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PERMANENT RIDGE-TILL SORGHUM WITH FURROW IRRIGATION

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Summary:

Permanent ridge-tillage (RT) was compared with conventional tillage and bed/furrow forming (BED) for furrow irrigated sorghum. Grain yield and water use efficiency were significantly higher for RT compared with BED planting.

Keywords:

Furrow Irrigation, Ridge-Tillage, Row Crop

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ABSTRACT

Planting of row crops on permanent ridges was developed primarily in the cornbelt, but is being adapted for graded furrow irrigation. This study was conducted during 1992-95 on the Southern High Plains at Bushland, TX, to determine the effect of permanent ridge-furrows on fallow season soil water storage, irrigation intake, evapotranspiration (ET), grain yield, and water use efficiency (WUE) with grain sorghum; and to determine effect of precision cultivation with reduced herbicide application for weed control. Treatments were ridge-till (RT), conventionally tilled bed planting (BED), and flat planting (FLAT) with furrows opened during cultivation on a 550 m (1800 ft) furrow run. Seedling emergence and heading were 1-2 days earlier for RT in 2 of 3 yrs. Grain yields averaged highest for RT at 7.91 Mg/ha (7400 lb/ac) compared with 7.17 and 7.54 Mg/ha (6380 and 6710 lb/ac) for BED and FLAT treatments, respectively. The WUE averaged 1.26, 1.08, and 1.19 kg/m^3 (285, 244, and 269 lb/ac-in) for RT, BED, AND FLAT treatments, respectively. The WUE for RT was significantly higher than for the BED treatment. The RT cultural operation and planting costs were about \$67.00/ha (\$27/ac) lower than for BED planting while FLAT planting treatment costs were \$12.50/ha (\$5.00/ac) lower than BED planting. RT and FLAT planting were less dependent on timely rainfall to provide a moist seed zone than was BED planting. Precision cultivation successfully controlled 90-95% of weeds compared with 95-98% control with atrazine herbicide.

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INTRODUCTION

Methods of primary tillage between annual crops of irrigated corn or sorghum on the Southern High Plains commonly include disking or disking and chiseling with occasional ripping or moldboarding for deeper loosening. With furrow irrigation, row crops are usually planted on elevated beds (ridges) separated by irrigation furrows. An alternate practice is to plant on a flat surface with furrowing performed after crop emergence during the first cultivation. In either case, crop residue is mostly mixed into the soil by planting time and the cultural operations result in a relatively dry seedbed which can require a preplant or an emergence irrigation for germination.

An alternative method of planting row crops on permanent ridges (ridge-till) was developed primarily in the cornbelt. The evolvement of ridge-till started after Buchele and associates (1955) introduced contour planting of corn on clean-tilled listed ridges in Iowa to reduce water erosion. Later, research in Nebraska by Wittmuss et al., (1971) indicated that successful planting could be accomplished on old crop ridges without primary tillage. They developed a till-planter that removed residue and some soil from the old ridges providing a clean seed row strip of relatively warm, moist, and mellow soil. Heavy duty cultivators were needed to operate through interrow residue, control weeds, and rebuild plant row ridges. Present refined ridge-till procedures may include a band application of herbicide to the cleared seed row strip for control of early weeds, but the basic technique still uses primarily sweep, finger, or disc clearing devices mounted on or operated ahead of row planters.

The cultural advantages of ridge-till were rather easily adapted by Norton and Eisenhauer (1991) to furrow irrigation since cultivation between crop rows to rebuild ridges established suitable water conveyance furrows. They found that ridge-till furrows had slower furrow water advance rates and higher irrigation intake, compared with clean tillage and reformed beds/ridges in tests on a Hastings silt loam in South Central Nebraska. Schlegel and Dhuyvetter (1995) found that ridge-till culture increased soil water storage available at planting by about 25 mm (1 in) because of some snow trapping and reduced evaporation under residues on a Ulysses silt loam in Western Kansas. Smith (1992) reported a $75/ha ($30/ac) reduction in production costs with ridge tillage without reducing irrigated corn yield on a nearby Ulysses soil. Unger (1994) found that ridge tillage increased soil water available at planting by 31 mm (1.2 in). They received 14 mm (0.6 in) above average precipitation during the between-crop period in a 6-yr study between 1986 and 1992 at Bushland, TX. Unger reported seasonal soil water depletion to be 66 mm (2.6 in) with ridge tillage compared with 51 mm (2 in) by conventional tillage.

