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EFFECT OF IRRIGATION FREQUENCY AND TIMING ON SUNFLOWER GROWTH AND YIELD[1]

By

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Abstract

Sunflowers (Helianthus annuus L.) "Hybrid 896" were grown on furrow-irrigated Pullman clay loam at Bushland, Texas, in 1975, 1976 and 1977. Irrigation treatments were: E - emergence only; EB - emergence and early budding; EF - emergence and start of flowering; E(F + 14) - emergence and 14 days after start of flowering; EB(F + 14) - emergence, early budding, and 14 days after start of flowering; EF(F + 14) - emergence, start of flowering, and 14 days after start of flowering; and E + A - emergence and adequately during the growing season. The E + A treatment resulted in the tallest plants, but these averaged only 14 cm taller than those for the EB treatment. Sunflowers irrigated after early budding were generally not much taller than those of the E treatment, which were the smallest. Achene yields were significantly higher each year with the E + A treatment than with the E treatment. Yields with other irrigation treatments generally were also significantly higher than with the E treatment. For the E and E + A treatments, yields ranged from 1580 to 3330, 820 to 2330, and 1740 to 2970 kg/ha in 1975, 1976 and 1977, respectively. In each year, however, at least one treatment with one or two fewer growing-season irrigations than for the E + A treatment resulted in achene yields not significantly lower than those of the E + A treatment. In general, yields were good with fewer irrigations if the sunflowers received effective rainfall or an irrigation at least once every 14 days from early budding until late flowering. Irrigation treatments had no consistent effects on achene test weights or oil contents.

Sunflowers (Helianthus annuus L.) are successfully grown in many areas of the world without irrigation. However, in subhumid and semiarid regions, precipitation often is highly erratic and achene yields are often low. Under such conditions sunflowers, like most crops, respond to irrigations (Bilgin, 1974; Costin and Platon, 1972; Decau et al, 1973; Dimitrov, 1975; Gimenez Ortiz et al, 1975; Marty et al, 1972; Muriel et al, 1975; Shipley and Regier, 1976). When adequately irrigated, achene yields may exceed 4 metric tons/ha (Decau et al, 1973; Delibaltov and Ivanov, 1973; Dimitrov, 1975; Marty et al, 1972; Mikhov, 1974, 1975). The most critical period for supplying adequate water is generally from early flowering to achene formation (Dhima and Gjergji, 1973; Mikhov, 1974, 1975). When full irrigation is not possible because of

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limited water supplies, like in the Southern Great Plains of the USA, irrigation at critical growth stages becomes increasingly important for obtaining satisfactory yields and the greatest return for the amount of water applied. This study was conducted to determine the response of sunflowers to irrigations applied at identifiable development stages on a semiarid region of Texas (USA). Response was measured in terms of plant height; achene yield, test weight, and oil content; and water use and use efficiency.

Experimental Procedures

The study was conducted in 1975, 1976 and 1977, on Pullman clay loam (Torrertic Paleustoll) at the USDA Southwestern Great Plains Research Center, Bushland, Texas. Bushland is in the northern part of Texas at 35,17^{o} north latitude and 102.1^{o} west longitude. Elevation above mean sea level is 1178 meters and precipitation averages 46.9 cm annually.

The plot area was irrigated either before or immediately after planting to ensure uniform seedling emergence.

Irrigation treatments were:

E	-- emergence only
EB	-- emergence and early budding
EF	-- emergence and start of flowering
E(F + 14)	-- emergence, and 14 days after start of flowering
EB(F + 14)	-- emergence, early budding, and 14 days after start of flowering
EF(F + 14)	-- emergence, start of flowering, and 14 days after start of flowering
E + A	-- emergence and adequately during the growing season (irrigated when afternoon wilt was observed).

Each treatment was replicated four times. The early budding irrigations were applied when sunflower buds were 2 to 3 cm in diameter. The early flowering irrigations were applied when about 5% of the plants had ray flowers. The F + 14 irrigations were applied 14 days after the early-flowering irrigations. The EB(F + 14) and EF(F + 14) treatments were not used in 1975.

