# Planting Date, Water Management, and Maturity Length Relations for Irrigated Grain Sorghum

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

**Abstract.** *Grain sorghum [*Sorghum bicolor (L) Moench*] is produced under widely varying planting dates and irrigation management in the Southern High Plains. This study was conducted to determine optimum planting date and maturity length hybrid under varying irrigation levels. The effects of medium and medium-late maturity sorghum hybrids on yield, water use, and water use efficiency (WUE) were investigated for three irrigation regimes; no post-plant irrigation, limited irrigation (one or two growing season applications), and adequate irrigation (three or four growing season applications). Planting dates were from early May through late June of 1989, 1990, and 1991 at Bushland, Texas. Grain yields averaged highest (about 8.9 Mg/ha) for both hybrids under adequate irrigation when planted near 23 May. When planting very early (near 5 May) with adequate irrigation, the medium-late hybrid was slightly more productive than the medium hybrid; but when planting in June, the medium hybrid was slightly more productive. With limited irrigation, the medium hybrid was slightly more productive (yield of 7.2 Mg/ha and WUE of 1.3 kg/m$^3$) than the medium-late hybrid (yield of 6.9 Mg/ha and WUE of 1.2 kg/m$^3$). Under a major soil-water deficit without any post-plant irrigations, the medium hybrid was more productive. With planting dates in May and adequate irrigation, either maturity-length hybrid would give acceptable performance. When planting in June, a medium hybrid would be acceptable for both limited and adequate irrigation management.* ***Keywords.*** *Irrigation, Surface irrigation, Sorghum, Planting date.*

Grain sorghum and corn are major irrigated feed grains produced on the Southern High Plains of the U.S.A. Grain sorghum, compared with corn, is more drought tolerant and hybrids have shorter growing season and lower irrigation water requirements. Grain sorghum is irrigated mostly through graded furrow application. Two practices for reducing irrigation water use by furrow irrigated sorghum in the Central and Southern High Plains are eliminating the preplant irrigation and the use of limited (deficit) irrigation management (Musick and Lamm, 1990). In a previous study, Allen and Musick (1990) demonstrated that the elimination of a preplant irrigation is an effective management practice to reduce irrigation water use, but there is a relatively high risk (two years in four) of delayed sorghum planting without a preplant irrigation. When planting is delayed until rainfall provides adequate seed zone soil water content, the hybrid maturity length may need to be shortened from medium-late (common for May planting of adequately irrigated sorghum) to medium maturity (common for early to mid-June planting for limited irrigation and dry land).

Yield results from previous irrigated sorghum planting date studies that include varying maturity length hybrids have been inconsistent. The studies were mostly conducted in the 1960s after hybrid sorghum introduction in the late 1950s. Reported data and discussion of results with hybrids available at that time were mostly limited to grain yield response (Allen et al., 1969; Malm, 1965). In a three-year test at Clovis, New Mexico (103°W. 33.5°N.), Malm (1965) reported that 1 June was the optimum planting time for a late maturity hybrid and 15 June was the optimum planting time for a medium maturity hybrid. In a one-year test at Bushland, Texas (102.2° W. 35.2° N.), Allen et al. (1969) reported that both medium and medium-late maturity hybrids had higher grain yield for 22 May compared with 10 June planting. The increased yield response to the May planting of a medium-late maturity hybrid was 18% compared with 7% for a medium-maturity hybrid. Results of a test at Bushland in 1975 by Musick and Dusek (unpublished) indicated that relatively early planting (mid May) increased grain yield over June planting for both adequate and deficit irrigation. Planting date response to deficit irrigation was highest for early planting and was influenced by growing season rainfall distribution.

More recently, Kreig and Lascano (1989) reported results from a two-year test with four grain sorghum planting dates at Lubbock, Texas (102° W. 33.6° N.) ranging from early May to late June. Their data indicated that early May planting reduced grain yield, with the effect being greater for shorter maturity-length hybrids. With planting in mid to late June, yield was reduced and the effect was greatest for the longer maturity hybrids.

We tested the hypothesis: 1) with adequate irrigation, grain yields are enhanced by relatively early planting of comparatively long medium-late maturity hybrids; and 2) with limited irrigation, yields may be increased by using a later planting date and a shorter maturity hybrid. The

Article was submitted for publication in November 1992; reviewed and approved for publication by the Soil and Water Div. of ASAE in June 1993. Presented as ASAE Paper No. 91-2124.

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

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

objectives were to evaluate effects and relationships involving deficit and adequate irrigation, planting dates, and maturity-length of hybrids on plant growth and development, grain yield, and water use efficiency (WUE). Treatment effects on the relationships of phenological development, dry matter accumulation, and yield will be published separately.

## PROCEDURE

A three-year field study (1989 through 1991) was conducted on level bordered plots at the USDA Conservation and Production Research Laboratory, Bushland, Texas. Tests were conducted on a Pullman clay loam (slowly permeable, fine mixed, thermic Torrertic Paleustoll) described by Unger and Pringle (1981). Plant available soil water storage capacity is about 180 mm to a 1.2-m rooting depth for water extraction by sorghum. Seasonal rainfall averages 200 to 250 mm depending upon planting date and maturity length of the hybrid. The study included four planting dates, two maturity-length hybrids, three irrigation water levels, and two plant populations. The experimental design was randomized block, split plot with four replications for each planting date block. Irrigation and hybrid main plot treatments were split for two plant population subplots. Main plots, (11-m wide × 40-m long) contained 12 (0.75-m spaced) plant rows. Plant population subplots (6 rows wide × 40-m long) contained targeted populations of 10 or 20 plants/$m^2$, to be compatible with deficit and adequate irrigation treatments.

