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Cotton Yield and Quality with SDI, LEPA, and Spray Irrigation in the North Texas High Plains

by P. D. Colaizzi, S. R. Evett, T. A. Howell

Producers in the Northern Texas High Plains (Amarillo and north) have recently shown renewed interest in cotton. This region is adjacent to one of the largest cotton producing areas in the United States, centered approximately at Lubbock (USDA-NASS, 1997). This renewed interest stems from, among other factors, lower water requirements relative to corn, which is presently more widely produced in the northern area and has a similar revenue potential (Howell et al., 1997; 2002). The primary limitation to cotton production in the Northern High Plains is the lack of heat units (Peng et al., 1989) and the lack of an industry infrastructure (gins, custom harvesters, etc.). The other main limitation is of course water, specifically the declining availability of irrigation water, insufficient and sporadic in-season rainfall, and high evaporative demand.

Water resources can be stretched using pressurized irrigation systems, which are highly efficient when properly designed and managed. These include mechanical move systems (i.e., center pivot or linear move) and subsurface drip irrigation (SDI). Mechanically moved systems have numerous variants of applicator packages, with the more common configurations being mid- and low-elevation spray application (MESA and LESA, respectively) and LEPA (Low Energy Precision Applicator; Lyle and Bordovsky, 1983). Cotton production has been documented using spray, LEPA, and SDI systems (e.g., Bordovsky et al., 1992; Bordovsky, 2001; Wanjura et al., 2000); and SDI has been widely adopted by commercial cotton producers throughout the South Plains and Trans Pecos regions of Texas during the last three decades (Henggeler, 1995; Pier, 1997; Enciso et al., 2003).

Cotton stripper at USDA-ARS-CRRL, Bushland, Texas 11/21/03 — I_{50} Irrigation Level with SDI

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Although SDI has greater capital costs and management requirements, it has less evaporative losses relative to spray or LEPA. This allows greater partitioning of soil water to plant transpiration, enhancing yield and water use efficiency under deficit irrigation when soil water is limited (Colaizzi et al., 2004). We hypothesized that less evaporation would also enhance heat unit accumulation, which is desirable for cotton production in a thermally limited environment. The objectives of this research were to compare cotton yield and quality for spray, LEPA, and SDI under full and deficit irrigation in a relatively cool or short growing season.

Procedures

An experiment was conducted during the 2003 growing season using MESA, LESA, LEPA, and SDI, and plans are to

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continue this experiment for two more seasons. Agronomic practices were similar to those practiced for high lint yield in the High Plains region of Texas. Cotton (*Gossypium hirsutum* L., Paymaster 2280 BG RR) was planted on 21 May 2003, and disked and replanted on 10 June 2003 (following severe hail damage to seedlings) at 70,000 plants per acre (17 plants m^{-2}), on east-west oriented raised beds spaced 30 in (0.76 m). The soil is a Pullman clay loam (fine, mixed, thermic torrertic Paleustoll) with slow permeability due to a dense B21t layer that is 6 to 16 in (0.15 to 0.40 m) below the surface and a calcic horizon that begins about 48 to 60 in (1.2 to 1.5 m) below the surface. Furrow dikes were installed after crop establishment to control runoff. Preplant fertilizer containing nitrogen (N) and phosphorous (P) (10-34-0) was incorporated into the raised beds, at rates resulting in 28 and 95 lbs ac^{-1} (31 and 107 kg ha^{-1}) of N and P, respectively, which were based on a soil fertility analysis. Additional N (32-0-0) was injected into the irrigation water from first square to early bloom, resulting in 43 lbs ac^{-1} (48 kg ha^{-1}) for the full irrigation treatment and deficit irrigation treatments receiving proportionately less. Treflan was applied at one time before planting at 1 qt ac^{-1} (2.3 L ha^{-1}) to control broadleaf weeds. No other in-season or post harvest chemical inputs were required.

The experimental design consisted of four irrigation methods (MESA, LESA, LEPA, SDI, described in more detail shortly), and five irrigation levels (I_0, I_{25}, I_{50}, I_{75}, and I_{100}). The I_{100} level was sufficient to prevent yield-limiting soil water deficits from developing, based on crop evapotranspiration (ET_c) estimates from the North Plains ET Network (NPET, Howell et al., 1998), and the subscripts are the percentage of irrigation applied relative to the full irrigation amount. The different irrigation levels were used to estimate production functions, and to simulate the range of irrigation capacities one might encounter in the region. The I_0 level received sufficient irrigation for emergence only and to settle and firm the furrow dikes and represents dryland production.

