FURROW TRAFFIC AND RIPPING FOR CONTROL OF IRRIGATION INTAKE

R. R. Allen, J. T. Musick
MEMBER ASAE MEMBER ASAE

ABSTRACT

Graded furrow applications of 100 to 200 mm (4 to 8 in.), which often exceed profile storage capacity, are common in the Southern High Plains for the first irrigation after primary tillage. This study evaluated furrow compaction by wheel traffic as a potentially low cost method of reducing excessive intake and conserving irrigation water. A two-year field study was conducted with irrigated grain sorghum on a slowly permeable Pullman clay loam (Torrertic Paleustoll). The objective was to determine the effects of furrow compaction by controlled wheel traffic on irrigation intake during the preplant irrigation following primary tillage. In addition, the effects of furrow ripping, before the second irrigation, were compared with the non-traffic control furrows as a means of restoring normal late-season intake. On relatively wide 1.5 m (5 ft) spaced furrows with a 0.15% slope, one traffic pass with a 6000 kg (13,200 lb) tractor increased average bulk density from 1.1 to 1.27 Mg/m^3 at the 50 mm (2 in.) depth. Furrow traffic reduced irrigation water advance time up to 45% to reach 400 m (1320 ft), and reduced total intake by about 17% during the first irrigation after tillage. Ripping traffic furrows before the second irrigation increased growing season irrigation intake by 10% compared with the non-traffic furrows. Controlled furrow traffic reduced average growing season irrigation water intake by 12%. Furrow traffic and furrow ripping treatments did not significantly affect grain sorghum yield.

KEYWORDS. Furrows, Irrigation, Infiltration, Soil compaction, Soil moisture.

INTRODUCTION

Improving irrigation management practices and reducing irrigation water requirements for furrow irrigation are important for the sustainability of irrigated agriculture on the southern High Plains. Relatively high energy costs for pumping from the Ogallala Aquifer and reduced well yields from a declining water table have caused an increased interest in improving irrigation management and application efficiency. One of the major reasons for low irrigation efficiencies is a relatively high irrigation intake when using graded furrow irrigation during the first application (preplant or postplant) after primary tillage on moderately permeable to permeable soils. The excessive intake results in deep percolation below the plant root zone. The high intake rates for these irrigations are related to loosened surface soil conditions from primary tillage and winter frost action. For example, Undersander and Regier (1988) reported average preplant furrow irrigation intake of 237 mm (9.3 in.) and 466 mm (18.3 in.), respectively, for fall and spring preplant applications following fall primary tillage on a fine-textured Sherm silty clay loam near Dumas, Texas. The much higher irrigation application in the spring was attributed to increased intake after winter soil weathering, especially on non-wheel-track furrows.

Preplant irrigations of 150 to 250 mm (6 to 10 in.) have been measured with graded furrow application after winter tillage on the fine textured Pullman clay loam in the Amarillo, Texas, area (Musick, 1987). Later applications, after surface consolidation, are normally about 80 to 120 mm (3 to 5 in.). Frequently, lesser amounts [70 to 100 mm (2.7 to 4 in.)] are adequate to rewet the soil profile during the first spring irrigation, because of some storage from non-growing season precipitation and some residual soil water from a preceding irrigated crop. Application beyond the amount needed to rewet the soil profile is mostly lost to profile drainage and tailwater runoff.

Trout and Kemper (1983) reported four major management factors that affect irrigation furrow intake. These are: 1) wheel compaction of furrows, 2) surface soil water content, 3) furrow flow rates, and 4) intermittent application such as "surge" irrigation. We addressed furrow compaction by wheel traffic in this study. Research at various locations indicated that controlled furrow compaction can help to control excess intake.

At Clay Center, Nebraska, Eisenhauer et al. (1982) reduced furrow intake up to 20-25% by wheel traffic before the first application after tillage. They used controlled furrow traffic on both conventional and reduced tillage systems. Trout and Kemper (1983) reported that wheel traffic in furrows reduced irrigation water advance time to the end of field by one-third and intake by one-half of that in non-traffic furrows. During the second irrigation after tillage, 80% of the difference in intake between traffic and non-traffic furrows still existed. Fornstrom et al. (1985) reported that weighted rollers firmed non-wheel-traffic furrows of a high intake soil near Powell, Wyoming, so that furrow irrigation advance rates were about equal for both wheel-tracked and non-wheel-traffic furrows.