The four planting date treatments were selected as early May, late May, early June, and late June. Two of the planting dates (late May and early June) were selected to bracket the normally considered optimum planting date. The early May date was selected to evaluate early planting in relation to relatively cool soil temperature. Late planting (late June to early July) is limited by the time needed for grain sorghum to reach physiological maturity by about the first week in October [before an early freeze (1 in 10 probability at Bushland)]. The average (50-year) freeze date is 23 October. The two maturity-length hybrids were DeKalb DK-41y (medium-maturity yellow endosperm) for dryland or limited irrigation and DK-59 (medium-late-maturity hetero-yellow) for irrigation. The maturity-length difference between the two hybrids is about eight days. The DK-59 hybrid develops two to three more and larger leaves than DK-41y because of a longer vegetative growth period to flowering, resulting in about 50% greater leaf area.

Three irrigation treatments were used to evaluate sorghum response over a range in soil water contents from adequate irrigation to a major soil water deficit during the growing season. The irrigation treatments were:

- W-1 — Preplant application only (major deficit).
- W-2 — Preplant plus about two applications (moderate deficit).
- W-3 — Preplant plus three to four seasonal applications (adequate irrigation).

The major basis of irrigation scheduling was on the adequate treatment. Previous research with irrigated sorghum (Allen and Musick, 1990) has shown seasonal ET with adequate irrigation to be about 600 to 650 mm. Long-term average rainfall during the sorghum growing season is about 300 mm at Bushland, leaving about 350 mm to be supplied by irrigation. This equates to three to four seasonal applications of about 100 mm each for surface application on a fine textured, slowly permeable soil, whether applied in level basins as in this experiment or through graded furrows. Applications on the adequate irrigation treatments were scheduled when plant available soil water was depleted to about 50% of field capacity; also considering key growth stages — boot, flowering, heading, and grain filling. Irrigation amounts for the W-2 deficit treatment were targeted at about 50% of adequate (hence about two applications) and were scheduled near the boot and heading growth stages. In this article, data from the low plant population subplots are presented for the W-1 treatment with no seasonal irrigation. Data from the higher plant population subplots are presented for the deficit (W-2) and adequate (W-3) irrigation treatments.

In each year, the sorghum was grown after fallow with clean tillage. Nitrogen was applied at 120 kg/ha as anhydrous ammonia and beds were formed on 0.75-m centers. Propazine was applied preplant for seasonal weed control. A small preplant irrigation (about 60 mm) was applied to the dead level furrows to wet and firm the loose beds before planting. All plots began the season with the soil profile pre-wetted to field capacity to the 1.2-m rooting depth. Planting was performed at seeding rates based on an expected 70% emergence. Soil temperature was monitored at the 50-mm seedling depth from planting time through emergence with a thermograph.

Irrigation water was applied through gated pipe and measured to plots with a propeller meter. In 1989, soil water was measured gravimetrically to the 1.8-m depth by 0.3-m increments at emergence, anthesis, physiological maturity, and at harvest. In 1990 and 1991, gravimetric samples were obtained at emergence and harvest; and a neutron meter was used to determine soil water content by 0.2-m increments to the 1.6-m depth at anthesis and physiological maturity. Water use (ET) was determined by the water balance of beginning- and end-of-season soil profile water contents, applied irrigation, and precipitation. The WUE was computed as the ratio of grain yield to seasonal ET. The irrigation water use efficiency (IWUE) was computed as the ratio of the yield increase from irrigation to the amount of irrigation water applied. Grain yield was determined by hand sampling 10-$m^2$ areas from the two center rows of subplots. Yields are reported as 13% moisture, wet basis. Treatment means were analyzed for variance with Statgraphics (1992) and LSDs were determined where F-tests indicated significant differences.

## RESULTS AND DISCUSSION

### CLIMATIC CONDITIONS, PLANTING, AND EMERGENCE

Seasonal precipitation amounts and distribution have major effects on irrigation water requirements, grain yield, and WUE. The effect is more pronounced with limited irrigation. The cumulative May through September seasonal rainfall during 1989 through 1991 and the cumulative 50-year average at Bushland are presented in figure 1. There was a major variation in May and June rainfall during the study. May through June rainfall was 230 mm or 60% above average in 1989, but was only 13 mm or about 10% of average in 1990. Although July rainfall in 1990 was above average and equalled that

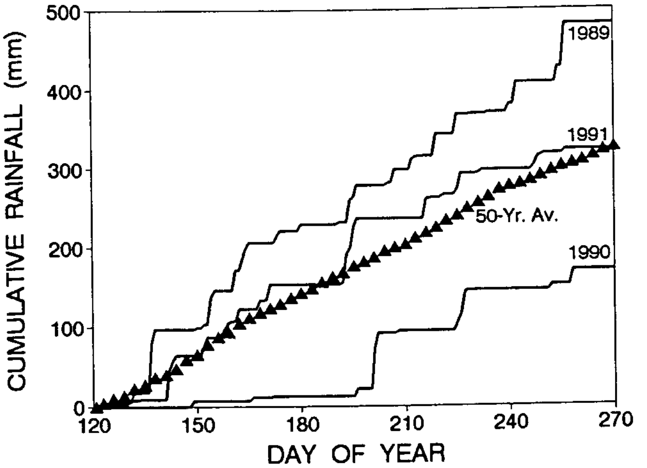


**Figure 1–Cumulative May through September seasonal rainfall during the three-year study period compared with the cumulative 50-year average at Bushland, TX.**

