bars). Zero impedance level interpreted as soil surface.

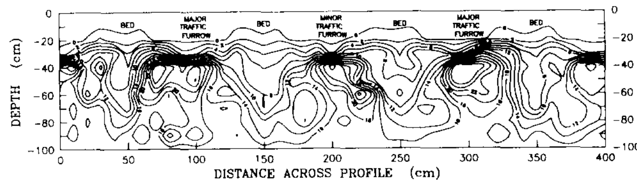

Figure 12–Iso-impedance profile for precision tillage system illustrating contrast between bed and furrows. Penetration resistance in MPa*10 (or bars). Zero impedance level interpreted as soil surface.

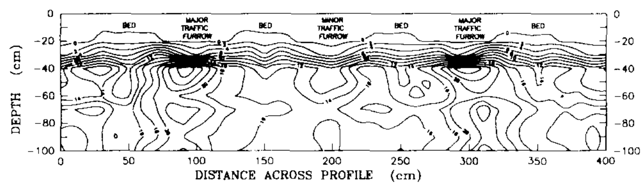

Figure 11–Iso-impedance profiles for the broadcast system illustrating differential effects of production traffic between major and minor traffic furrows and overall increase compared to the zone system. Penetration resistance in MPa*10 (or bars). Zero impedance level interpreted as soil surface.

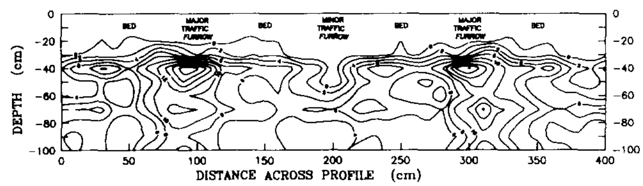

Figure 13–Iso impedance profile obtained by subtraction of figure 10 from figure 11 showing the overall increase and the dramatic major traffic furrow increase in penetration resistance for broadcast system compared to the zone system. The contours represent a relative change rather than absolute values. Penetration resistance change in MPa*10 (or bars). Negative values not plotted.

precision tillage imposed upon the broadcast system is easily viewed by subtracting the precision tillage profile from the broadcast. Areas of decreased impedance exist under each bed (centered at 50, 150, 250, and 350 cm in the profile) caused by the subsoil shank operating to a depth of 56-cm which is equivalent to the 81-cm level in the graph.

Water infiltration was measured on 5 dates in 1988. As expected, the water infiltration rate for the first post-plant irrigation was 1.75 times greater for the zone system compared to the broadcast system (fig. 14). The infiltration rate decreased with time for both zone and broadcast. The two treatments approached the same rate on the fifth post-plant irrigation. We interpret this data in two ways:

1. The initial difference between treatments is related to hydraulic conductivity, related to soil state.
2. The decrease with time is related to mechanical and/or biological soil surface sealing.

Although we have no hard evidence, the circumstance of increased infiltration after drying and exposure to sunlight indicate that sealing may be at least partially biological. In either case the implication of the data is that early season irrigation infiltration rate can be appreciably improved with a zone system which corresponds with the critical period for fruit initiation and development for cotton. Recent studies in California relate high cotton yields to efficiency of early fruiting. (Kerby, 1987).

Wheel traffic altered the soil bulk density in the furrow to a depth of 25 cm. Below 25 cm no differences were detected among treatments (Table 3). Near the surface there is a trend for higher density in the minor traffic furrow of the broadcast system compared to the zone system. Below 15 cm this trend disappeared. The effects of traffic on bulk density did not extend as deep as the effects on penetration resistance. The soil beneath the zone system furrows were appreciably lower in density than the major traffic furrow in the broadcast system to a depth of 20 cm with a trend for differences to a depth of 25 cm. The minor traffic furrow of the broadcast system had lower density to a depth of 15 cm with a trend to a depth of 25 cm than the

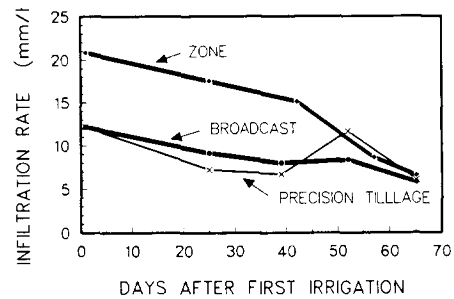

Figure 14–Change in water infiltration measured 2 h after initial wetting for the zone, broadcast, and precision tillage systems during selected irrigations after the first postplant irrigation in 1987.

major traffic furrow. The changes in bulk density are restricted, primarily to the depth of tillage within the broadcast and precision tillage systems.