The objectives were to:

* Determine the effect of permanent cultivated ridge/furrows on between crop soil water storage, irrigation intake, ET, grain yield, and WUE with grain sorghum production.
* Determine the effect of precision cultivation of furrows with permanent crop ridges versus a triazine herbicide for seasonal weed control.

PROCEDURE

The study was conducted during 1992 to 1995 at the USDA Conservation and Production Research Laboratory, Bushland, Texas. The soil, a fine textured and slowly permeable Pullman clay loam (Torrertic Paleustoll), was described by Unger and Pringle (1981). This soil has a plant available water holding capacity of 180 mm (7.2 in) to a 1.2 m (4 ft) rooting depth for sorghum.

Treatments were:

RT = Permanent ridges with herbicide subplots.

BED = Conventional chisel-disk, rebed.

FLAT = Chisel, flat plant, open water furrows during cultivation.

The experimental design was randomized block, split plot with four replications. Main plot tillage treatments for continuous irrigated grain sorghum were 4.6 m (15 ft) wide by 550 m (1800 ft) long and contained six 0.75 m (30 in) spaced ridge-furrows on a 0.35% grade. The upper 360 m (1200 ft) of RT treatment strips were divided into four 90 m (300 ft) length subplots alternately having herbicide and no herbicide treatments.

The experimental site was previously cropped to grain sorghum after fallow in the summer of 1992 and had relatively low weed density. Stalks were shredded and a disk-bedder was used during the winter on RT plots to move soil to the stalk row and form the permanent ridges for the 3-yr study. Anhydrous ammonia was knifed into row middles at 200 kg/ha (160 lb/ac) N. The BED and FLAT clean tillage treatments were chiseled to the 150 mm (6 in) depth on 0.3 m (1 ft) centers followed by rotary tillage for residue/soil mixing. Bed-furrows were formed with a disk-bedder on the BED treatment.

Before planting, glyphosate herbicide was applied at 1.75 kg/ha (25 oz/ac) total material to control weeds and volunteer sorghum on RT treatments. A tank mix of propazine at 2.25 kg/ha (2 lb/ac) and Dual at 2.25 kg/ha (2 lb/ac) AI was applied preplant on BED and FLAT treatments for broadleaf and grass control. A 6-row IH[3] 800 Cyclo planter was used having staggered double-disk seed slot openers. ACRA-Plant "trash whippers", having staggered and notched residue/soil clearing disks forming a "V", were mounted in front of seed openers to remove 25 to 50 mm (1 to 2 in) of soil from the ridge on RT treatments. Atrazine was applied post-emergent at 1.7 kg/ha (1.5 lb/ac) AI as the herbicide treatment on RT subplots. After plants were at the 5-8 leaf stage, a relatively heavy-duty Buffalo 6300 ridge-till residue cultivator was used with an electronic plant-row sensing guidance hitch to cultivate and reform water furrows while moving soil to the plant row, reforming the ridge. The cultivator was also used to form irrigation furrows on the FLAT treatment and to reshape furrows on the BED treatment.

Irrigation was applied through gated pipe and measured with a propeller meter. Individual furrow inflow rates were measured and adjusted by use of a volumetric container and stopwatch. Tailwater was measured through individually calibrated portable H-flumes having float operated, electric clock driven, FW-1 type water-stage recorders. Furrow inflow rates were set at 0.62 L/sec (10 gpm) to complete the advance phase in 18-20 h. Soil water content was measured gravimetrically by core samples in 0.3 m (1 ft) increments to 1.8 m (6 ft) deep. Samples were obtained (four/plot) before planting, emergence, and at harvest. Grain yields were determined by combine harvesting 4 rows by 90 m (300 ft) length of run subplots, adjusted to 13.5% moisture (wet basis). Water use efficiency (WUE) was determined as the ratio of grain yield to seasonal ET (water used including net irrigation). Subplot treatment means were tested for significance at the $P<0.05$ level using Statgraphics (Manugistics, 1992) for analysis of variance.

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[3]The mention of trade or manufacturer names is made for information only and does not imply an endorsement, recommendation, or exclusion by USDA-Agricultural Research Service.