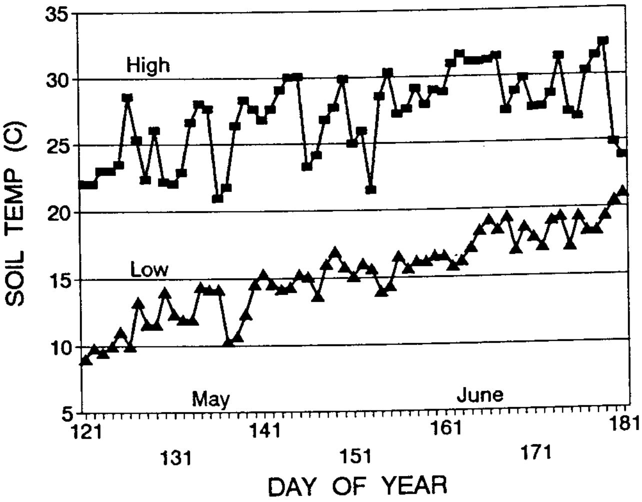


**Figure 2–Average 24-h high and low soil temperatures during May and June (1989-1991) at the 50-mm seedling depth, Bushland, TX.**

received in 1989, rain did not occur until 19 to 21 July; and was followed by a relatively dry August. In 1991, May to September rainfall was average (325 mm); however the June to July portion was 20% above average (170 mm), followed by a relatively dry August to September which received only about 65% of the 70 mm average.

Planting and emergence dates are presented in table 1. The above average May to June rainfall in 1989 and 1991 resulted in wet soil during early June which delayed the third planting date from early June until mid to late June. Thus, planting of PD-4 was delayed until early July in 1989 and 1991. Cold temperature stress from a night time

**Table 1. Grain sorghum planting and emergence dates, 1989, 1990, and 1991, Bushland, TX**

| | | Planting | Emergence | Days to Emerge |
|---|---|---|---|---|
| | | **1989** | | |
| PD-1 | DK-41y | 5 May | 20 May | 15 |
| | DK-59 | | 18 May | 13 |
| PD-2 | DK-41y | 24 May | 3 Jun | 10 |
| | DK-59 | | 31 May | 7 |
| PD-3 | DK-41y | 21 Jun | 28 Jun | 7 |
| | DK-59 | | 28 Jun | 7 |
| | | **1990** | | |
| PD-1 | DK-41y | 10 May | 21 May | 11 |
| | DK-59 | | 20 May | 10 |
| PD-2 | DK-41y | 24 May | 2 Jun | 9 |
| | DK-59 | | 2 Jun | 9 |
| PD-3 | DK-41y | 7 Jun | 14 Jun | 7 |
| | DK-59 | | 14 Jun | 7 |
| PD-4 | DK-41y | 22 Jun | 27 Jun | 5 |
| | DK-59 | | 27 Jun | 5 |
| | | **1991** | | |
| PD-1 | DK-41y | 1 May | 16 May | 16 |
| | DK-59 | | 14 May | 14 |
| PD-2 | DK-41y | 21 May | 29 May | 8 |
| | DK-59 | | 29 May | 8 |
| PD-3 | DK-41y | 14 Jun | 20 Jun | 6 |
| | DK-59 | | 20 Jun | 6 |

temperature decline to 0° C during flowering in 1989 caused a major delay in grain filling for PD-4. This problem, along with low plant emergence from surface crusting in 1991, prevented obtaining valid data for PD-4 which are not reported for those years. In 1990, planting was accomplished near targeted dates. Dry surface soil required a small 50-mm emergence irrigation after each planting. The three-year average planting dates were 5 May (PD-1), 23 May (PD-2), and 14 June (PD-3).

The three-year average daily minimum and maximum soil temperature, for the 50-mm seedling depth during the May to June planting time, are presented in figure 2. Early planting (1 to 5 May) required from 13 to 16 days for emergence compared with 7 to 10 days for 20 to 25 May planting, whereas June plantings required only 5 to 7 days for emergence. The DK-41y yellow endosperm hybrid is noted for slow emergence and was about two days later emerging compared with DK-59 for early May plantings. The slower emergence of both hybrids in early May is the result of lower soil temperature. Daily minimum soil temperature averaged about 10° C during early May. The average daily minimum soil temperature did not remain near or above the 15° C threshold for sorghum planting and emergence until about 20 May which is near the 23 May average planting date for the PD-2 treatment. Average daily low soil temperatures during June ranged from 15 to 20° C and resulted in the rapid seedling emergence previously mentioned.

### Yearly Grain Yield Response

Treatment effects on irrigation water applied, seasonal ET, grain yield, and WUE are presented in tables 2 to 4. In 1989, the above average seasonal rainfall reduced response to irrigation and caused grain yields for all treatments to be in a fairly narrow range of 6.0 to 8.35 Mg/ha. Grain yields were 6.0 to 7.4 Mg/ha, even without a seasonal irrigation, and the W-3 treatment produced only slightly higher grain yields than the W-2 treatment. DK-41y produced highest yields with the 21 June planting, whereas DK-59 produced the highest yields with the 24 May planting.