Spray and LEPA irrigations were applied with a hose-fed Valmont (Valmont Irrigation, Valley, Neb.) Model 6000 lateral move irrigation system. Drop hoses were located over every other furrow at 60 in. (1.52 m) spacing. Applicators were manufactured by Senninger (Senninger Irrigation Inc., Orlando, Fla.) and were equipped with 10 psi (69 kPa) pressure regulators and #17 plastic nozzles, giving a flow rate of 6.5 gpm (0.41 L s^{-1}). The MESA and LESA spray heads were positioned 60 and 12 in. (1.5 and 0.3 m) above the furrow, respectively. A double-ended drag sock (A. E. Quest and Sons, Lubbock, Tex.) was used with LEPA. The SDI consisted of Netafim (Netafim USA, Fresno, Calif.) Typhoon dripline that was shank injected under alternate furrows at a 12 in. (0.3 m) depth below the surface (before bedding). Irrigation treatment levels were controlled by varying the speed of linear move for the spray and LEPA methods, and by different emitter flow and spacing for the SDI method. All treatments were irrigated uniformly with MESA at the I_{100} level until furrow dikes were installed to ensure crop establishment.

Soil water was measured gravimetrically prior to planting and just after harvest in the 60 in. (1.8 m) profile in 12 in. (0.3 m) increments, oven dried, and converted to volumetric contents using known soil bulk densities by profile layer. During the season, soil water was measured volumetrically on a weekly basis by a calibrated neutron attenuation in the 94 in. (2.4 m) profile in 8 in. (0.2 m) increments. The gravimetric samples were used to compute seasonal water use, and the neutron measurements were to verify that irrigation was sufficient so that no water deficits developed in the I_{100} treatment. Further details of experimental design, procedures, and equipment can be found in Colaizzi et al. (2004).

Plants were mapped in all plots on a weekly basis beginning with 1st square, which included data on height, width, nodes, and number and position of fruit forms. Hand samples of bolls were collected from each plot on 19 Nov 2003 from a 108 ft^2 (10 m^2) area that was sequestered from other activity during the season. Lint was harvested on 21 Nov 2003 with a commercial cotton stripper. Cotton stalks were shredded on 8 Dec 2003 and rotary-tilled into the beds on 10 Dec.

Results and Discussion

Figure 1 shows the cumulative rainfall, cumulative irrigation + rainfall for each LEVEL treatment, cumulative crop water use (ET_c), cumulative growing degree days (heat units), and the observed growth stages. The 2003 growing season had much less rainfall and greater temperatures than average, and some record highs were set during the fall (16 Sept to 23 Oct). Total rainfall from planting to harvest (10 June to 21 Nov) was 6.6 in. (167 mm), whereas the 65-year average for this period is 11.0 in. (280 mm). There were 2.5 in. (64 mm) of rainfall between 10 and 30 June, which allowed in-season irrigations to be delayed until 8 July as there was sufficient water stored in the soil profile. No significant rainfall occurred again until 29 Aug, and the last irrigation was on 20 Aug. Pre-season irrigations (3.9 in. to 7.9 in.) were applied to uniform soil water

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contents are not included in Fig. 1. Crop water use (ET_c) shown here was computed by the North Plains ET Network based on short-season cotton. The irrigation + rainfall totals for the I_{100} treatment tracked ET_c fairly well until irrigations were terminated (just after maximum bloom), indicating irrigation timing and amounts were appropriate. Additional water for consumptive use after 20 Aug was provided by water stored in the soil profile.

The record heat from 16 Sept to 23 Oct was probably fortuitous in that it compensated for a late start (recall hail damage required replanting on 10 June). The first open boll was not observed until 22 Sept, but nearly all bolls were open by 20 Oct, and the first frost occurred on 26 Oct. Additional frost events defoliated all remaining vegetative matter so that chemical defoliant was not required by harvest (21 Nov). The crop reached full maturity with only 1937°F-days (1076°C-days) growing degree days based on a 60°F (15.6°C) base temperature (DD60s). This is considerably less than the 2610°F-days (1450°C-days) thought to be required for full maturity cotton in the Southern High Plains (Peng et al., 1989), but only slightly less than that reported by Howell et al. (2002) for the 2000 and 2001 cotton seasons at our location.

Table 1 shows lint yield, seasonal water use, water use efficiency (WUE), irrigation water use efficiency (IWUE), total discount, and total return (see footnotes below table 1 for explanations of these parameters). At the I_{25} LEVEL, lint yield, seasonal water use, and total return of SDI were significantly greater than MESA, but not LESA or LEPA; however, WUE, IWUE, and total discounts of SDI were significantly greater than both MESA and LESA but not LEPA. LEPA tended to be numerically greater than spray and less than SDI for most parameters. At the I_{50} LEVEL, a similar trend was observed, with a greater number of significant differences between both MESA/LESA and SDI. Again, LEPA was numerically greater than (less than) spray methods (SDI), except for total discount. At the I_{75} and I_{100} LEVEL, there were no significant differences in any parameter between METHODS, with the single exception of total discount between MESA and LESA at the I_{100} LEVEL. Although differences were statistically insignificant, at the I_{75} LEVEL, LEPA tended to outperform SDI, and SDI tended to outperform spray; however, at the I_{100} LEVEL, spray tended to outperform both LEPA and SDI. Similar trends for all METHODS within each LEVEL were also observed for three seasons of grain sorghum (Colaizzi et al., 2004).