Article was submitted for publication in July 1991; reviewed and approved for publication by the Soil and Water Div. of ASAE. Presented as ASAE Paper No. 89-2179.

Contribution from USDA-Agricultural Research Service, Conservation and Production Research Laboratory, Bushland, TX.

The mention of a product or trade name is for information purposes only and does not constitute or imply an endorsement or recommendation for use by the USDA.

The authors are Ronald R. Allen, Agricultural Engineer, and Jack T. Musick, Agricultural Engineer, USDA-ARS, Conservation and Production Research Laboratory, Bushland, TX.

Musick et al. (1985) and Musick and Pringle (1986) reported wheel traffic effects of furrow intake on a moderately permeable Olton clay loam in the Texas Panhandle. Furrow traffic reduced water advance time on 400-m (1320 ft) length furrows by 48%, water intake by 33%, and estimated profile drainage by about 50%.

Objectives

The objectives of this field study were to determine:

- the effects of furrow compaction by controlled tractor wheel traffic on reducing intake during the preplant irrigation following primary tillage,
- the effects of furrow ripping before the second irrigation on removing the furrow compaction of wheel traffic and restoring normal intake, and
- the effect of ripping non-compacted furrows on increasing intake of a slowly permeable Pullman clay loam.

Procedure

A two-year field study was conducted to evaluate the effects of four furrow treatments on irrigation intake and yield of grain sorghum. The two main treatments were no furrow traffic as a control and furrow traffic. Main plots, 9 m (30 ft) (six furrows) wide by 400 m (1320 ft) long, were split into two three-furrow width subplots with three replications in a randomized block split-plot design. Subplot treatments were furrow ripping and no furrow ripping.

The four furrow treatments are designated as follows:

NFT = No furrow traffic (control)
FT = Furrow traffic
NFT-FR = No traffic (furrows ripped before second irrigation)
FT-FR = Furrow traffic (furrows ripped before second irrigation)

The study was conducted during 1985 and 1986 at Bushland, Texas. Furrows were spaced 1.5 m (5 ft) apart on a 0.15% grade. The soil, a fine textured and slowly permeable Pullman clay loam (Torrertic Paleustoll), was described by Unger and Pringle (1981). This soil has a silty clay loam Ap horizon [0-150 mm (0-6 in.)], a slowly permeable clay B21t horizon [150-400 mm (6-16 in.)], and a silty clay B22t horizon [400-700 mm (16-28 in.)].

Soil preparation was accomplished during late winter by chiseling and disking to incorporate sorghum residue. Anhydrous ammonia was chisel applied 45° to row direction at 160 kg/ha (140 lb/ac) N before furrows were formed in April. Propazine was applied for weed control. Wheel traffic was confined to the center of the beds (fig. 1) except when tractor passes were made in furrows of traffic compaction treatments. One furrow compaction pass was made in furrows on the compaction plots with a 6000-kg (13,200 lb) tractor immediately after furrows were formed but prior to the preplant irrigation. Soil water content in the tillage zone was from 40 to 50% of field capacity when furrows were compacted.

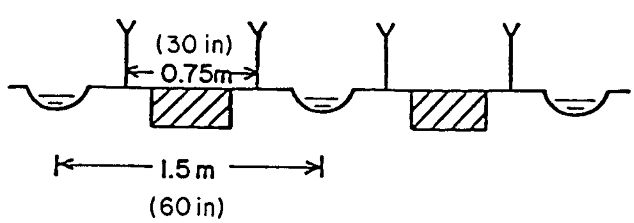

Figure 1–Bed-furrow configuration showing location of sorghum rows, cross-hatched wheel traffic zones, and irrigation furrows.

Grain sorghum hybrid Pioneer 8333 (medium-late maturity) was planted in two 0.75-m (2.5 ft) spaced rows per bed on 10 June 1985 and 21 May 1986 with a six-row IH 800 Cyclo planter. The seeding rate was set to achieve 20 plants per m^2 (80,000 plants/ac), based on an expected 70% germination and seedling emergence.