In 1990, with major drought conditions, response to varying levels of irrigation caused grain yields to range

Table 2. Treatment effects on water applied, seasonal water use, grain yield, and water use efficiency, 1989

| Treatments: Plant Date | Treatments: Irrig Treat | Season Rain (mm) | Season Irrig (mm) | Profile Deplete (mm) | Season Water Use (mm) | Grain Yield (Mg / ha) | Season WUE (kg / m$^3$) | Grn Yld Gain by Irrig (Mg / ha) | IWUE (kg / m$^3$) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | DK-41y | | | | | |
| PD-1 | W-1 | 455 | 0 | 111 | 566 | 6.34 | 1.12 | 0 | 0 |
| | W-2 | 455 | 100 | 99 | 655 | 6.94 | 1.06 | 0.60 | 0.59 |
| | W-3 | 455 | 200 | 96 | 753 | 7.44 | 0.99 | 1.10 | 0.55 |
| PD-2 | W-1 | 434 | 0 | 120 | 554 | 6.11 | 1.10 | 0 | 0 |
| | W-2 | 434 | 100 | 101 | 636 | 7.18 | 1.13 | 1.07 | 1.06 |
| | W-3 | 434 | 200 | 60 | 696 | 7.46 | 1.07 | 1.34 | 0.66 |
| PD-3 | W-1 | 311 | 0 | 61 | 372 | 7.41 | 1.99 | 0 | 0 |
| | W-2 | 311 | 100 | 109 | 521 | 8.31 | 1.59 | 0.90 | 0.89 |
| | W-3 | 311 | 190 | 30 | 531 | 8.35 | 1.57 | 0.94 | 0.49 |
| | | | | DK-59 | | | | | |
| PD-1 | W-1 | 455 | 0 | 146 | 601 | 6.00 | 1.00 | 0 | 0 |
| | W-2 | 455 | 100 | 125 | 681 | 7.50 | 1.10 | 1.50 | 1.49 |
| | W-3 | 455 | 200 | 124 | 781 | 7.95 | 1.02 | 1.94 | 0.96 |
| PD-2 | W-1 | 434 | 0 | 158 | 592 | 6.98 | 1.18 | 0 | 0 |
| | W-2 | 434 | 100 | 104 | 639 | 8.14 | 1.27 | 1.17 | 1.15 |
| | W-3 | 434 | 200 | 89 | 725 | 8.61 | 1.19 | 1.64 | 0.81 |
| PD-3 | W-1 | 311 | 0 | 69 | 380 | 7.03 | 1.85 | 0 | 0 |
| | W-2 | 311 | 100 | 107 | 519 | 7.74 | 1.49 | 0.71 | 0.70 |
| | W-3 | 311 | 190 | 25 | 526 | 7.82 | 1.49 | 0.80 | 0.42 |
| LSD (0.05) | Planting date | | | | 41 | 0.43 | 0.08 | 0.38 | 0.28 |
| | Irrigation level | | | | 58 | 0.48 | 0.22 | 0.28 | 0.23 |
| | Hybrid | | | | NS | 0.37 | 0.15 | 0.31 | 0.23 |

widely from 2.3 to 9.4 Mg/ha. With adequate irrigation, DK-59 produced high yields, 9.4 Mg/ha for PD-1, and 9.3 Mg/ha for PD-2. With limited irrigation (W-2) and early planting, DK-59 yields were reduced markedly to about 4.7 Mg/ha. Late season rainfall reduced the DK-59 yield response to adequate irrigation as reflected by nearly equal grain yields (7 to 7.5 Mg/ha) for both W-2 and W-3 irrigation treatments on PD-3 and PD-4.

Table 3. Treatment effects on water applied, seasonal water use, grain yield, and water use efficiency, 1990

| Treatments: Plant Date | Treatments: Irrig Treat | Season Rain (mm) | Season Irrig (mm) | Profile Deplete (mm) | Season Water Use (mm) | Grain Yield (Mg / ha) | Season WUE (kg / m$^3$) | Grn Yld Gain by Irrig (Mg / ha) | IWUE (kg / m$^3$) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | DK-41y | | | | | |
| PD-1 | W-1 | 241 | 0 | 129 | 370 | 3.29 | 0.89 | 0 | 0 |
| | W-2 | 241 | 180 | 81 | 502 | 6.26 | 1.25 | 2.97 | 1.65 |
| | W-3 | 241 | 380 | 60 | 681 | 8.58 | 1.26 | 5.29 | 1.39 |
| PD-2 | W-1 | 241 | 0 | 104 | 345 | 3.46 | 1.00 | 0 | 0 |
| | W-2 | 241 | 150 | 98 | 489 | 7.36 | 1.51 | 3.90 | 2.60 |
| | W-3 | 241 | 400 | −3 | 638 | 8.93 | 1.39 | 5.47 | 1.35 |
| PD-3 | W-1 | 236 | 0 | 133 | 369 | 4.65 | 1.26 | 0 | 0 |
| | W-2 | 236 | 280* | 39 | 555 | 7.14 | 1.29 | 2.49 | 0.89 |
| | W-3 | 236 | 280 | 70 | 586 | 7.30 | 1.25 | 2.65 | 0.95 |
| PD-4 | W-1 | 236 | 0 | 113 | 349 | 3.50 | 1.00 | 0 | 0 |
| | W-2 | 236 | 180 | 42 | 458 | 7.34 | 1.60 | 3.84 | 2.13 |
| | W-3 | 236 | 280 | −32 | 484 | 8.07 | 1.67 | 4.57 | 1.63 |
| | | | | DK-59 | | | | | |
| PD-1 | W-1 | 241 | 0 | 128 | 369 | 2.30 | 0.62 | 0 | 0 |
| | W-2 | 241 | 180 | 79 | 500 | 4.76 | 0.95 | 2.46 | 1.37 |
| | W-3 | 241 | 380 | 57 | 678 | 9.42 | 1.39 | 7.12 | 1.87 |
| PD-2 | W-1 | 241 | 0 | 128 | 369 | 2.83 | 0.77 | 0 | 0 |
| | W-2 | 241 | 150 | 96 | 487 | 5.20 | 1.07 | 2.37 | 1.58 |
| | W-3 | 241 | 400 | 10 | 651 | 9.28 | 1.41 | 6.45 | 1.59 |
| PD-3 | W-1 | 236 | 0 | 117 | 353 | 3.78 | 1.07 | 0 | 0 |
| | W-2 | 236 | 180 | 32 | 448 | 7.04 | 1.57 | 3.26 | 1.81 |
| | W-3 | 236 | 380 | −29 | 588 | 7.59 | 1.29 | 3.81 | 1.00 |
| PD-4 | W-1 | 236 | 0 | 123 | 359 | 3.54 | 0.99 | 0 | 0 |
| | W-2 | 236 | 180 | 78 | 494 | 7.00 | 1.42 | 3.47 | 1.93 |
| | W-3 | 236 | 280 | 26 | 542 | 7.50 | 1.38 | 3.96 | 1.41 |
| LSD (0.05) | Planting date | | | | 52 | 0.36 | 0.21 | 0.90 | 0.55 |
| | Irrigation level | | | | 24 | 0.36 | 0.17 | 0.50 | 0.28 |
| | Hybrid | | | | 45 | 0.26 | 0.15 | 0.64 | 0.39 |