Table 1 also shows results averaged for each irrigation LEVEL. In most cases, each parameter increased significantly with each increment in LEVEL, including WUE and IWUE. This contrasts somewhat with the grain sorghum results, where WUE and IWUE tended peak at the I_{50} LEVEL. Note that WUE at the I_{50} and I_{100} LEVELS were more than doubled and almost quadrupled, respectively, compared to dryland (I_0). The lint yield, seasonal water use, and WUE were generally within the range of values reported by Howell et al. (2002) for the 2000 and 2001 cotton seasons under MESA irrigation; however, total irrigation applied (including pre-season irrigation) in the present study was somewhat less due to both a shorter growing season and slightly greater pre- and early season precipitation.

Finally, Table 1 shows each irrigation METHOD averaged for all LEVELS. There were no significant differences for any parameter between methods, except for total discounts; however, for all parameters, SDI was numerically greater than LEPA, and LEPA was numerically greater than spray methods. For total discounts (mostly influenced by color grade but also includes micronaire, strength, and uniformity; positive values *increase* final loan values), SDI was significantly greater than both MESA and LESA, and LEPA was significantly greater than LESA.

Conclusions

Relative response of cotton to spray, LEPA, and SDI tended to vary with irrigation capacity. At lower irrigation system capacity (I_{25} and I_{50}), SDI outperformed (either numerically or significantly) both spray and LEPA; whereas at full irrigation system capacity (I_{100}), spray outperformed both LEPA and SDI but only on a numerical basis. At the I_{75} level, LEPA numerically outperformed SDI, and SDI numerically outperformed spray. Cotton

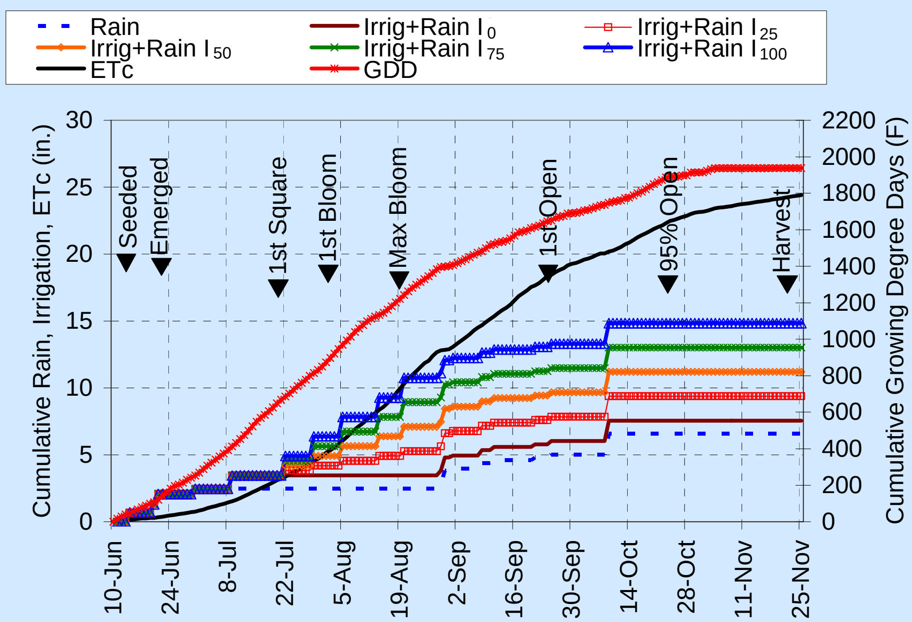

Figure 1: Seasonal rainfall, irrigation + rainfall for each LEVEL treatment, NPET-computed crop water use (ET_c), and growing degree days (F, based on 60° F base temperature), and growth stages for 2003 cotton season.

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response had greater variation between irrigation capacities than irrigation methods. Although no obvious differences in cotton growth and development (through accumulated heat units) were observed among irrigation methods, the more favorable discounts for SDI (except for I_{100}) indicate better fiber quality is possible with this technology.

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One of the most feared expressions in modern times is "The computer is down" ~ Norman Augustine

Table 1. Results for 2003 cotton season.