Plots were 30 meters long and 4 meters (four 1-meter bed-furrows) wide, with a slope of about 0.3%. The three center furrows of each plot were irrigated through gated pipe. Water application rates and times were determined, but tailwater runoff to determine infiltration was measured only in 1977. For 1975 and 1976, water infiltration during irrigations was estimated from infiltration percentages previously determined for this soil under similar conditions.

Before planting sunflowers, anhydrous ammonia at 112 kg/ha of N was chiseled into the furrows of the plot area, except in 1977 when the soil contained adequate residual N. Weeds were controlled with applications of trifluralin (a,a,a,-trifluoro-2,6-dinitro-N,N-dirophyl-p-toluidine) in 1975 and and 1976 and profluralin (N-(cyclopropymethyl)-a,a,a-trifluoro-2,c-dinitro-N-propyl-p-toluidine) in 1977. Sunflower "Hybrid 896" seed were planted with unit planters in single rows per bed at a rate to obtain about 64,000 plants/ha.

Treatment[†]	Irrigation dates	Plant height	Achene: Yield[‡]	Achene: Test wt.	Achene: Total oil contents[§]	Growing-season water use: Irrig.	Precip.	Soil	Total	Water-use efficiency
		cm	kg/ha	g/liter	%	cm	cm	cm	cm	kg/ha-cm
1975										
E	5/13	118 c[¶]	1580 d	316 b	42.5 b	--[#]	21.1	17.5[††]	38.6	40.9
EB	5/13; 7/1	151 a	2200 c	338 a	43.1 b	6.6	21.1	19.8	47.5	46.3
EF	5/13; 7/16	125 b	2770 b	338 a	44.9 b	7.9	21.1	21.1	50.1	55.3
E(F + 14)	5/13; 7/30	124 b	3070 ab	359 a	47.4 a	7.9	21.1	20.6	49.6	61.9
E + A	5/13; 6/26; 7/16; 7/30	155 a	3330 a	352 a	45.0 b	23.6	21.1	18.8	63.5	52.4
1976										
E	5/17	86 d	820 d	386 a	44.9 a	7.6	15.7	7.6	30.9	26.5
EB	5/17; 6/30	117 b	1500 bc	364 b	41.9 cd	15.2	15.7	9.1	40.0	37.5
EF	5/17; 7/9	97 c	1570 b	337 c	40.1 e	15.2	15.7	6.6	37.5	41.9
E(F + 14)	5/17; 7/23	86 d	1190 cd	368 b	44.1 ab	15.2	15.7	6.1	37.0	32.0
EB(F + 14)	5/17; 6/30; 7/23	117 b	2280 a	356 b	43.2 bc	22.9	15.7	9.7	48.3	47.7
EF(F + 14)	5/17; 7/9; 7/23	94 cd	1860 b	338 c	41.6 cd	22.9	15.7	7.4	46.0	40.4
E + A	5/17; 6/22; 7/9; 7/23	137 a	2330 a	330 c	41.0 de	30.5	15.7	5.6	51.8	45.0
1977										
E	3/25	108 e	1740 c	409 c	50.2 abc	--	32.9	17.6	50.5	34.5
EB	3/25; 6/29	137 b	2060 c	396 d	47.7 e	10.3	32.9	21.6	64.8	31.8
EF	3/25; 7/13	115 d	2050 c	403 cd	49.1 cd	10.4	32.9	15.7	59.0	34.7
E(F + 14)	3/25; 7/27	115 d	2470 b	424 b	50.9 ab	10.1	32.9	17.7	60.7	40.7
EB(F + 14)	3/25; 6/29; 7/27	128 c	2560 b	437 a	51.1 a	19.2	32.9	20.6	72.7	35.2
EF(F + 14)	3/25; 7/13; 7/27	116 d	2930 a	431 ab	48.7 de	18.7	32.9	17.8	69.4	42.2
E + A	3/25; 6/29; 7/13; 7/27	145 a	2970 a	421 b	49.7 bcd	27.8	32.9	17.4	78.1	38.0

TABLE 1: Irrigation dates; plant heights; achene yields, test weights, and oil contents; growing-season water use; and water-use efficiency for sunflowers grown under irrigation at Bushland, Texas, in 1975, 1976, and 1977.