* Treatment received an extra 100 mm irrigation by mistake.

Table 4. Treatment effects on water applied, seasonal water use, grain yield, and water use efficiency, 1991

| Treatments: Plant Date | Treatments: Irrig Treat | Season Rain (mm) | Season Irrig (mm) | Profile Deplete (mm) | Season Water Use (mm) | Grain Yield (Mg / ha) | Season WUE (kg / m$^3$) | Grn Yld Gain by Irrig (Mg / ha) | IWUE (kg / m$^3$) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | DK-41y | | | | | |
| PD-1 | W-1 | 331 | 0 | 146 | 477 | 4.27 | 0.90 | 0 | 0 |
| | W-2 | 331 | 100 | 137 | 568 | 6.32 | 1.11 | 2.05 | 2.05 |
| | W-3 | 331 | 200 | 123 | 654 | 8.57 | 1.31 | 4.30 | 2.15 |
| PD-2 | W-1 | 322 | 0 | 187 | 509 | 5.06 | 1.00 | 0 | 0 |
| | W-2 | 322 | 100 | 161 | 583 | 7.00 | 1.20 | 1.94 | 1.94 |
| | W-3 | 322 | 200 | 106 | 628 | 9.21 | 1.47 | 4.15 | 2.08 |
| PD-3 | W-1 | 221 | 0 | 144 | 365 | 4.72 | 1.29 | 0 | 0 |
| | W-2 | 221 | 100 | 152 | 473 | 5.29 | 1.12 | 0.57 | 0.57 |
| | W-3 | 221 | 200 | 78 | 499 | 5.83 | 1.17 | 1.11 | 0.56 |
| | | | | DK-59 | | | | | |
| PD-1 | W-1 | 331 | 0 | 186 | 517 | 3.16 | 0.61 | 0 | 0 |
| | W-2 | 331 | 100 | 177 | 608 | 6.64 | 1.09 | 3.48 | 3.48 |
| | W-3 | 331 | 200 | 160 | 691 | 8.37 | 1.21 | 5.21 | 2.61 |
| PD-2 | W-1 | 322 | 0 | 190 | 512 | 4.41 | 0.86 | 0 | 0 |
| | W-2 | 322 | 100 | 173 | 595 | 7.30 | 1.23 | 2.89 | 2.89 |
| | W-3 | 322 | 200 | 137 | 659 | 8.98 | 1.36 | 4.57 | 2.29 |
| PD-3 | W-1 | 221 | 0 | 157 | 378 | 5.12 | 1.35 | 0 | 0 |
| | W-2 | 221 | 100 | 159 | 480 | 6.06 | 1.26 | 0.94 | 0.94 |
| | W-3 | 221 | 200 | 81 | 502 | 6.21 | 1.24 | 1.09 | 0.55 |
| LSD (0.05) | Planting date | | | | 38 | 0.85 | 0.11 | 0.80 | 0.52 |
| | Irrigation level | | | | 31 | 0.46 | 0.08 | 0.35 | 0.31 |
| | Hybrid | | | | 37 | NS | 0.11 | 0.78 | 0.52 |

In contrast, DK-41y produced a slightly higher yield with PD-2 compared with PD-1 in 1990. The drop in yield for both hybrids on PD-3 is the result of a 70-mm, 19 July rain occurring immediately after an irrigation, which ponded water in the furrows for several days, thereby reducing soil aeration. The W-1 treatments, with no seasonal irrigation, resulted in very low grain yields in this extremely dry summer. The medium maturity DK-41y hybrid for PD-1 yielded 3.3 Mg/ha whereas the medium-late maturity DK-59 hybrid yielded only 2.3 Mg/ha under the same conditions. The medium maturity hybrid exhibited better drought tolerance than the medium-late hybrid, and the yield comparison illustrates the advantage of hybrids more adapted for conditions of major water deficits. Late planted DK-59 may have experienced a slight yield reduction by a light freeze on 9 October that caused a 10 to 20% loss in green leaf area before grain filling was complete on all irrigation treatments. Late planted DK-41y was mature by this date and yields were not affected.