Irrigation Level [a]	Irrigation Method	Lint Yield ($lb\ ac^{-1}$)	Seasonal Water Use [c] (in.)	WUE [d] ($lb\ ac^{-1}\ in.^{-1}$)	IWUE [e] ($lb\ ac^{-1}\ in.^{-1}$)	Total Discount [f] ($\$\ cwt^{-1}$)	Total Return [g] ($\$\ ac^{-1}$)
I_0 (1.0 in.)	-----	175	17.2	10.4	-----	$-7.16	$78.02
I_{25} (2.8 in.)	MESA	190b [b]	18.8b	10.1b	5.5c	$-7.48b	$84.29b
I_{25}	LESA	257ab	19.5ab	13.2b	29.4bc	$-6.30b	$116.82ab
I_{25}	LEPA	323ab	19.5ab	16.4ab	52.9ab	$-3.68a	$153.67ab
I_{25}	SDI	438a	20.9a	20.9a	94.0a	$-1.80a	$218.98a
I_{50} (4.6 in.)	MESA	478b	23.8ab	20.1b	65.2b	$-3.68b	$229.62b
I_{50}	LESA	513b	22.9b	22.2b	72.6b	$-5.05b	$239.63b
I_{50}	LEPA	611ab	24.8a	24.6ab	93.8ab	$0.68a	$322.8ab
I_{50}	SDI	753a	24.7a	30.5a	124.2a	$2.67a	$408.94a
I_{75} (6.5 in.)	MESA	893a	27.8a	32.1a	111.0a	$2.83a	$486.61a
I_{75}	LESA	877a	27.0a	32.4a	108.6a	$2.75a	$477.55a
I_{75}	LEPA	1025a	27.6a	37.0a	131.4a	$2.27a	$554.19a
I_{75}	SDI	965a	28.1a	34.3a	122.2a	$3.77a	$535.27a
I_{100} (8.3 in.)	MESA	1096a	29.6a	37.0a	111.3a	$4.32a	$613.75a
I_{100}	LESA	1077a	29.7a	36.3a	108.9a	$2.12b	$578.71a
I_{100}	LEPA	1028a	28.6a	35.8a	103.0a	$2.53ab	$557.00a
I_{100}	SDI	1026a	28.6a	35.8a	102.7a	$3.72ab	$567.97a
Irrigation Level Averages							
I_0 (1.0 in.)	-----	175d	17.2e	10.4c	-----	$-7.16c	$78.02d
I_{25} (2.8 in.)	-----	302d	19.7d	15.1c	45.5c	$-4.82c	$143.44d
I_{50} (4.6 in.)	-----	589c	24.0c	24.3b	88.9b	$-1.35b	$300.25c
I_{75} (6.5 in.)	-----	940b	27.6b	33.9a	118.3a	$2.90a	$513.41b
I_{100} (8.3 in.)	-----	1057a	29.1a	36.2a	106.5ab	$3.17a	$579.36a
Irrigation Method Averages							
-----	MESA	665a	25.0a	24.8a	73.2a	$-1.00bc	$353.56a
-----	LESA	681a	24.8a	26.0a	79.9a	$-1.62c	$353.18a
-----	LEPA	747a	25.1a	28.4a	95.3a	$0.45ab	$396.92a
-----	SDI	796a	25.5a	30.4a	110.8a	$2.09a	$432.79a

$1\ lb\ ac^{-1} = 1.121\ kg\ ha^{-1}$
1 in. = 25.4 mm
$1\ lb\ ac^{-1}\ in.^{-1} = 4.42 \times 10^{-3}\ kg\ m^{-3}$

[a] Numbers in parentheses are in-season (i.e., planting to harvest) irrigation totals for each irrigation level, and do not include 3.9 to 7.9 in. (100 to 200 mm) of preseason irrigation applied prior to gravimetric sampling.
[b] Numbers followed by the same letter are not significantly different ($p \leq 0.05$) within an irrigation level, between irrigation level averages, or between irrigation method averages.
[c] Seasonal water use = irrigation + effective rainfall – soil water depletion. Soil water depletion was computed from gravimetric samples taken before planting and after harvest. Effective rainfall was 6.6 in. (167 mm) from plant to harvest, and 9.1 in. (230 mm) between gravimetric sampling.
[d] Water use efficiency (WUE) = (Yield) / (Seasonal Water Use).
[e] Irrigation water use efficiency = (Yield – Dryland Yield) / (Irrigation Applied).
[f] Includes micronaire, strength, color grade, and length uniformity (data not shown). Positive amounts INCREASE loan values.
[g] Based on base loan value of $51.60 cwt^{-1}.

Events, Meetings & Presentations since last newsletter. . .

SWMRU scientists attended the Ogallala Initiative Workshop at West Texas A&M University in Canyon, Texas on December 15-17, 2003 to plan and discuss research projects.

Steve Evett and Nolan Clark attended the joint meeting of the Texas Section of the American Society of Agricultural Engineers and the Texas Council of Chapters of the Soil and Water Conservation Society at Corpus Christi, Texas, February 24-27, 2004. The meeting theme was Texas Coastal Ecosystems Conservation: Now and the Future. Over 100 persons attended.

Paul Colaizzi attended the Workshop on Application of Technology to Water Measurement and Management, U.S. Committee on Irrigation and Drainage (USCID), in Scottsdale, Arizona, February 25-26, 2004. The retirements of John Replogle (USDA-ARS Water Conservation Laboratory, Phoenix, AZ) and Marinus Bos (International Institute for Land Reclamation and Improvement) were recognized.