RESULTS

Cultural Operations

For discussion, crop years 1993, 1994, and 1995 are referred to as yrs 1, 2, and 3. The RT plots required no cultural operations during winter and early spring, except in yr 3 when animal burrowing required a furrow clearing operation with the cultivator to remove random furrow mounds. The preplant application of glyphosate on RT treatments was successful in controlling kochia and volunteer sorghum which confirmed previous results with minimum-till, graded furrow irrigated sorghum research (Allen, 1985). On BED and FLAT treatments, one pass of a rotary tiller mixed residue and soil about the same as two passes with a tandem disk, without the drawback of soil surface unevenness associated with disking. Planting on RT ridges was accomplished with the assistance of guide cones to hold the planter openers on ridge centers. Only 25 to 50 mm (1 to 2 in) of ridge soil and old root crown were removed with the trash whippers which left a firm moist seedbed for planting. In yr 1, the newly prepared beds were dry from tillage operations and required an emergence irrigation to germinate seed. The RT and FLAT treatments had adequate soil water content for seedling emergence. Over winter soil water storage is discussed in the following section on water management. In yrs 2 and 3, all tillage treatments were planted without a preplant or emergence irrigation.

Cultivation accomplished both the opening of a water furrow and the reestablishment of a ridge at the plant row. The electronic guidance hitch maintained cultivator alignment and permitted positioning of borrowing disks close to plants to control small weeds and volunteer sorghum.

Subplot treatments with atrazine had minor affect on weed and annual grass control. In yr 1, atrazine had about 95% control and cultivation-only produced 90% control. In year 2, there was about 98% pigweed control with atrazine and 95 to 97% control with cultivation only. There were a few random clusters of crabgrass not related to herbicide treatment or tillage. In yr 3, there was no apparent effect from atrazine treatment. There were a few more random clusters of crabgrass and increased incursion of crabgrass at edges of the plot area. It appeared that annual grass pressure will require rotating ridge tillage to new clean field areas after 3 to 4 yrs of continuous summer row cropping. To some degree, this is also true for conventional clean tillage with full herbicide treatment.

Costs of cultural operations through planting and cultivating are presented in Table 2. Costs for RT were \$67.50/ha (\$27.35/ac) less than for conventional tillage and bedding and \$55.20/ha (\$22.35/ac) less than for the FLAT treatment. These operational costs savings with RT are similar to those reported by Smith (1992).

Cone index (soil strength) values in furrows are presented in Figure 1 as and indicator of increased soil density from compaction. Soil strength peaked sharply at about 75 mm (3 in) deep in wheel track furrows whereas strength increased gradually to the 150 to 200 mm (6 to 8 in) depth in non-traffic furrows. All strengths were about the same below 150 mm (6 in) which was below tillage depth and is at the top of the B horizon of a Pullman soil. These values were measured in yr 3 for the RT and BED treatments on August 7, 1995 after two seasonal irrigations when the furrow surface was consolidated and relatively smooth. The RT wheel track furrows were slightly more dense than were conventionally tilled and bedded wheel track furrows. Soil strengths for the FLAT treatment were about equal to the BED treatment and are not included in the graph in order to improve clarity.

Water Management

Preseason November through May precipitation (Table 3) was near the average at 174 mm (6.85 in) during crop yrs 1 and 2. In yr 3, preseason precipitation through April was only 51 mm (2 in) or 48% of average and all treatments were too dry for planting until 119 mm (4.7 in) of May rainfall occurred. This May rainfall was 74% above average and provided adequate soil water for early June planting (Fig. 2). Plant available soil water (ASW) content to the 1.8 m (6 ft) depth at emergence is presented in Table 3 for the 3 crop yrs. The ASW was lowest at planting in yr 2, but was adequate for germination to the 0.6 m (2 ft) depth. Growing season precipitation was below average in each yr (table 3) and especially so in yr 3 when only 191 mm (7.5 in) or 63% of average was received. Maintaining the surface flat over winter before planting provided about the same soil profile water storage and nearly as moist a seed zone as did RT and lessened the need for a preplant or emergence irrigation that can be required for conventionally tilled and reformed beds before planting. Similar results were reported previously with flat vs conventional bed planting (Allen and Musick, 1990).

Profile ASW at planting is presented in Fig 2. In yr 1, an emergence irrigation was necessary to wet the BED treatment after tillage and bed forming. In this study, we did not experience an average 25+ mm (1 in) increase in over winter soil water storage in the soil profile at planting with RT as did Schlegel and Dhuyvetter at Tribune, KS (1995) and Unger at Bushland, TX (1994). We attribute this to the relatively dry winters during the study with very little snow.