Furrow ripping [200-250 mm (8-10 in.) deep] was performed with a Blue-Jet inter-row ripper prior to the second irrigation at about the eight-leaf stage (about 30 days after emergence). The ripper shanks were inclined and had a "V"-shaped forward cutting edge to minimize soil surface disturbance. Soil water content, to the depth ripped, was expected to be about 35 to 40% of field capacity at this plant growth stage. The first irrigation (preplant) was applied 20 May 1985 and 6 May 1986. Sorghum growing season irrigations were applied 16 July, 6 August, and 20 August 1985; and 8 July and 29 July 1986. Irrigation water was applied through gated pipe and measured with a propeller meter. Furrow inflow rates were set at 53 L/min (14 gal/min). Individually calibrated portable "H" flumes, equipped with water level recorders, were used to measure furrow runoff from three furrows per treatment.

Irrigations were scheduled when soil water content was depleted to about 40% of field capacity. Soil water contents were measured gravimetrically to 1.8 m (6 ft) in 0.3-m (1-ft) increments before and after irrigations and at crop emergence and harvest. Seasonal crop water use (ET) was determined by the change in soil water content between crop emergence and harvest plus rainfall and irrigation. Soil density was measured with a Troxler 3400 series nuclear density gage to the 0.2-m (8-in.) depth after furrow compaction traffic and after irrigations.

Grain yields were measured by combine harvesting 3×70 m (10×230 ft) samples centered in the upper, middle, and lower one-third of each 400-m (1320 ft) subplot. Grain mass was measured by a grain cart equipped with an electronic scale. Grain yields are reported at 14% moisture content (wet basis).

Results and Discussion

Furrow Bulk Densities

The effect of tractor wheel compaction on increasing furrow surface layer bulk density, to the 200-mm (8-in.) depth, is presented in figure 2. A single traffic pass with a 6000 kg (13,200 lb) tractor increased furrow bulk density at the 50-mm (2-in.) depth from an average 1.1 to 1.27 Mg/m^3. The relatively low density of non-traffic furrows at the 50-mm (2-in.) depth reflects the loose-unconsolidated surface after primary tillage and before the first irrigation (fig. 2). Before the 1985 crop season, a relatively wet soil surface limited the depth of late winter tillage to only 120 mm (5 in.). In contrast, tillage before the 1986 crop season could be performed at the more normal 200-mm (8-in.) depth. Thus, furrow densities in 1986 were lower because of the deeper tillage. Because of this lower (tillage loosened) density in 1986,

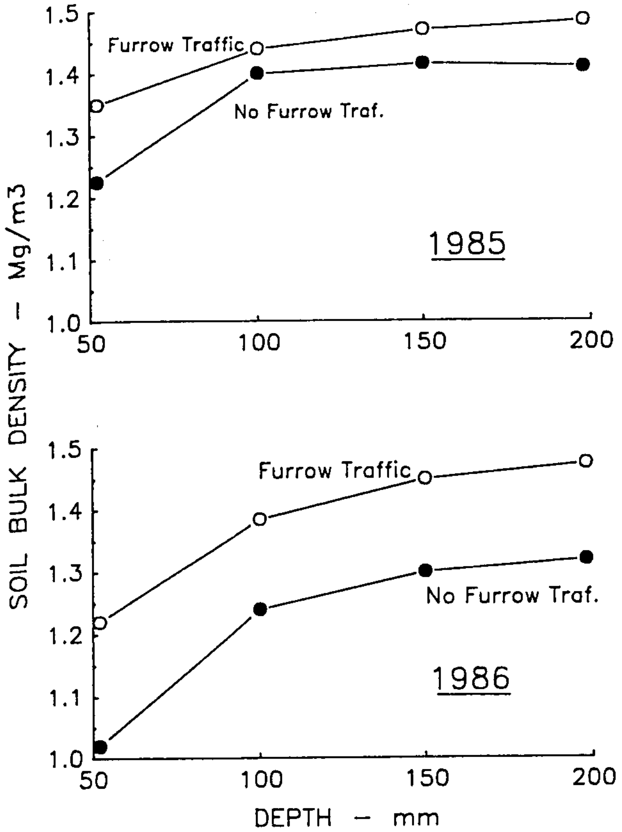

Figure 2–Soil bulk density by furrow treatment and depth beneath furrow before first irrigation, 1985-86. (25 mm = 1 in.)