Table 1 (continued)

† Treatments were: E--emergence only; EB--emergence and early budding; EF--emergence and start of flowering; E(F + 14)--emergence and 14 days after start of flowering; EB(F + 14)--emergence, early budding, and 14 days after start of flowering; EF(F + 14)--emergence, start of flowering, and 14 days after start of flowering; E + A--emergence and adequately during the growing season.

‡ Yields based on 9% achene moisture content.

§ Oil contents based on achenes dried in oven at 60°C (100°C in 1977).

¶ Column values for a given year followed by the same letter or letters are not significantly different at the 5% statistical level (Duncan's Multiple Range Test).

Emergence irrigation applied before planting.

†† Based on available soil water contents at planting and harvest to 1.8-meter depths in 1975 and to 3.0-meter depths in 1976 and 1977.

Plant spacing in the row was about 15 cm. Planting dates were 12 May 1975, 7 May 1976, and 9 May 1977.

Soil samples for gravimetric water content determinations at planting and harvest were obtained at 30-cm increments to the 1.8-meter depth in 1975 and the 3.0-meter depth in 1976 and 1977. Sunflowers were sprayed with methyl parathion (O,O-diethyl O-(p-nitrophenyl) phosphorothioate) as necessary during flowering to control sunflower moth (*Homoeosoma electellum* Hulst). Plant heights were measured at full flowering. Head samples were hand-harvested from 3-meter lengths of the two center rows of each plot, dried, and threshed with a stationary thresher. Achene yields were adjusted to 9% moisture. Oil contents were determined by the nuclear magnetic resonance (NMR) technique (Granlund and Zimmerman, 1975). Water-use efficiency values are based on achene yields and estimated total water use (irrigations - estimated infiltration - soil water use, and precipitation). Where appropriate, data were analyzed by the analysis of variance technique.

Results and Discussion

Sunflower plant height; achene yield, test weight, and oil content; growing-season water use; and water-use efficiency (WUE) data are given in Table 1.

Plant Height

Plant height was significantly influenced by time of irrigation. The adequate irrigation (E + A) treatment resulted in the tallest plants, but they averaged only about 14 cm taller than those receiving early budding irrigations (EB and EB(F + 14) treatments). Sunflowers first irrigated at early or late flowering (EF and EF(F + 14) treatments) were significantly shorter than those irrigated at early budding. The generally taller plants in 1975 than in 1976 and 1977 resulted from more favorable rainfall distribution early in the 1975 growing season. Thus, early-season water stress may reduce plant height but, as shown in the next section, achene yield may not be reduced.

Achene Yield

Achene yields with all treatments, except the emergence only (E), were highest in 1975 and lowest for all treatments in 1976. Sunflowers receiving one or more growing-season irrigations yielded significantly more than those irrigated for emergence only, except for the E(F + 14) treatment in 1976 and the EB and EF treatments in 1977. In 1975, irrigation at early budding increased achene yields by 620 kg/ha over yields with the E treatment. Yield increases of 1190 and 1490 kg/ha over the E treatment resulted from delaying the first growing-season irrigation until early flowering (EF treatment) or until late flowering (E(F + 14) treatment). The E + A treatment, with three growing-season irrigations, resulted in a 1750-kg/ha higher yield than the E treatment. This yield, however, was only 260 kg/ha higher than that with the E(F + 14) treatment, which received only one growing-season irrigation.

In 1976, the response to one growing-season irrigation was greatest when it was applied at early flowering (EF treatment). The yield increase over the E treatment was 750 kg/ha. In 1975, the response was greatest to the E(F + 14) treatment. Different yield responses in the two years resulted from variation in rainfall amount and distribution. Growing-season rainfall was 5.4 cm greater in 1975 than in 1976. In 1975, much of the rain fell in May and June, resulting in good early growth without irrigations. Then, late-season irrigations (EF and E(F + 14) treatments) furnished water during achene development and maturation.