Net irrigation application, ET, grain yield, and water use efficiency (WUE) are presented in Table 3. The emergence irrigation for the BED treatment in yr 1 significantly increased ET and lowered WUE. The 3-yr average ET for RT and FLAT treatments were nearly equal at 636 to 640 mm (25.0 to 25.2 in). WUE was significantly higher for RT compared with the BED treatment. Average WUE for FLAT planting was nearly as high as for RT, 1.18 kg/m^3 vs 1.24 kg/m^3 (267 vs 280 lb/ac-in), respectively.

Furrow water advance times were nearly equal for all treatments and wheel track furrows advanced faster than did non-track furrows. For example, on the first irrigation on June 28, 1994, times to advance 550 m (1800 ft) averaged 12.2 h for the wheel track furrows and 15.5 h for non-track furrows. Wheel track furrows were expected to advance faster than non-track furrows because of the compaction exhibited by greater soil strength, and discussed in the previous section. The furrow cultivation and ridging operation before the first seasonal irrigation eliminated furrow surface variables, which is the reason for similar advance times on each tillage treatment.

Plant Growth and Grain Yield

In yr 1, the RT treatment emerged and headed two to three days earlier than other treatments. This is attributed to the rapid germination associated with rapid soil warming and the more moist and firm condition of the ridge. In yr 2, the RT treatment emerged and headed 1 day earlier than conventional tillage. This resulted in grain yield increasing for RT during yrs 1 and 2. In yr 3, after a very dry winter, old plant residue from a furrow clearing operation to remove some animal burrowing mounds, remained largely undecomposed leaving a loose fluffy seedbed.

In yr 3, plant growth was similar for all treatments and flat planting produced the highest yields, although not significantly higher than for RT. For the 3-yr average, RT had highest grain yield and WUE. The BED treatment grain yield and WUE averaged significantly lower than the other treatments.

In yr 1, some plant stress occurred on the lower end of the field during late grain filling. As a result, some stress associated lodging occurred with conventional tillage on the lower end, but none occurred with ridge tillage. The RT treatment had slightly higher ASW at harvest in yr 1 (Fig 3), having about 20 mm (0.8 in) more. This higher late season ASW with RT resulted in about 0.6 Mg/ha (500 lb/ac) higher yield on the lower 1/3 of the field (Fig. 4), compared with conventional tillage, and avoided the late season stress-related lodging that occurred on other treatments. In yr 2, ASW on the lower end of the field was down to 50 mm (2 in), but no stress related lodging occurred. In yrs 2 and 3, ASW declined with length of run, however grain yield (Fig. 4) was relatively uniform throughout the field length indicating that late season soil water contents were not yield limiting.

CONCLUSIONS

1. Ridge-tillage (RT) culture produced higher average grain yield and WUE compared with conventional tillage and bed and flat planting. RT grain yield and WUE was significantly higher than for BED planting.

2. RT operational costs were reduced by \$67.55/ha (\$27.35/ac) compared with conventional tillage and BED planting.

3. RT and FLAT planting are less dependent on timely rainfall for seedling germination and emergence than is conventional tillage and BED planting.

4. Precision furrow cultivation was nearly as effective as conventional herbicide in seasonal weed control, thus reducing herbicide application needs.

5. Soil strength (density) was higher under wheel track furrows than in non-track furrows, but RT furrows were only slightly more dense than on the annually tilled BED treatment.

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Table 1. Planting, irrigation, and harvest dates, Bushland, TX

Year	Plant date	Irrigation dates	Harvest
1993	Jun 2	Jun 8*, Jul**, Aug 17	Oct 28
1994	May 31	Jun 28, Aug 1, Aug 22	Oct 20
1995	Jun 8	Jul 13, Jul 27, Aug 14, Aug 31	Oct 30

* Emergence application for BED treatment.