Steve Evett attended the ARS Congressional Briefing Conference in Washington, D.C., March 1-4, 2004 to learn more about how the legislative branch operates and how federal research is authorized and funded.

Terry Howell, Troy Peters, Keith Brock, Jim Cresap, Grant Johnson,

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Modeling Grain Sorghum Growth and Yield

by R.Louis Baumhardt

Grain sorghum [*Sorghum bicolor* (L.) Moench] is well adapted and grown throughout the southern Great Plains. As a result, grain production under both dryland and irrigated conditions in Kansas and Texas account for approximately 70% of the U.S. crop. Improved hybrids and residue management practices that conserve soil water have increased dryland grain sorghum yields 139% from 1600 to 3800 kg ha^{-1} during the years 1956 to 1997 at the USDA-ARS Conservation and Production Research Laboratory, Bushland, TX (Unger and Baumhardt, 1999). Extensive irrigation research has, likewise, improved water application and use efficiencies for sorghum varying from deficit to full irrigation (Krieg and Lascano, 1990). Interest in deficit irrigation has grown as ground-water declines in an effort to facilitate potential transition to dryland production systems (Baumhardt et al., 1985; Norwood, 1995). The primary challenge to deficit irrigation of grain sorghum is optimizing irrigation amount, planting date, and crop maturity (Allen and Musick, 1993). Similarly, no universally best planting date or population has been established for dryland grain sorghum because planting date, population, variety, and row spacing are interdependent and vary annually with the growing season conditions. One method to minimize risks from climatic variability and to expand the basis for comparing different cultural practices used in growing grain sorghum is to utilize computer simulation models to calculate crop growth and yields using long-term recorded weather conditions.

Using the crop simulation model SORKAM version 2000 (W.D. Rosenthal and R.L. Vanderlip, pers. comm., 2000), long-term (1958-1998) weather records at Bushland and known Pullman soil (fine, mixed, superactive, thermic Torrertic Paleustoll) properties; crop growth and yield were compared for all combinations of crop maturity, planting date, plant population and row spacing under dryland and deficit irrigation conditions. Sorghum grain yields were simulated for combinations of planting date (15 May, 5 June, 25 June), population (3, 6, 12, 16 plants m^{-2}) [12,100, 24,300, 48,600, and 64,800 plants ac^{-1}], row spacing (0.38 and 0.76 m) [15 and 30 in.], and cultivar maturity (early, medium, late). Water levels varied from dryland (no-irrigation) to deficit irrigation (irrigation + rain = 2.5 mm d^{-1}) [0.10 in. d^{-1}] and to full irrigation (irrigation + rain = 5.0 mm d^{-1}) [0.20 in. d^{-1}]. Minimum irrigations were 25 or 50 mm [1.0 or 2.0 in.] applied on a 10 day or longer interval.

> **"Regardless of irrigation level, any variation of the planting date or cultivar maturity must strike a balance between extending the potential growing season and exposing the crop to late summer heat and water deficit or fall freeze risks."**

The accuracy of SORKAM modeled grain sorghum yield was established by comparing measured experimental yields obtained during a 14-year period described by (Jones and Popham, 1997) with the corresponding modeled yields calculated for late (19-leaf) and medium (17-leaf) maturity cultivars (Fig. 1.).

Calculated grain yields ranged from 1310 to 7110 kg ha^{-1} [21 to 113 bu ac^{-1}] with a mean of 4035 kg ha^{-1} [64 bu ac^{-1}] that was approximately 5% greater than the mean measured experimental yield, 3830 kg ha^{-1} [61 bu ac^{-1}] (range 1210 to 6460 kg ha^{-1}) [19 to 103 bu ac^{-1}], with a $r^2 = 0.69$ (RMSE = 791.7 kg ha^{-1} [12.6 bu ac^{-1}]). This grain yield difference was expected, however, because the model did not consider the impact of common biotic pressures such as weed competition, insect injury, or planting moisture effects on emergence and stand uniformity when simulating crop growth and yield. The SORKAM simulated sorghum growth and grain yields accurately reflected measured crop performance throughout a broad range of environmental conditions and tested cultural practices. These results suggest that modeled grain yields will reflect the impact of planting date conditions on sorghum growth and grain yield.