In 1976, early-season rainfall was low. Thus, irrigations at early budding or early flowering enhanced plant development. Then, some late-season rainfall resulted in higher achene yields with the EB and EF treatments than where the irrigation was applied at late flowering (E(F + 14) treatment). The irrigation for the E(F + 14) treatment in 1976 was applied too late to greatly increase yields because severe water stress earlier in the growing season retarded plant growth before flowering. While yields with the EB and EF treatments were similar, the second irrigation at late flowering caused a significant yield increase with the EB(F + 14) treatment. With adequate irrigation (E + A treatment), yields were only 50 kg/ha greater than with the EB(F + 14) treatment.

Yields in 1977 were not significantly different for the E, EB, and EF treatments. One growing-season irrigation at late flowering (E(F + 14) treatment) resulted in a significant yield increase over the E, EB, and EF treatments. Like in 1975, yield trends were related to rainfall distribution. In 1977, May and June rainfall totaled 11.7 cm, but the July total was only 0.7 cm. While total growing season rainfall was high in 1977, most of it fell in August, too late to greatly influence yields. Consequently, rainfall and the early irrigations (EB and EF treatments) provided generally sufficient early growing-season water, but stress was severe at late flowering and achene development. Plants of the E(F + 14) treatment also benefited from early rainfall and were not stressed at late flowering because of the irrigation at that time. Hence, the higher yields with the E(F + 14) treatment than with the EB and EF treatments, each of which received one growing-season irrigation.

The yield difference in 1977 between the EB(F + 14) and EF(F + 14) treatments, which was significant, was also related to rainfall distribution. The EF(F + 14) treatment provided irrigation water on 13 and 27 July, thus averting severe water stress during the almost rainless month. In contrast, plants of the EB(F + 14) treatment received no irrigation or effective rainfall from 29 June until 27 July. The timeliness of the irrigations of the EF(F + 14) treatment, along with the early-season rainfall, resulted in similar yields with the EF(F + 14) and E + A treatments. The difference (40 kg/ha) was not statistically significant.

Yield data for this study show that one or two well-timed irrigations during the growing season can result in sunflower achene yields similar to those obtainable with adequate irrigation on Pullman clay loam. The time of irrigation depends on growing-season rainfall distribution. For highest achene yields, the data suggest that sunflowers on Pullman clay loam should be irrigated or receive effective rainfall at least every 14 days, especially from early budding until late flowering. When water for irrigation is limited, thus permitting only one growing-season irrigation, it should be applied with-in about 14 days after early flowering. Results of this study are in general agreement with those of Bilgin (1974), Dhima and Gjergji (1973), Gimenez Ortiz et al (1975), and Muriel et al (1975).

Achene Test Weight

Test weights ranged from 316 g/liter (24.6 lb/bu) with the E treatment in 1975 to 437 g/liter (34.0 lb/bu) with the EB(F + 14) treatment in 1977. The E treatment resulted in the lowest test weight in 1975 and the highest in 1976. No definite trends in test weights resulted from irrigations applied at various stages of sunflower development.