** First application for RT and FLAT treatments.

Table 2. Cultural Operation Costs

Operation	RT	BED	FLAT
		$/ha	
Shred stalks	14.80*	14.80	14.80
Apply NH^3	14.80	14.80	14/80
Disk x 2		24.70	24.70
Chisel		13.60	13.60
Bed		12.30	
Spray/incorp. herb.	12.30**	32.10	32.10
Plant	17.70	14.80	14.80
Cult.	17.70	17.70	17.70
TOTAL	73.20	140.80	126.00

* Source = Kansas Department of Agriculture (1995)

** Herbicide banded at planting.

Table 3. Treatment Effects on Soil Water Content, Water Applied, ET, Grain Yield, and WUE, Bushland, TX

		Available Soil Water to 1.8 m			Rainfall				
		Plant	Harvest	Irrig. Net	Preseason (Nov-May)	Growing Season (Jun-Oct)	ET	Grain Yield	WUE
		mm	mm	mm	mm	mm	mm	Mg/ha	kg/m^3
1993	RT	178	69	221	174	274	604	7.82	1.29
	BED	234*	60	242			689	7.37	1.07
	FLAT	171	69	208			584	7.50	1.28
	LSD (005)						(32)	(0.28)	(0.12)
1994	RT	96	64	410	170	273	715	8.77	1.23
	BED	89	74	400			688	7.42	1.08
	FLAT	108	85	402			698	7.73	1.11
	LSD (005)						(NS)	(0.30)	(0.10)
1995	RT	126	152	396	199	191	561	7.13	1.27
	BED	140	123	399			607	6.71	1.11
	FLAT	140	112	398			617	7.40	1.20
	LSD (0.05)						(41)	(0.31)	(0.10)
MEANS	RT	133	95	342	181	246	627	7.91	1.26
	BED	114**	86	347			661	7.17	1.08
	FLAT	140	89	336			633	7.54	1.19
	LSD (0.05)						(NS)	(0.47)	(0.13)
56 Yr Avg Precip					174	302			