Modeled sorghum grain yields did not vary significantly with population, averaging from 4000 to 4110 kg ha^{-1} [64 to 65 bu ac^{-1}] for 3 to 12 plants m^{-2} [12,100 to 48,600 plants ac^{-1}] under dryland conditions, or from 5510 to 5470 kg ha^{-1} [88 to 87 bu ac^{-1}] for 12 and 16 plants m^{-2} [48,600 to 64,800 plants ac^{-1}] with irrigation. The ability of grain

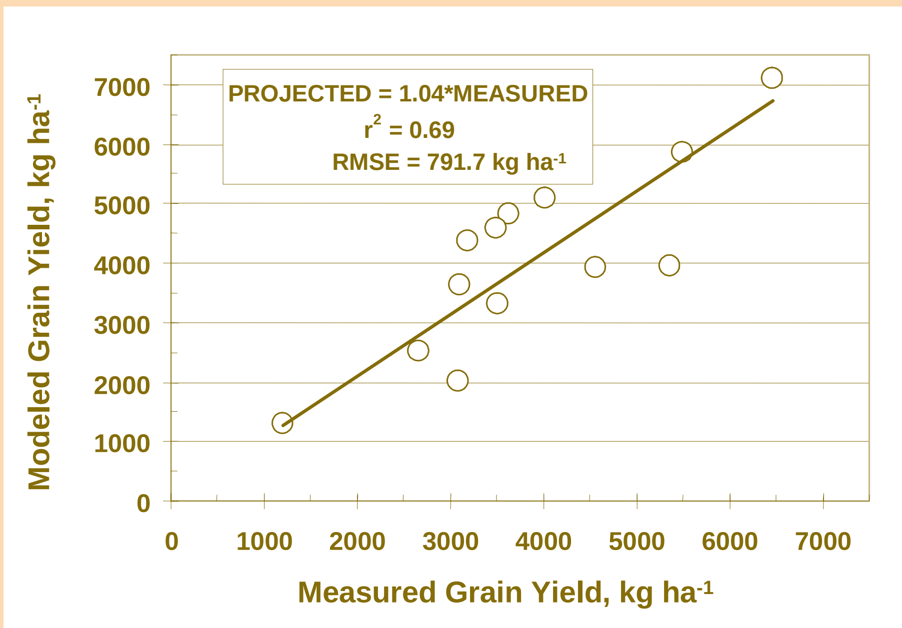

Fig. 1. Sorghum grain yields calculated using SORKAM with known planting conditions and recorded precipitation plotted in comparison with the corresponding measured experimental grain yields observed from 1984 to 1998. [1000 kg ha^{-1} = 16 bu ac^{-1}]

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sorghum to adapt to the prevailing growing conditions permitted the plants to compensate for the differences in population and resulted in relatively consistent yields. In contrast, dryland sorghum benefited from narrow row-spacing (0.38m [15 in.]) with mean grain yields of 4240 kg ha^{-1} [68 bu ac^{-1}] that were about 9% greater than the 3900 kg ha^{-1} [62 bu ac^{-1}] with 0.76-m [30-in.] wide row spacing. Irrigated grain yields of 5300 kg ha^{-1} [84 bu ac^{-1}] with 0.76-m [30-in.] rows increased 7% to 5685 kg ha^{-1} [91 bu ac^{-1}] with 0.38-m [15 in.] row spacing. For fixed plant populations, reducing the distance between rows distributes plants more evenly within the field and decreases early season competition between plants; thus, improving light interception and partitioning of soil-water for use in evapotranspiration, ET, as reported for field measurements by Steiner (1986). Implementing this narrow row spacing cultural practice would require a relatively simple modification of equipment.

Crop management decisions for optimum grain yield are complicated by the complex interaction between irrigation level, cultivar maturity, and date of planting (Fig. 2.). As expected, the progressive addition of irrigation resulted in corresponding yield increases from an overall mean of 4070 kg ha^{-1} [65 bu ac^{-1}] for dryland to 5140 kg ha^{-1} [82 bu ac^{-1}] and 7395 kg ha^{-1} [118 bu ac^{-1}] for the deficit- and full-irrigation regimes, respectively. Deficit irrigation to meet a 2.5 mm [0.1 in.] daily ET replacement required fewer than six 25 mm [1.0 in.] applications for 95% of the years modeled, and resulted in only modest yield increases that were, generally, less variable than dryland. In contrast, calculated sorghum grain yield increased 44% under the "full" irrigation, 5.0 mm [0.20 in.] ET replacement, which required as many as eight 50 mm [2.0 in.] irrigation during 95% of the years modeled.

Regardless of irrigation level, any variation of the planting date or cultivar maturity must strike a balance between extending the potential growing season and exposing the crop to late summer heat and water deficit or fall freeze risks. Under dryland conditions, the overall modeled grain yield averaged 4295 kg ha^{-1} [68 bu ac^{-1}] for the 5 June planting date and was significantly greater than mean grain yields of 4040 kg ha^{-1} [64 bu ac^{-1}] for 25 June and 3870 kg ha^{-1} [62 bu ac^{-1}] or 15 May dates, respectively. Similarly, modeled yields for irrigated sorghum averaged 5730 kg ha^{-1} [91 bu ac^{-1}] when planted on 5 June compared with 5450 and 5300 kg ha^{-1} [87 and 84 bu ac^{-1}] for sorghum planted 15 May and 25 June, respectively. Compared with the 5 June planting date, earlier planted sorghum matured during late summer water deficit stress and sorghum planted 25 June often failed to reach physiological maturity because of freezing weather. Modeled grain yields for early maturing sorghum exceeded yields of both medium and later maturing cultivars for all planting dates under dryland conditions (Fig. 2). Compared with medium and late maturing cultivars, the calculated grain yield benefit of the early cultivar was negated under deficit irrigation. Under full irrigation, the calculated grain yields for early maturing sorghum averaged 6860 kg ha^{-1} [109 bu ac^{-1}] compared with the medium and late maturing cultivar yields that ranged from 7940 to 8350 - kg ha^{-1} [126 to 133 bu ac^{-1}] when planted sufficiently early to reach physiological maturity.