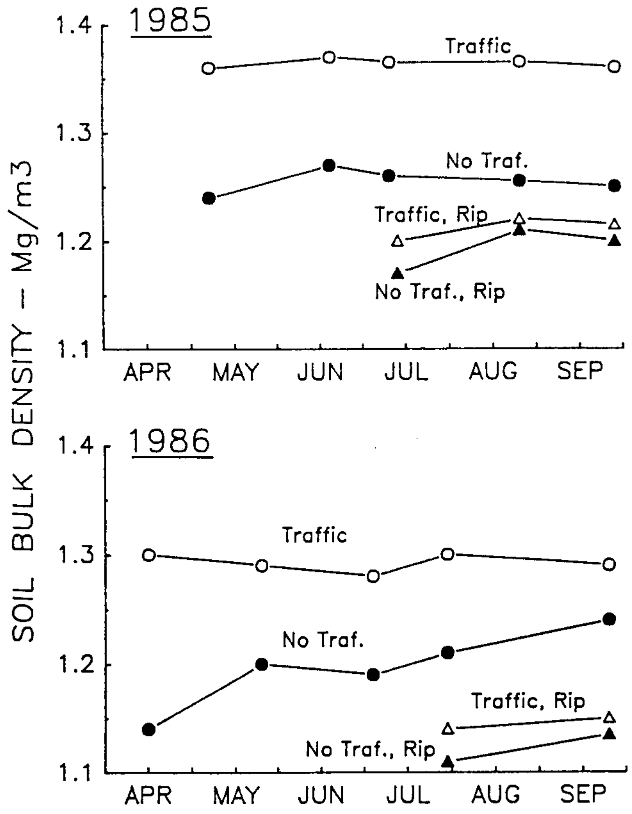

Figure 3–Average soil bulk density in furrow, for depth increment of 50 to 100 mm during crop season, 1985-86. (25 mm = 1 in.)

the increase in furrow density from traffic compaction was greater than in 1985. Bulk density below the 200-mm (8-in.) tillage depth in the relatively dense B21t soil horizon was in the 1.4 to 1.5 Mg/m^3 range which is common for the Pullman soil (Pringle, 1988).

The average bulk densities for the 50 to 100-mm (2 to 4-in.) depth increment throughout the crop season are presented in figure 3 for each furrow treatment. Densities in no-traffic furrows at the second sampling date (planting time) were higher than at the first sampling date because of furrow reconsolidation after the preplant irrigation. Following the preplant irrigation, differences in furrow density between the no-traffic control and the compacted traffic furrows remained through the rest of the crop season in each year. Ripping markedly reduced furrow bulk density and the effect remained through the crop season. Ripping reduced furrow traffic bulk density below that of the no-traffic control treatment in each year.

Water Applied, Runoff, and Intake During First Irrigation (Preplant)

The irrigation application, runoff, net intake, soil water storage, application efficiency, and soil water storage efficiency for the first application (preplant) are presented in Table 1. Furrow traffic reduced two-year average intake from 124 to 103 mm (4.9 to 4.1 in.) or 17%. The first irrigation in 1986 had higher intake than in 1985 because of the increased tillage depth and drier soil at the time of irrigation.

Furrow compaction in 1985 reduced water advance times to the end of the 400 m (1320 ft) furrows from 17 to 9.25 hours or by 45%. For the higher intake condition in 1986, furrow compaction reduced average advance times from 28 to 22 hours. Since the same irrigation amounts were applied for furrow traffic and no-traffic treatments, furrow traffic compaction resulted in increased runoff and reduced application efficiency. In practice, the reduced intake effect will permit a reduction in application time, thus, avoiding increased runoff. Application efficiency (irrigation intake/application) for the furrow traffic treatment averaged 74% compared with 90% for the non-furrow traffic control. Soil water storage efficiency

TABLE 1. Treatment effects on irrigation application and soil water storage efficiency for first application after tillage on 1.5 m (60 in.) spaced furrows, Bushland, Texas

Treatment	Irrigation Appli.	Run-Off	Intake	Storage	Appl. Eff.	Storage Eff.
	(mm)*				(%)	
1985						
T-1 No traf.	105	11	94	46	89	49
T-2 Furrow traf.	105	29	76	48	72	63
LSD (0.05)		(7)	(10)	(NS)	(10)	(8)
1986						
T-1 No traf.	170	15	155	31	91	20
T-2 Furrow traf.	170	40	130	28	76	21
LSD (0.05)		(10)	(25)	(NS)	(13)	(NS)
Mean						
T-1 No traf.	137	13	124	38	90	34
T-2 Furrow traf.	137	34	103	38	74	42

* Metric to English unit conversion: 25 mm = 1 in.