* Includes emergence irrigation

** Average of 1994-1995

25.4 mm = 1 in, 1 Mg/ha = 890 lb/ac, 1 kg/m^3 = 226 lb/ac-in

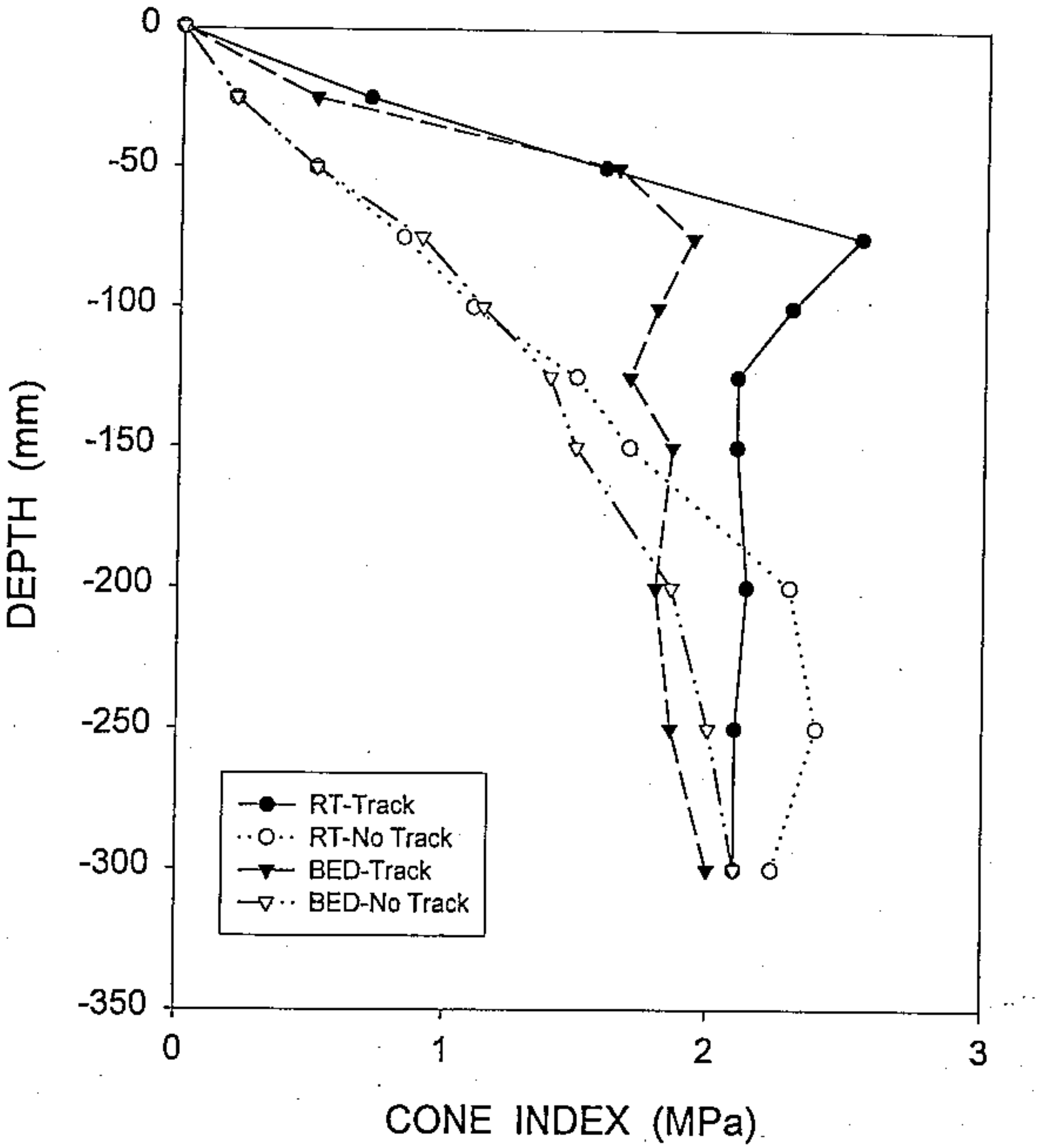

Figure 1. Cone index (soil strength) versus depth in wheel track furrows and non-track furrows on August 9, 1995, for ridge (RT) and bed (BED) treatments. (1 MPa = 145 psi, 25 mm = 1 in)