Achene Total Oil Content

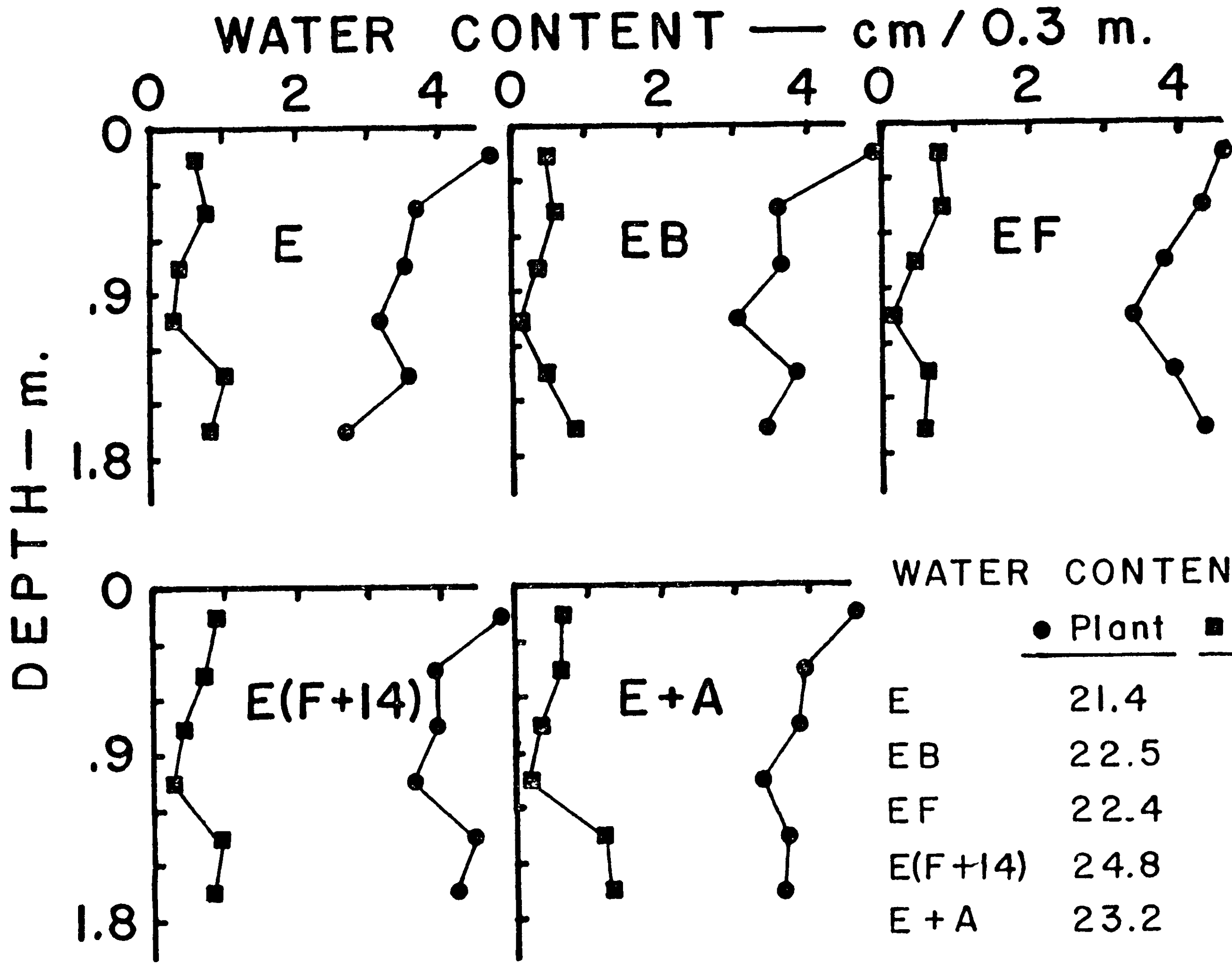
Oil contents, based on moisture-free samples (dried at 60°C -- 100°C in 1977 -- for 20 hours), were significantly different among irrigation treatments in all years of the study. In 1975, except for the E + A treatment, oil contents tended to increase as the irrigations were made at later developmental stages. In 1976 and 1977, however, no definite oil content trends related to irrigations were apparent.

In 2 out of 3 years, oil content differences between the E and E + A treatments were not statistically significant. In 1976, the E treatment resulted in a significantly higher oil content than the E + A treatment. These results generally contradict those reported by Decau et al (1973), Delibaltov and Ivanov (1973), Dimitrov (1975), Gimenez Ortiz et al (1975), Longo and Restuccia (1975), Marty et al (1972), Stoyanova et al (1975), and Vitkov and Gruev (1973). A possible reason for variable oil contents resulting from irrigations may have been the soil's fertility level. At planting, the soil contained more than 100 kg/ha N, an amount generally considered adequate for sunflowers. Other fertilizer elements were not applied because crops do not respond to added P and K on Pullman clay loam (Eck et al, 1965; Mathers et al, 1975). Hence, soil fertility was adequate for high yields. High fertility rates or amounts, however, have reduced achene oil contents (Delibaltov and Ivanov, 1973; Unger et al, 1976). While oil contents often were lower with irrigation during the growing season than with the emergence irrigation only, oil yields were higher because the increased yields with irrigation more than compensated for the oil content decreases.

Growing-Season Water Use

Differences in irrigation amounts among years for the same treatments resulted primarily from timing of the emergence irrigation. In 1975 and 1977, it was applied before planting while in 1976, it was applied after planting. Hence, the greater irrigation amounts in 1976.