From these simulations we conclude that narrow row spacing increases grain yield of sorghum regardless of irrigation through improved partitioning of soil-water for plant transpiration and decreased competition between plants for water and light. Planting early did not beneficially extend the growing season to increase grain yield except under full irrigation; however, planting late reduced grain yield by increasing the risk that sorghum would not reach physiological maturity due to freeze injury. Early maturing cultivars decreased crop exposure to water stress and increased dryland yields, but medium and late maturing cultivars achieved the greatest yields with full irrigation.

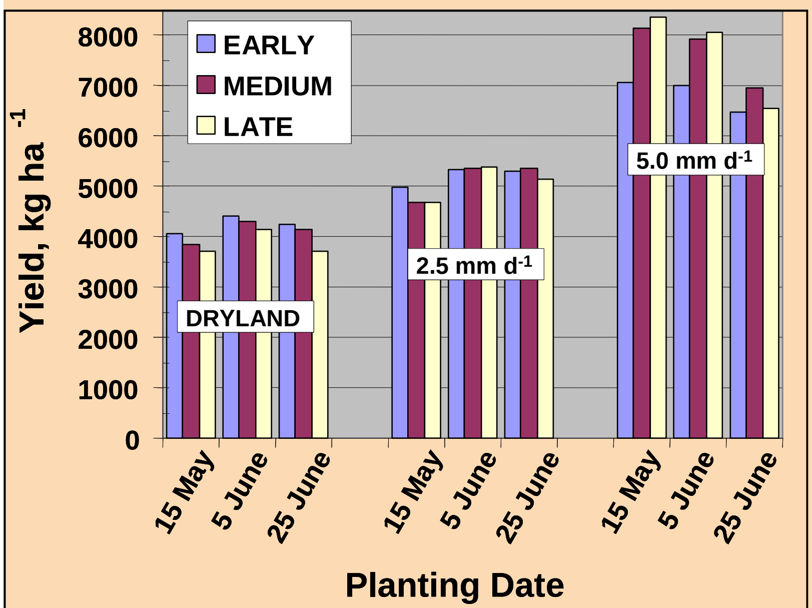

Fig. 2. Modeled sorghum grain yields for early, medium, and late maturing cultivars planted on 15 May, 5 June, and 25 June under dryland and deficit or "full" irrigation conditions. Yield advantages with early maturing varieties under dryland conditions are neutralized with deficit irrigation. Except for late plantings, modeled sorghum grain yields under full irrigation were greatest with medium and late maturing cultivars. [1000 kg ha^{-1} = 16 bu ac^{-1}; 1.0 mm d^{-1} = 0.04 in. d^{-1}]

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Don McRoberts, Brice Ruthardt, and Thomas Marek (TAES-Amarillo) attended a four-day ESRI ArcGIS training course in Ft. Worth, TX in December provided by USDA-NRCS.

Terry Howell and Thomas Marek (TAES-Amarillo) participated in a planning workshop in San Francisco, CA in January for on-farm irrigation optimization for a USDA-CSREES NRI with Oregon State University.

Terry Howell attended the National ARS Scientific Leadership conference in New Orleans, LA in January.

Terry Howell presented a paper on “Evaporative Losses from Sprinkler Packages” at the 2004 Central Plains Irrigation Conference in Kearney, NE.

Terry Howell attended the ASCE-EWRI leadership weekend in Reston, VA in February.

In April, Terry Howell presented a paper on “The Penman-Monteith Method” to the Colorado and Denver Bar sponsored by CBA-CLE and ASCE.

Upcoming Events, Meetings, and Presentations. . .

Steve Evett and Bill Purdy will travel to Uzbekistan in support of a joint research project on crop water use, irrigation scheduling and irrigation water quality in collaboration with the Uzbekistan National Cotton Growing Research Institute and the Veterinary Institute of Uzbekistan.

Steve Evett will travel to Cyprus for a Workshop Promoting Cooperation in Agricultural R&D in the Middle East Region where he will make a presentation on irrigation research at the Bushland ARS Laboratory. The workshop is sponsored by the Binational Agricultural Research and Development Fund (BARD).

Paul Colaizzi will attend the World Water & Environmental Resources Congress 2004 in Salt Lake City, UT in June sponsored by ASCE.

Paul Colaizzi will attend the Remote Sensing & Modeling of Ecosystems for Sustainability in Denver, CO in August to present a paper on Radiometric and Aerodynamic Temperatures of Irrigated Alfalfa.