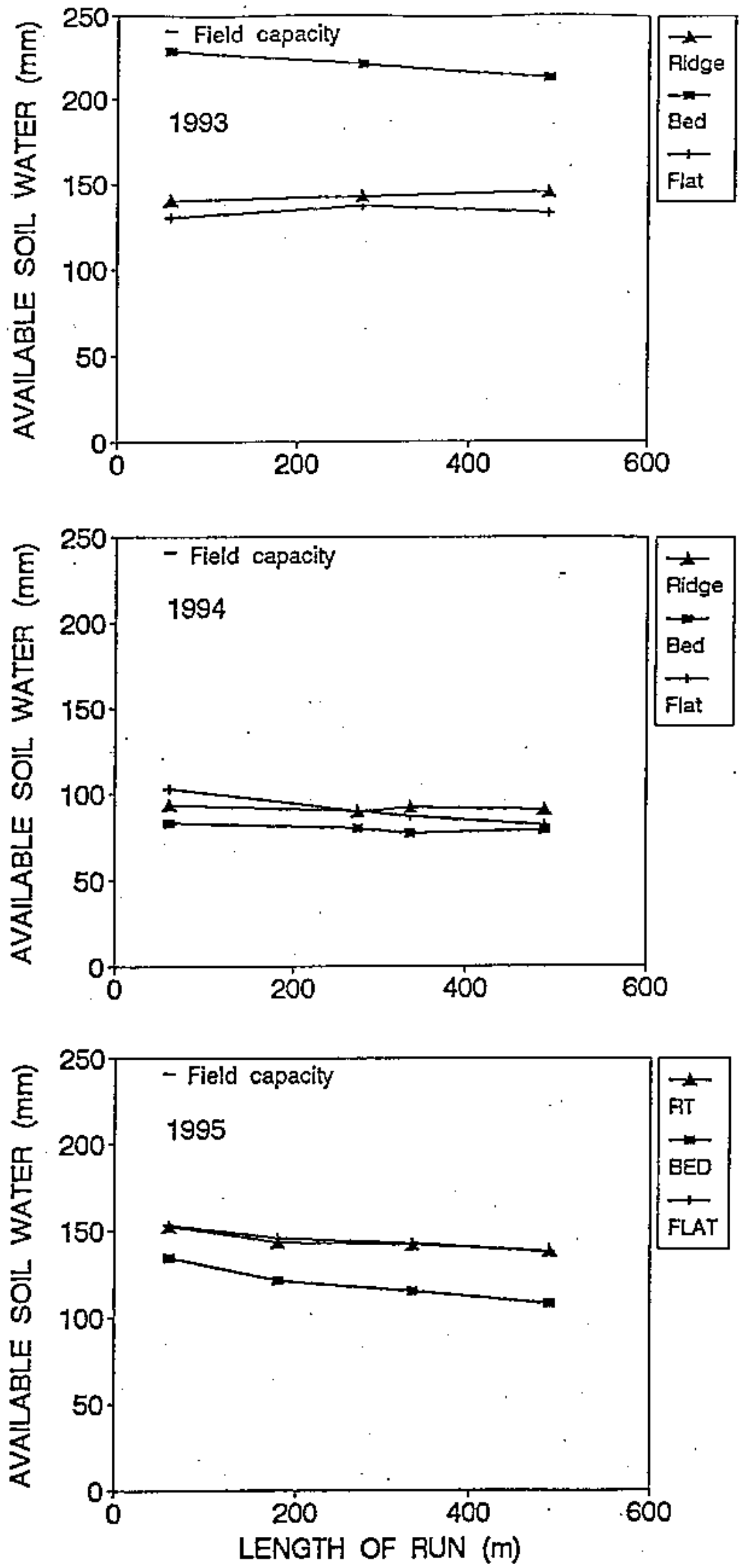

Figure 2. Plant available soil water to the 1.8 m (6 ft) depth versus length of run at plant emergence. (1 m = 3.28 ft, 25 mm = 1 in)

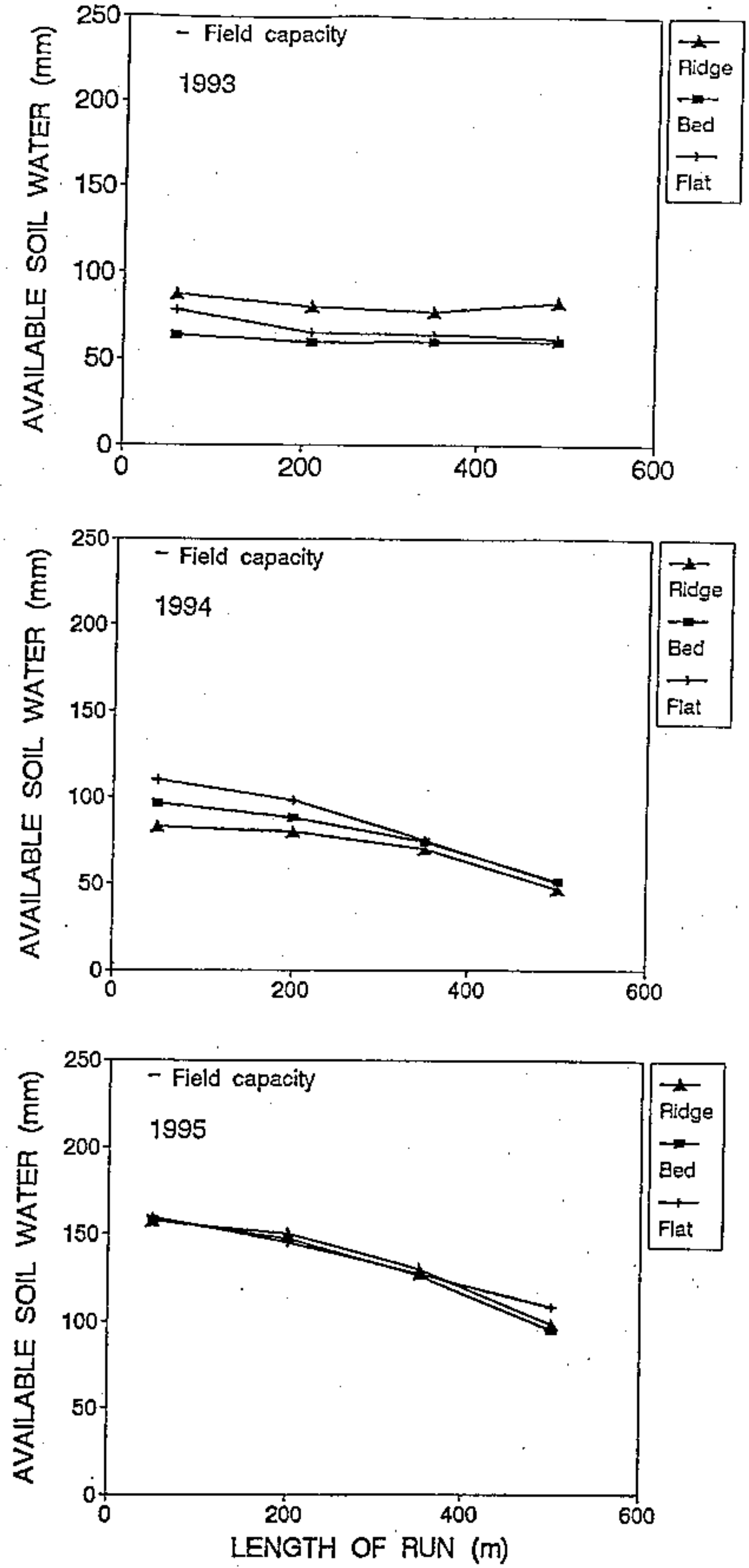

Figure 3. Plant available soil water to the 1.8 m (6 ft) depth versus length of run at harvest. (1 m = 3.28 ft, 25 mm = 1 in)