Of particular interest is the lack of difference between the minor and major traffic furrows for the precision tillage system. The minor traffic furrows for this treatment received two passes per year of a 29.5 kN wheel which resulted in the same bulk density as the combined passes totaling 250.1 kN in the major traffic furrow for both precision tillage and broadcast systems (Tables 3a and 4).

Attempts to characterize the soil bulk density using the same methodology under the drill row were unsuccessful because the soil was too 'loose' under the precision tillage treatment for installation of double access tubes. However, the backscatter procedure could be used. The differences among treatments are less than in the furrow since only preplant wheel compaction is involved (Table 3b). Random preplant traffic increased the bulk density of the upper 30 cm of soil by 0.05 to 0.08 as estimated by comparing the broadcast treatment to the zone treatment. Precision tillage usually resulted in a lower bulk density in the bed in the top 46 cm. Small changes in bulk density were observed with post-plant traffic within the bed except with precision tillage at the 30 and 46 cm measured depth. The

TABLE 3a. Double probe soil bulk density, Mg m^{-3}, 24 June 1987

System	Bulk Density Under the Furrow at Depth of							
	10 cm	15 cm	20 cm	25 cm	30 cm	40 cm	50 cm	60 cm
Zone	1.62 c	1.74 b	1.72 b	1.65 b	1.63 a	1.59 a	1.58 a	1.55 a
Broadcast*	1.88 a	1.85 a	1.78 ab	1.73 ab	1.69 a	1.63 a	1.59 a	1.58 a
Broadcast†	1.71 bc	1.74 b	1.73 b	1.67 b	1.68 a	1.66 a	1.63 a	1.59 a
PT*	1.89 a	1.88 a	1.85 a	1.77 a	1.71 a	1.65 a	1.63 a	1.59 a
PT‡	1.86 ab	1.89 a	1.78ab	1.72 ab	1.67 a	1.60 a	1.59 a	1.56 a

Means separation are at a given depth using Duncans multiple range, P = 0.95.
* Samples from furrow 3; normal cultivation wheel traffic.
† Samples from furrow 4; harvest traffic only.
‡ Samples from furrow 4; PT and harvest traffic.

TABLE 3b. Backscatter soil bulk density, Mg m^{-3}, under the drill row*

1987 Date	Treatment	Bulk Density Under Drill at Depth of:				
		18 cm	30 cm	46 cm	61 cm	76 cm
7 May	Zone	1.60 b	1.64 a	1.64 a	1.61 a	1.60 a
	Broadcast	1.68 a	1.69 a	1.64 a	1.58 a	1.54 a
	PT	1.53 c	1.38 b	1.41 b	1.59 a	1.59 a
4 Jun	PT	1.55	1.41	1.48	1.61	1.60
30 Jul	Zone	1.52 b	1.60 b	1.61 a	1.60 a	1.59 a
	Broadcast	1.59 a	1.65 a	1.64 a	1.59 a	1.55 a
	PT	1.52 b	1.50 c	1.54 b	1.58 a	1.59 a

* Means separation are at a given depth using Duncans multiple range P = 0.95.

reconsolidation within the precision tillage beds between 7 May and 30 July could be explained with either water consolidation or lateral components of forces from the wheels or a combination.

Plant response to the different systems was confounded by unknown factors among replications. Detailed field mapping of soil texture, plant emergence, plant biomass, leaf temperature, and yield were made for each 10 m square within the field. Patterns within each measurement were obvious but no correlations among them or with treatment have yet been identified. These data will become a test data-set for a more sophisticated analysis. For the purposes of this report, the only conclusion that is justified is that the zone system yields were not lower than the broadcast system yields (Table 5).