In 1991, there was a significant grain yield response to irrigation for PD-1 and PD-2. DK-41y yielded slightly, but not significantly, higher than DK-59 for both PD-1 and PD-2 under W-2 and W-3 irrigation treatments. With no seasonal irrigation on PD-1, DK-41y yielded significantly higher (4.3 versus 3.2 Mg/ha) or 35% more than did DK-59. Both hybrids yielded slightly higher on PD-2 compared with PD-1. The very early planting date, 1 May for PD-1, resulted in very slow emergence (14 to 16 days) which limited any advantage to very early planting. The third planting date suffered from erratic stands caused by wet planting conditions and surface crusting, and grain yields for W-2 and W-3 irrigation treatments were markedly reduced.

### Average Grain Yield Response

The three-year average results of grain yield versus planting date are presented in figure 3 for each irrigation regime. There was very little difference in the average yield performance between the two hybrids. With adequate

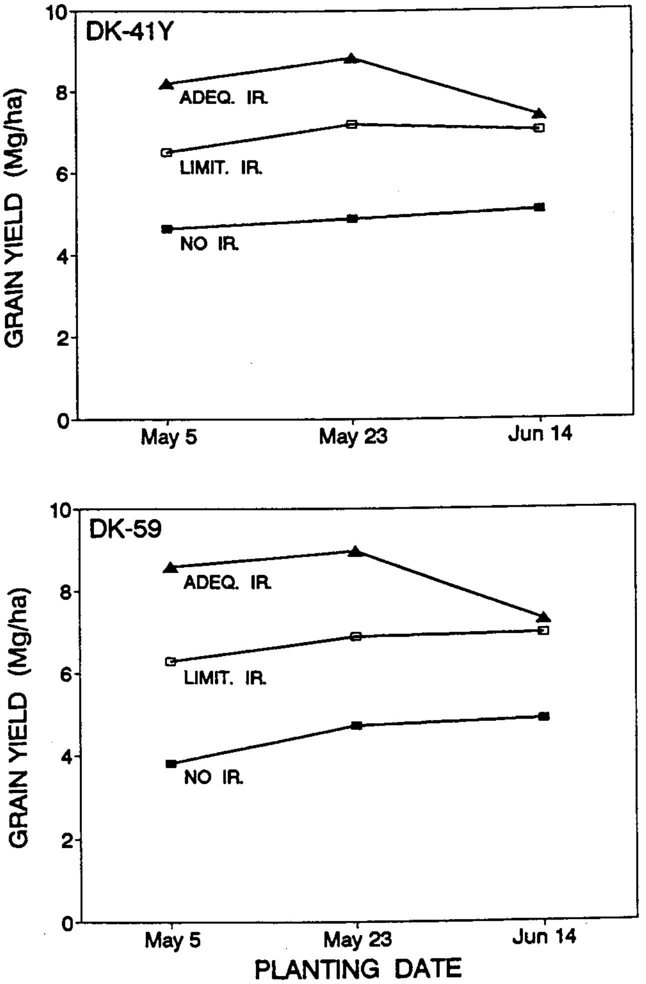


**Figure 3–Three-year average sorghum grain yield by average planting date and irrigation treatment during 1989-1991, Bushland, TX.**

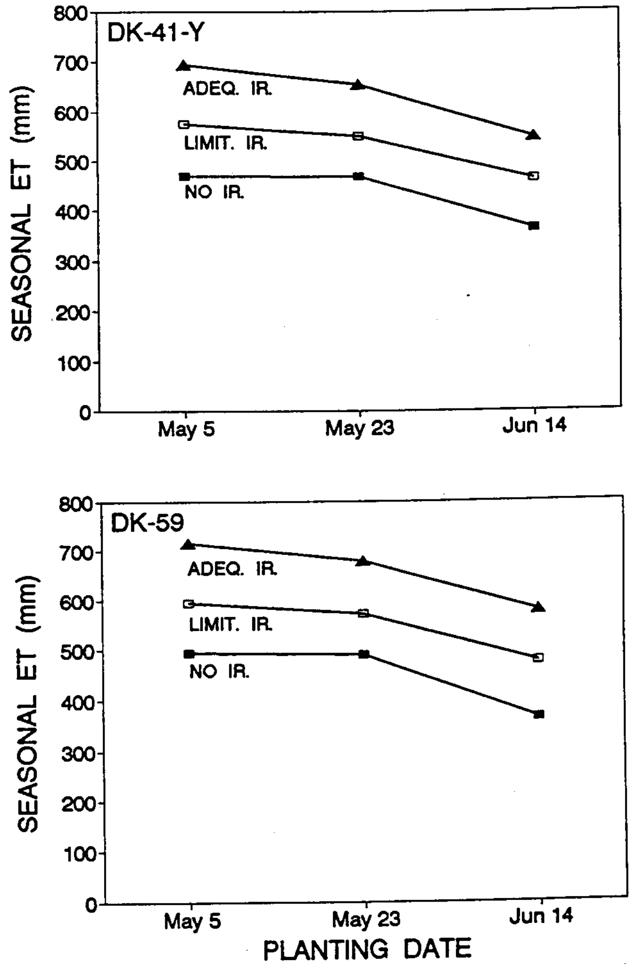


**Figure 4–Three-year average seasonal ET by average planting date and irrigation treatment during 1989-1991, Bushland, TX.**

irrigation, yields for both hybrids were within a rather narrow range (8.2 to 9.0 Mg/ha) for planting dates PD-1 and PD-2, then dropped off to about 7 Mg/ha for PD-3. With limited irrigation, the grain yields for both hybrids were very similar for each planting date; averaging 6.4 Mg/ha for PD-1 and increasing to about 7.0 Mg/ha for PD-2 and PD-3. With the major soil water deficits that developed without a seasonal irrigation, the yellow endosperm medium maturity hybrid (DK-41y) with early planting averaged a 20% higher grain yield (4.6 Mg/ha) compared to the medium-late hybrid (DK-59) at 3.8 Mg/ha, but there was only a slight difference for later plantings.