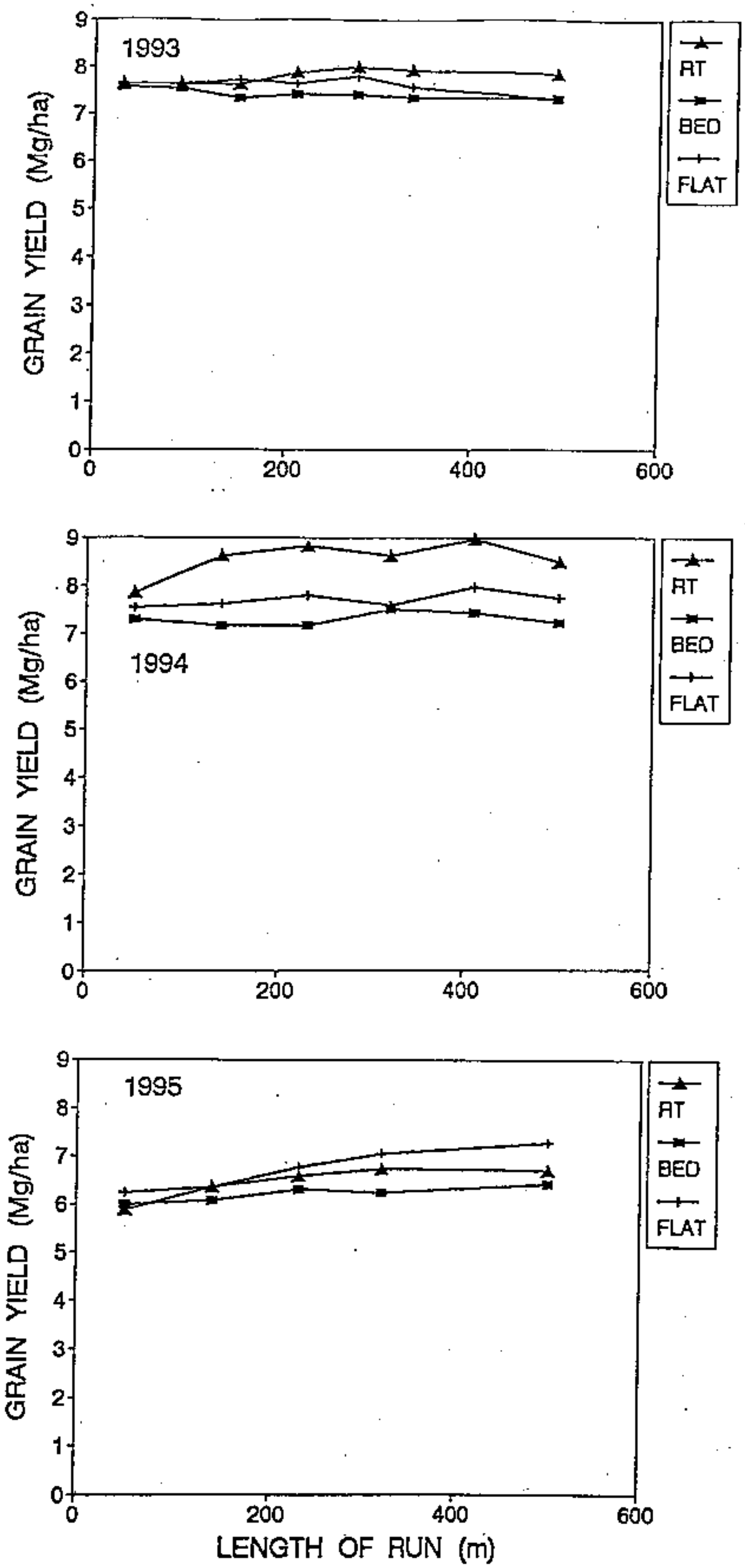

Figure 4. Grain yield with length of furrow run.
(1 m = 3.28 ft, 1 Mg/ha = 890 lb ac)