Paul Colaizzi will attend the Water Supply and Water Rights in Salt Lake City, UT in October.

Technology Transfer News. . .

In January, Jim Cresap, Terry Howell, and Judy Tolk met with Dallas Hensley, technician to Norman Klocke of Kansas State University, concerning the design and construction of a rain shelter for a lysimeter facility.

Judy Tolk met with Jenny Chadick, junior at Shamrock High School, and her school counselor January 21st as part of a job shadowing project.

Steve Evett visited the laboratory of Dennis Timlin, USDA-ARS, Beltsville, to discuss implementation of a TDR system for soil moisture measurement, and to resolve a problem with the TACQ program for TDR data acquisition.

Simon van Donk, ARS Wind Erosion Research Laboratory, Manhattan, Kansas, visited the laboratory on January 27 and 28, 2004 to discuss modeling of surface energy and water balances using the ENWATBAL model, his improvements to the model, and research underway at Manhattan on wind erosion prediction.

Steve Evett visited the NRCS National Water Management Center and the Arkansas Soil and Water Conservation Commission at Little Rock, Arkansas on February 17-19 to work on irrigation and water resource research needs in the Mississippi Delta.

Terry Howell and Thomas Marek (TAES-Amarillo) met with Colorado State University and Colorado Division of Water Resources staff at Rocky Ford, CO to discuss weighing lysimeter siting and construction.

In February, Terry Howell participated in the USDA-NRCS Conservation Security Program planning workshop in Irving, TX.

New Publications. . .

2003. Ambati, S., Payne, W. B., Baumhardt, R. L., Bronson, K., and Stewart, B. A. Response of dryland grain sorghum to labeled nitrogen paced at different soil depths. CD-ROM. ASA-CSSA-SSSA, Denver, CO. Annual Meeting Abstracts 2003.

2003. Balota, M., Payne, W. A., and Evett, S. R. Morphological and physiological traits related with reduced canopy temperature depression in two closely-related wheat lines. CD-ROM. ASA-CSSA-SSSA, Denver, CO. Annual Meetings Abstracts 2003.

2003. Baumhardt, R. L., Schwartz, R. C., and Jones, O. R. Cropping Sequence effects on long-term dryland production in the semiarid Southern Great Plains. Cd-Rom. ASA-CSSA-SSSA, Denver, CO. Annual Meetings Abstracts 2003.

2003. Colaizzi, P.D., A.D. Schneider, T.A. Howell, and S.R. Evett. Comparison of SDI, LEPA, and spray efficiency for grain sorghum. Paper Number: 032139. 2003 ASAE Annual International Meeting, Sponsored by American Society of Agricultural Engineers, Riviera Hotel and Convention Center, Las Vegas, Nevada, USA, 27-30 July 2003.

2003. Enciso, J., Unruh, B., Colaizzi, P .D., Multer, W. Cotton response to subsurface drip irrigation frequency under deficit irrigation. Applied Engineering in Agriculture 19(5):555-558.

2003. Evett, S.R. Soil water measurement by time domain reflectometry. In B.A. Stewart and Terry A. Howell (editors). Encyclopedia of Water Science, Marcel Dekker, Inc. New York. Pp. 894-898

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2003. S.R. Evett, J.A. Tolk, and T.A. Howell. A depth control stand for improved accuracy with the neutron probe. Vadose Zone Journal. Vol. 2. pp. 642-649.

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2003. Ibragimov, Nazirbay, Evett, Steve, Esanbekov, Yusupbek, Kamilov, Bakhtiyor, and Heng, Lee. Cotton and winter wheat irrigation scheduling improvements in Uzbekistan. IN Understanding and Addressing Conservation and Recycled Water Irrigation. Proc. International Irrigation Association Technical Conference. P. 26-34. November 2003. (CD-ROM)

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2003. Piccinni, G., Laffere, M. K., Kolenda, K. A., Marek, T. H., Dusek, D. A., and Howell, T. A. Determination of crop coefficients and water use of corn. CD-ROM. ASA-CSSA-SSSA, Denver, CO. Annual Meetings Abstracts 2003.

2003. Schwartz, R. C. and Evett, S. R. Conjunctive use of tension infiltrometry and time-domain reflectometry for inverse estimation of soil hydraulic properties. Vadose Zone Journal 2:530-538.

2003. Schwartz, R. C. and Dao, T. H. Net phosphorus extractability from soils amended with cattle manure. CD-ROM. ASA-CSSA-SSSA, Denver, CO. Annual Meetings Abstracts 2003.

2003. Stewart, B. A. and Howell, T. A. Editors. Marcel-Dekker, Inc., New York, NY. Encyclopedia of Water Science. 1076 P. (Book)

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The *Wetting Front* newsletter is designed to foster technology transfer from our research to industry and to agricultural producers in the Southern High Plains and to improve communications with our stakeholders and partners.

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