SUMMARY

Controlled traffic as a basis for new production systems has been demonstrated to have potential for reducing tillage costs and energy requirements and to change the soil characteristics consistent with the criteria for improved soil and water conservation. The reduced tillage costs will result by minimizing the number of total tractor operations required for soil preparation for cotton and increasing the tractive efficiency. Investigating the monetary value of the reduction is beyond the scope of this research; however, it has been demonstrated that the total number of soil preparation tractor operations can be reduced from 10 to 4 without sacrificing yield. Normally there are 10 operations, 7 requiring heavy, high-powered tractors compared to only two high-powered operations in the zone system. This advantage for the zone system may be greater than indicated by this study: three of the four operations could be combined with minor modifications of existing equipment reducing the number of preparation operations

TABLE 4. Traffic wheel force in furrows for broadcast and precision tillage sysytems

	Range of Wheel Force		Cumulative Force	
	Lightest (kN)	Heaviest (kN)	Broadcast system (kN)	Precision tillage system (kN)
Major traffic furrow	14.3	29.47	250.08	250.08
Minor traffic furrow	25.74	25.74	25.74	55.22

TABLE 5. Seed cotton yield history

System	Seed Cotton Yield		
	1986 Mg/ha	1987 Mg/ha	1988 Mg/ha
Zone	4.18	3.44	4.08
Broadcast	4.13	3.34	4.18
Precision tillage	4.36	3.46	4.40

to two. Of at least equal importance, fewer operations during the winter provide two potential advantages: 1) lower capitalization and labor costs; and 2) greater probability that all operations can be accomplished near optimum soil moisture.

In the zone system, with no traffic or tillage, the soil was changed to a low impedance and low bulk density state which did not increase with time and for which there were no detectable differences between beds and furrow. This was not achievable with trafficked systems. Pre-plant random traffic affected the soil to approximately the depth of tillage in this trial.

Changes in soil detrimental to root exploration were measured considerably below annual tillage depth in post-plant trafficked furrows. The wheel effect of the single spring precision tillage tractor operation affected essentially an equivalent volume of soil as repeated post-planting operations. The effect of the single fall harvesting operation, with the greatest tire forces but following production traffic, was not measurable. However, it should be restated that harvester wheels were not allowed in the zone system, so it would be incorrect to state that harvest wheels can be tolerated without tillage implications.

Tillage, then, is required in this type of soil in any area where wheels are operated to return the soil to a low impedance for root exploration and maintain a reasonable water infiltration rate. Post-plant traffic, which is limited to furrows, modifies the soil below normal subsoiling and requires great expenditures of energy to ameliorate. This deep layer (50 to 75 cm) of high penetration resistance can be found in most fields in the arid west. The data from this study implicates furrow traffic as the cause of deep compaction. In either case, shallow or deep soil consolidation, the tillage required must be depreciated in one year. The zone system offers the potential for minimizing or eliminating this annual cost.

The hypothesis of improved cotton plant response with 'improved' soil environment is not proved (or rejected) by this study. H. Taylor (1971) stated "Plant yields will be reduced by high-strength layers if an adequate plant population is not established or if the layer causes the plant to undergo substantial additional stress for water or nutrients". To follow this dictum, we were prepared to irrigate and fertilize differentially. On two occasions irrigations were intentionally delayed for the zone system to create equal water stress based upon the other systems. In past studies of this project conducted on farmers fields where yield increases with precision tillage were measured, the decision for irrigation and amount and the timing of fertilizer were left to the discretion of the farmer (Carter, 1965). We presume that irrigation was scheduled based upon the farmer's experience with the 'broadcast' type systems and therefore the water stress for the precision tillage and controlled traffic systems was lower than for the conventional systems. We would argue that water availability was less often limiting in that series of trials for the experimental systems and therefore the systems were inadvertently managed better. The dilemma for the researcher is a choice between:

- biasing the results by allowing stress in some treatments with a fixed water and fertilizer management and thus altering yield or
- masking an important grower advantage by eliminating inherent difference among treatment that affect yield.

At this time, the merits of zone production systems must be evaluated on the basis of unit cost reduction, management improvements and benefits to other crops in the rotation. We simply do not know what, if any, the expected yield response might be.

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