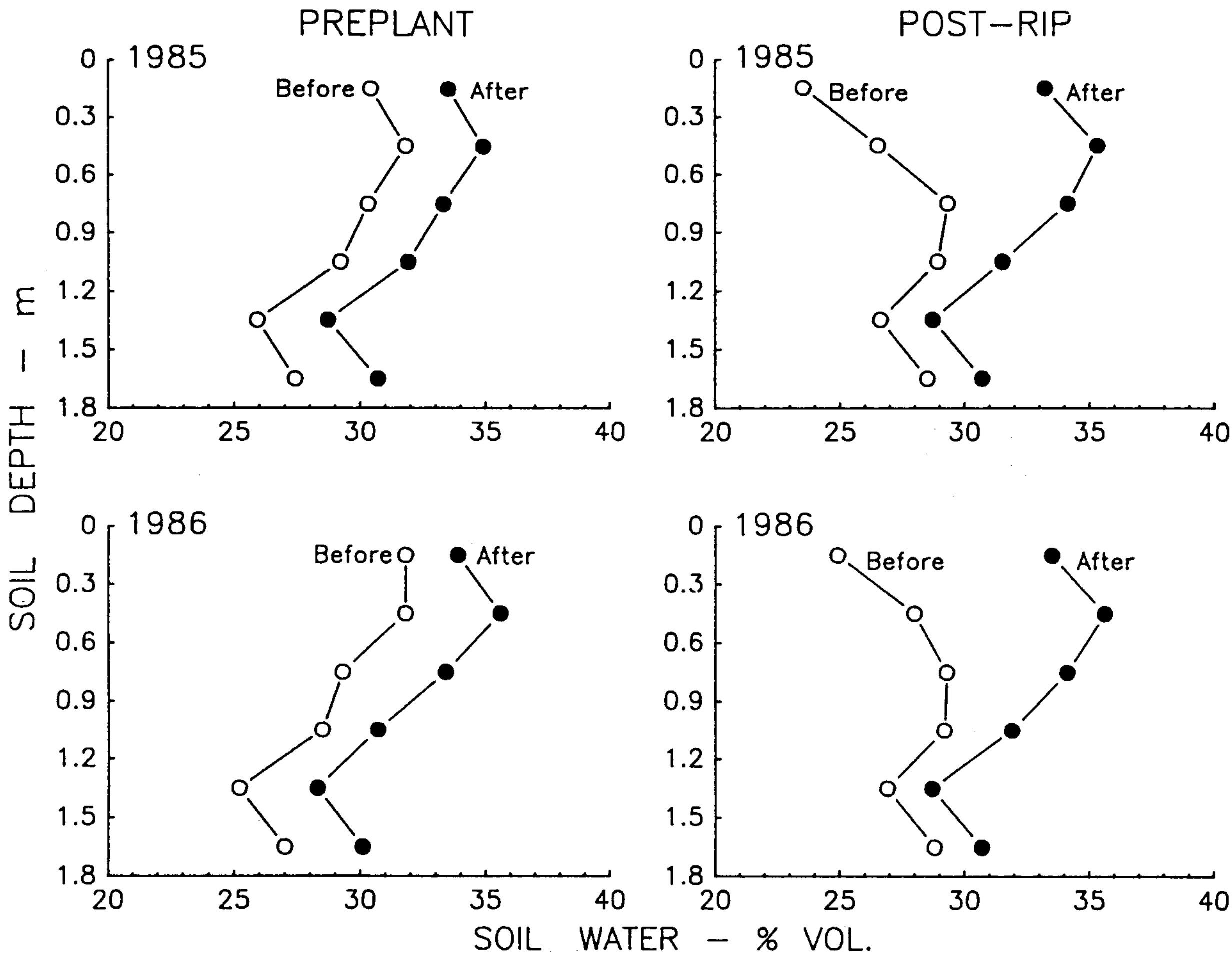

Figure 4–Soil water content with depth before and after preplant irrigation; and before and after the second (post-rip) irrigation, 1985-86. (1 m = 3.28 ft)

(irrigation storage/intake) varied widely between the two years (20 to 63%). The relatively high preplant irrigation intake and low storage, associated with deeper tillage in 1986, indicates that losses occurred from deep percolation. Average preplant irrigation application efficiencies in the 75 to 90% range are reasonably good. Musick et al. (1973) reported furrow application efficiencies of 85 to 95% (5 to 15% runoff) with well-managed systems on the same soil.