### Evapotranspiration and Water Use Efficiency

Seasonal irrigation requirements were relatively low (200 mm for W-3 treatment) in 1989 and 1991 because of above average rainfall in 1989 and below average evaporative demand during June through August in both years. Evaporation (June through August) from a Young's sunken and screened (0.6 m diameter) pan was 77, 122, and 90% of the 600-mm average during 1989, 1990, and 1991, respectively. In 1990, seasonal irrigation requirements were up to 400 mm for the W-3 treatment. Seasonal water use for adequately irrigated W-3 treatments was 10 to 15% higher in 1989 than in other years, possibly because of some deep percolation from the relatively high rainfall.

The three-year average ET versus planting date relationships for each irrigation regime are presented in figure 4. There was almost no effect by hybrid on ET. There was a noticeable reduction in ET (75 to 100 mm) between the second and third planting dates. This reduction was about the same for each irrigation treatment. The reduced ET for mid-June planting is a result of a shorter growing season and less evaporative demand during September grain filling, compared with late-May planted sorghum being in grain filling during a relatively warm August. The reduced evaporative demand for mid-June planting also resulted in increased seasonal WUE (fig. 5) except for the adequately irrigated treatments. With adequate irrigation, late-May planting had the highest seasonal WUE. With the deficit irrigation treatments W-1 and W-2, June planting was most efficient.

Irrigation water use efficiencies are presented in figure 6. These values reflect grain yield response to varying seasonal irrigation amounts. These IWUEs, with both limited and adequate irrigation, averaged notably higher for DK-59 (1.83 to 1.95 kg/m$^3$) compared with (1.37 to 1.48 kg/m$^3$) for DK-41y on the first planting date.

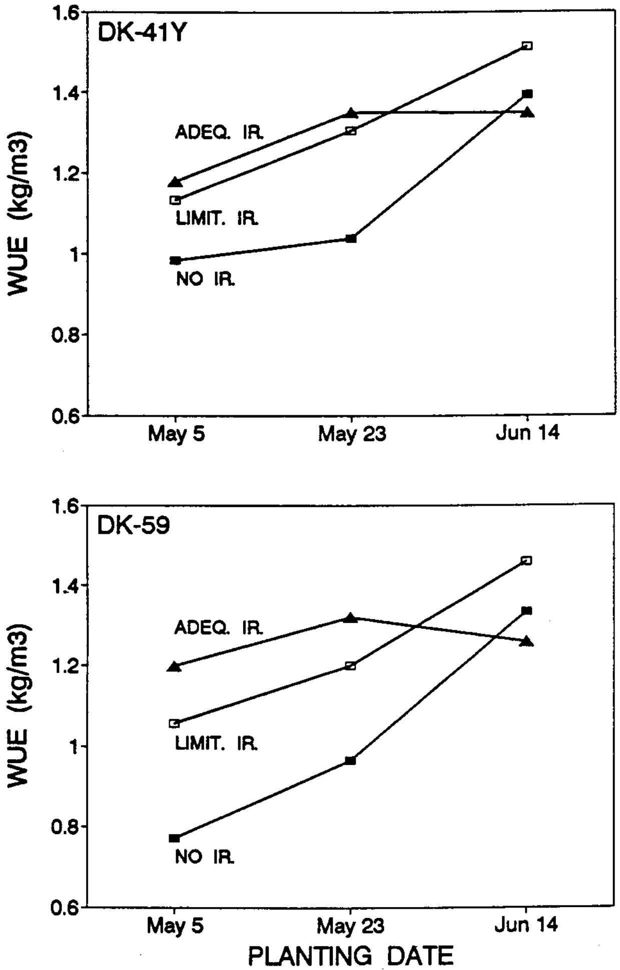


**Figure 5–Three-year average seasonal WUE by average planting date and irrigation treatment during 1989-1991, Bushland, TX.**

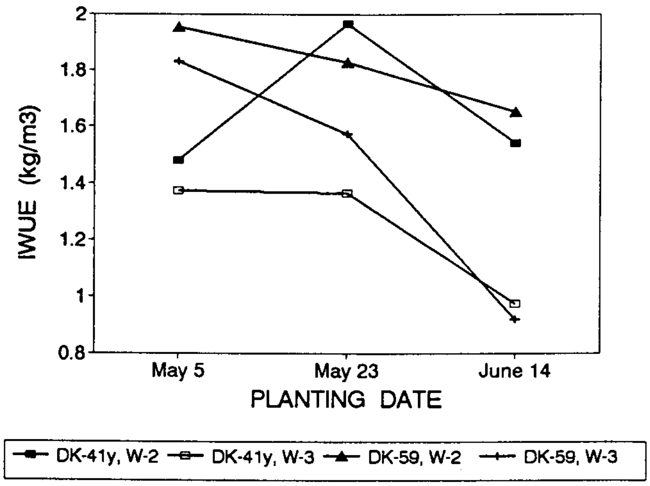


**Figure 6–Three-year average IWUE by average planting date and irrigation treatment during 1989-1991, Bushland, TX.**

For PD-2, DK-41y averaged a slightly higher IWUE (1.97 versus 1.83 kg/m$^3$) for the limited irrigation treatment, but DK-59 averaged higher (1.57 versus 1.37 kg/m$^3$) for the adequate irrigation treatment. Thus, the longer maturity DK-59 hybrid was more efficient with May planting and adequate irrigation. Both maturity length hybrids produced very low IWUEs (less than 1.0 kg/m$^3$) with later mid-June planting under adequate irrigation. These results emphasize the importance of very judicious application of irrigation water with relatively late planting, because of reduced ET requirements.