The relatively small increase in soil water storage after the preplant irrigations in both years resulted from limited capacity for additional storage at the time of irrigation (fig. 4). The differences in soil water content at the 1.8-m (6-ft) depth before and after preplant irrigations also indicated drainage loss to deep percolation below the root zone. The apparent deep percolation losses are reflected in low two year average soil profile storage efficiencies of 34% and 42%, respectively, for NFT and FT treatments.

Water Application, Intake, Runoff, and Application Efficiency for Season Growing Applications

Total growing season water application, runoff, and net intake are presented in Table 2 and cumulative intake from successive irrigations is presented in figure 5. The FT treatment was effective in reducing average total irrigation water intake from 335 to 292 mm (13 to 11 in.) or 13% compared with the NFT control treatment.

Furrow ripping, when grain sorghum was near the eight-leaf stage, increased the intake of both traffic and non-traffic furrows (Table 2 and fig. 5). The increased intake effect after ripping continued during subsequent irrigations. Average intake for FT-FR was slightly higher than for the NFT-FR treatments. Total irrigation intake for both ripped treatments averaged 363 mm (14.3 in.) or 25% higher than for the FT treatment at 292 mm (11.5 in.). The intake on ripped treatments averaged 10% higher than on the control.

Furrow traffic increased average growing season runoff from 80 to 123 mm (3.2 to 4.8 in.) or by 53%. Average irrigation application efficiencies for the NFT, NFT-FR, and FT-FR treatments were very similar at 79 to 83%. The FT treatment averaged somewhat less at 70%.

Soil water contents before and after the post-rip irrigation in 1986 are presented in figure 6 to illustrate length-of-run effects. The furrow traffic treatment had noticeably less soil water storage after the post-rip irrigation than did the other furrow treatments. The decline in soil water content with length of run was similar across all furrow treatments. The decline is a function of reduced intake, related to reduced opportunity time with length of run, and is not a function of furrow treatment. There was

TABLE 2. Treatment effects on irrigation and growing season water use

Treatment	Irrigation: Applic.	Irrigation: Run-Off	Irrigation: Intake	Irrigation: Appl. Eff.	Growing Season: Water* Use	Growing Season: Grain Yld.	Growing Season: WUE
	-----(mm)†	-----	-----	(%)	(mm)	(Kg/ha)	(Kg/m³)
1985							
NFT (no-traf)	420	98	324	77	575	4570	0.79
FT (traffic)	420	149	272	65	545	4770	0.88
NFT-FR(no-tr, Rp)	450	89	357	79	620	4570	0.74
FT-FR (traf, Rp)	450	112	336	75	590	4290	0.73
LSD (0.05)		(NS)	(NS)	(NS)	(NS)	(NS)	(NS)
1986							
NFT (no-traf)	410	63	347	85	629	7800	1.24
FT (traffic)	410	97	313	76	594	7700	1.30
NFT-FR (no-tr, Rp)	448	69	388	87	674	7800	1.16
FT-FR (traf, Rp)	448	75	375	84	656	7940	1.21
LSD (0.05)		(32)	(NS)	(NS)	(NS)	(NS)	(NS)
Mean							
NFT (no-traf)	415	80	335	81	602	6185	1.01
FT (traffic)	415	123	292	70	570	6235	1.09
NFT-FR (no-tr, Rp)	449	79	372	83	647	6185	0.95
FT-FR (traf, Rp)	449	93	355	79	623	6115	0.97

* Growing season water use includes rainfall during the crop season, which was 273 mm in 1985 and 334 mm in 1986.

† Metric to English unit conversion: 25 mm = 1 in.; 1 Kg/ha = 0.89 Lb/ac; 1 Kg/m³ = 226 Lb/ac-in.

noticeably more gain in soil water storage in the upper one-third of the irrigation run for all furrow treatments. The relatively wide 1.5-m (5-ft) spaced furrows limit intake and profile wetting to a greater extent on the lower part of the field when compared with 0.75 m (2.5 ft) spaced furrows (Allen and Musick, 1972). Grain yield declined with length of run in 1986 (fig. 7) similarly to the decline in soil water with length-of-run as just discussed.

Although wheel traffic increased the furrow zone bulk density of the slowly permeable Pullman clay loam, furrow compaction did not reduce water intake as much as that measured by Musick and Pringle (1986), which was about 33% on a moderately permeable Olton clay loam. Some of the differences in wheel traffic compaction between these two soils may be due to differences in tractor mass. A 6000 kg (13,200 lb) tractor was used on the slowly permeable soil and a 9000 kg (20,000 lb) tractor was used on the moderately permeable soil at a relatively high water content.

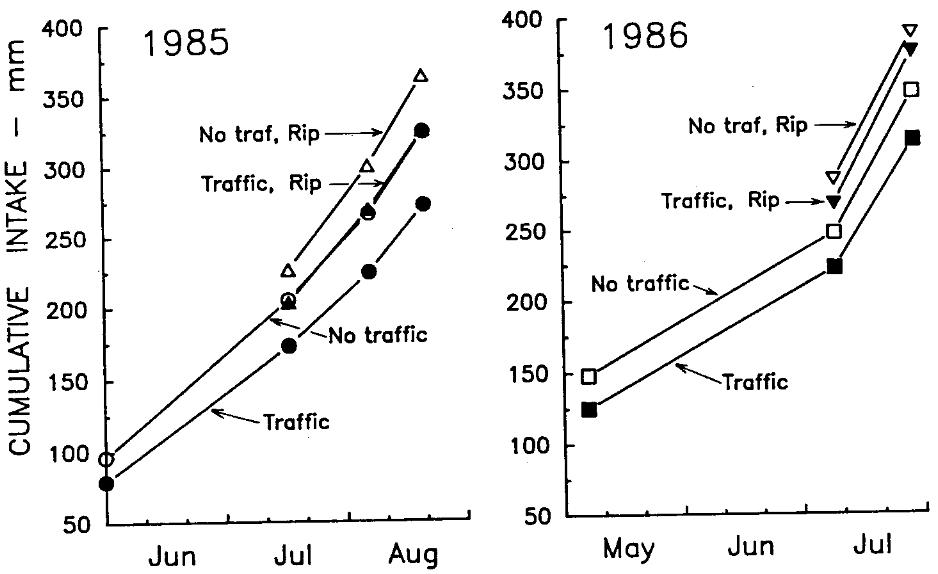

Figure 5–Furrow treatment effects on cumulative irrigation water intake, 1985-86. (25 mm = 1 in.)

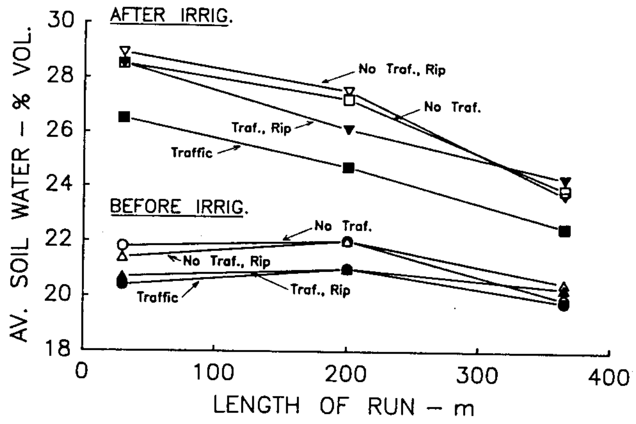

Figure 6–Soil water content to 1.8-m depth by furrow treatment along the irrigation run, before and after the post-rip irrigation, 7 July 1986. (1 m = 3.28 ft)

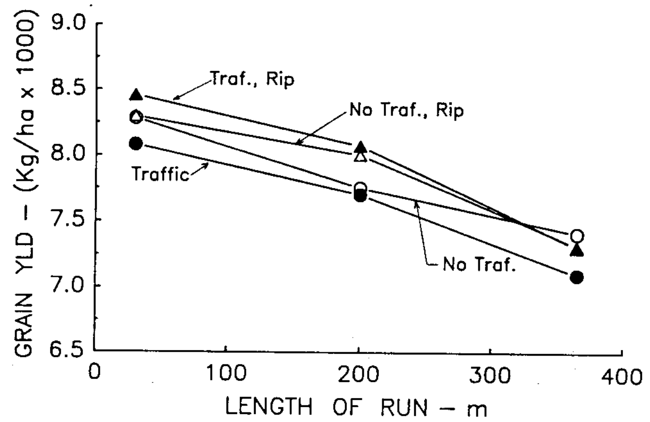

Figure 7–Grain yield along length of irrigation run by furrow treatment, 1986. (1 kg/ha = 0.89 lb/ac, 1 m = 3.28 ft)

Growing Season Water Use and Grain Yield

Growing season water use, grain yield, and water use efficiency (WUE) are also presented in Table 2. Growing season water use for the FT treatment averaged 5% less than did the control at 600 mm (24 in.). Water use for the ripped furrow treatments averaged 5% higher than did the control. There were no significant differences in grain yield between furrow treatments in either year of the study.