A comparison of figures 5 and 6 reveals that conditions favoring a high IWUE do not necessarily produce the highest seasonal WUE. The medium-late hybrid has the potential for a high IWUE when planted relatively early to allow time for greater response to irrigation. However, a higher seasonal WUE can be achieved by June planting and the use of limited irrigation management with either maturity-length hybrid.

## Overall Results

The overall results indicate that both medium and medium-late maturity sorghum hybrids are most productive when planted relatively early (before 1 June) in the Southern High Plains. If early May planting is desired under adequate irrigation, the longer season medium-late maturity hybrids have some additional grain yield potential compared with medium hybrids. The medium-maturity hybrids are better adapted if planting is delayed until June, and are better adapted than longer season hybrids to limited irrigation. Fall freeze damage before physiological maturity is a risk when planting a medium-late hybrid later than mid-June as evidenced by DK-59 being adversely affected by the 22 June planting in 1990.

The optimum planting time for either maturity hybrid can shift by two to three weeks depending upon soil temperatures in May. The occurrence of 15 and 18° C air temperatures is representative of very early and optimum planting times for sorghum at Bushland. The average cumulative probability of the occurrence of 15 and 18° C daily mean air temperatures is presented in figure 7. Soil temperatures at the 5-mm depth lag air temperatures by about four days. The 50% probability for 18° C air temperature is 19 May. Adding four days for seed zone soil temperature lag brings the 50% probability date to 23 May, which is the same date as the average for PD-2 in this study. The lower 15° C air temperatures occur about 20 days earlier than do the 18° C temperatures.

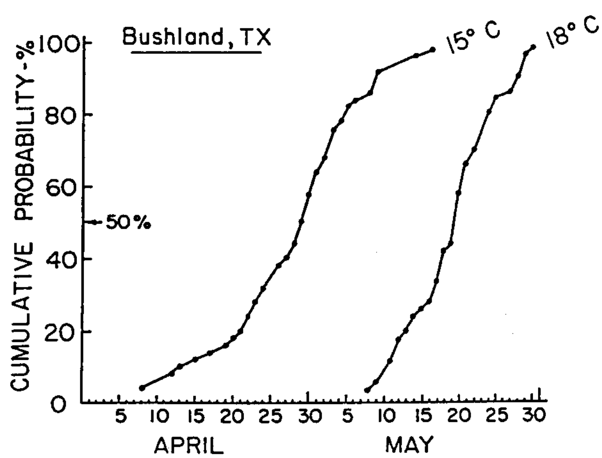


**Figure 7–Cumulative probability dates for daily mean air temperatures; 15° C as marginal for early sorghum planting and 18° C as adequate for normal planting, based on 50-year climatic data, Bushland, TX.**

Previous research (Allen and Musick, 1990) revealed that planting sorghum without a preplant irrigation can increase WUE up to 20%. However, there is a risk of planting being delayed until rainfall is received because of dry surface soil. If planting is delayed, then grain yield potential decreases after 1 June under a full irrigation regime. With deficit irrigation management using a medium-maturity hybrid, then planting can be delayed until mid-June without reduced grain yield potential (fig. 3).

## CONCLUSIONS

With adequate irrigation, a medium-late maturity hybrid planted in early May, has slightly higher grain yield potential than a medium hybrid. Yield potential, for both maturity hybrids with adequate irrigation, is highest (near 9 Mg/ha) when planting in late May. If planting is delayed until mid-June, a medium maturity hybrid has the highest relative yield and WUE potential because of a shorter growing season which minimizes the adverse effects of late season cool temperatures. The drought tolerant, dryland-type medium maturity hybrids are better adapted for conditions of limited irrigation and periods of moderate stress. The allowable planting date for either maturity hybrid, based on soil temperature, can shift two to three weeks from early to late May in different years. Soil temperatures in June are more favorable for rapid germination but delayed planting shortens the growing season, and thus the need to use shorter maturity hybrids is increased. Precipitation has a major effect on irrigation water requirements and yield response. The time and amount of rainfall occurrence has a major effect on crop response to limited irrigation.

## REFERENCES


Allen, R. R., J. T. Musick, F. O. Wood and D. A. Dusek. 1969. Grain sorghum yield response to row spacing in relation to seeding date, days to maturity, and irrigation level in the Texas Panhandle. Texas Agric. Exp. Stn. PR 2697. College Station.

Allen, R. R. and J. T. Musick. 1990. Effect of tillage and preplant irrigation on sorghum production. *Applied Engineering in Agriculture* 6(5):611-618.

Kreig, D. R. and R. S. Lascano. 1989. Sorghum. In *Irrigation of Agricultural Crops*, eds. B. A. Stewart and D. R. Nielsen, Chapter 23, 719-739. Madison, WI: ASA.

Malm, N. R. 1965. Planting dates for grain sorghum on the High Plains. New Mexico Agric. Exp. Stn. Res. Rpt. 109. Las Cruces.

Manuqistics, Inc. 1992. Rockville, MD.

Musick, J. T. and F. R. Lamm. 1990. Preplant irrigation in the Central and Southern High Plains - A review. *Transactions of the ASAE* 33(6):1834-1842.

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