Grain yields in 1985 were low because of an early freeze on 30 September, (24 days earlier than average) which occurred before physiological maturity. Therefore, the growing season WUE values (grain yield/ET) were correspondingly low. The FT treatment had the highest WUE and the ripped treatments had the lowest values in each year. Conversely, the FT treatment had the lowest irrigation application efficiency because of greater runoff. Furrow ripping can be used to increase the intake of non-traffic furrows (fig. 5). Increasing intake can be beneficial under both furrow and low-pressure application by sprinklers such as LEPA (Lyle and Bordovsky, 1983) on slowly permeable soils. Leaving furrow compaction during the season on a slowly permeable soil can be detrimental to water intake and crop yield, especially during dry seasons when precipitation contribution to crop water requirements is low. Precipitation, during the May-October growing seasons in this study, was 13% above the 50-year average of 367 mm (14.4 in.). Thus, growing conditions were favorable and irrigation demand and related water intake needs were below average. This may have been the reason for the absence of furrow treatment effect on crop yield.

Summary and Conclusions

Furrow compaction, which increases soil bulk density and reduced intake, offers furrow irrigators a relatively inexpensive tool to reduce early season excess intake. Furrow traffic was effective in reducing irrigation intake by an average of 17% during the first application (preplant) after tillage when intake normally exceeds available soil storage. Furrow traffic reduced cumulative irrigation intake by 13% for the preplant plus growing season irrigations. Ripping traffic compacted furrows, before the second irrigation, fully restored normal intake for succeeding later season irrigations.

Grain yields were not affected by furrow traffic or furrow ripping treatments. The absence of furrow treatment effect on yield may have been caused by 13% above average growing season precipitation.

References

Allen, R. R. and J. T. Musick. 1972. Wheat and grain sorghum irrigation in a wide bed-furrow system. *Transactions of the ASAE* 15(1):61-63.

Eisenhauer, D. E., E. C. Dickey, P. E. Fischbach and K. D. Frank. 1982. Influence of reduced tillage on furrow irrigation infiltration. ASAE Paper No. 82-2587. St. Joseph, MI: ASAE.

Fornstrom, K. J., J. A. Michel, J. Borrelli and G. D. Jackson. 1985. Furrow firming for control of irrigation advance rates. *Transactions of the ASAE* 28(2):529-531, 536.

Lyle, W. M. and J. P. Bordovsky. 1983. LEPA irrigation system evaluation. *Transactions of the ASAE* 26(3):776-781.

Musick, J. T. and F. B. Pringle. 1986. Tractor wheel compaction of wide-spaced irrigation furrows for reducing water application. *Applied Engineering in Agriculture* 2(2):123-128.

Musick, J. T., F. B. Pringle and P. N. Johnson. 1985. Furrow compaction for controlling excessive irrigation water intake. *Transactions of the ASAE* 28(2):502-506.

Musick, J. T. 1987. Preplant irrigations in the southern High Plains - A review. ASAE Paper No. 87-2558. St. Joseph, MI: ASAE.

Musick, J. T., W. H. Sletten and D. A. Dusek. 1973. Evaluation of graded furrow irrigation with length of run on a clay loam soil. *Transactions of the ASAE* 16(6):1075-1080.

Pringle, F. B., Soil Scientist, USDA-SCS, Personal Communication, 1988.

Trout, T. J. and W. D. Kemper. 1983. Factors which affect furrow intake rates. In *Proc. Adv. in Infiltration*, 302-312. ASAE, Chicago, IL, Dec. 12-13. St. Joseph, MI: ASAE.

Undersander, D. J. and C. Regier. 1988. Effect of tillage and furrow irrigation timing on efficiency of preplant irrigation. *Irrig. Sci.* 9:57-67.

Unger, P. W. and F. B. Pringle. 1981. Pullman soils: Distribution, importance, variability, and management. Texas Agric. Exp. Stn. Bull. 1372.