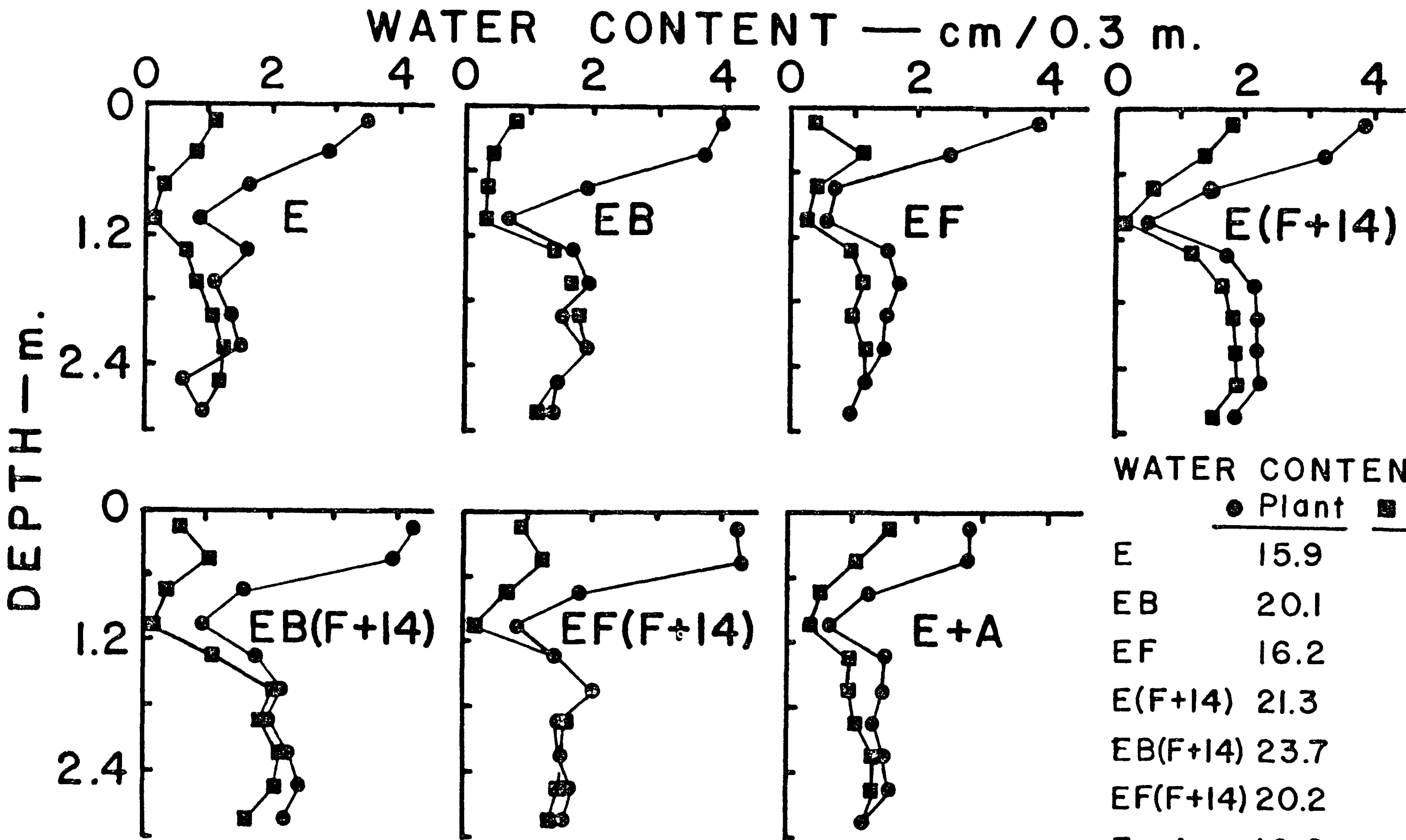
Influence of timing of the emergence irrigations is also reflected in differences in growing-season soil water use among years (Table 1 and Figures 1, 2, 3). In 1976, water content was determined immediately after planting and before the emergence irrigation. Hence, soil water use values were low



WATER CONTENT—cm

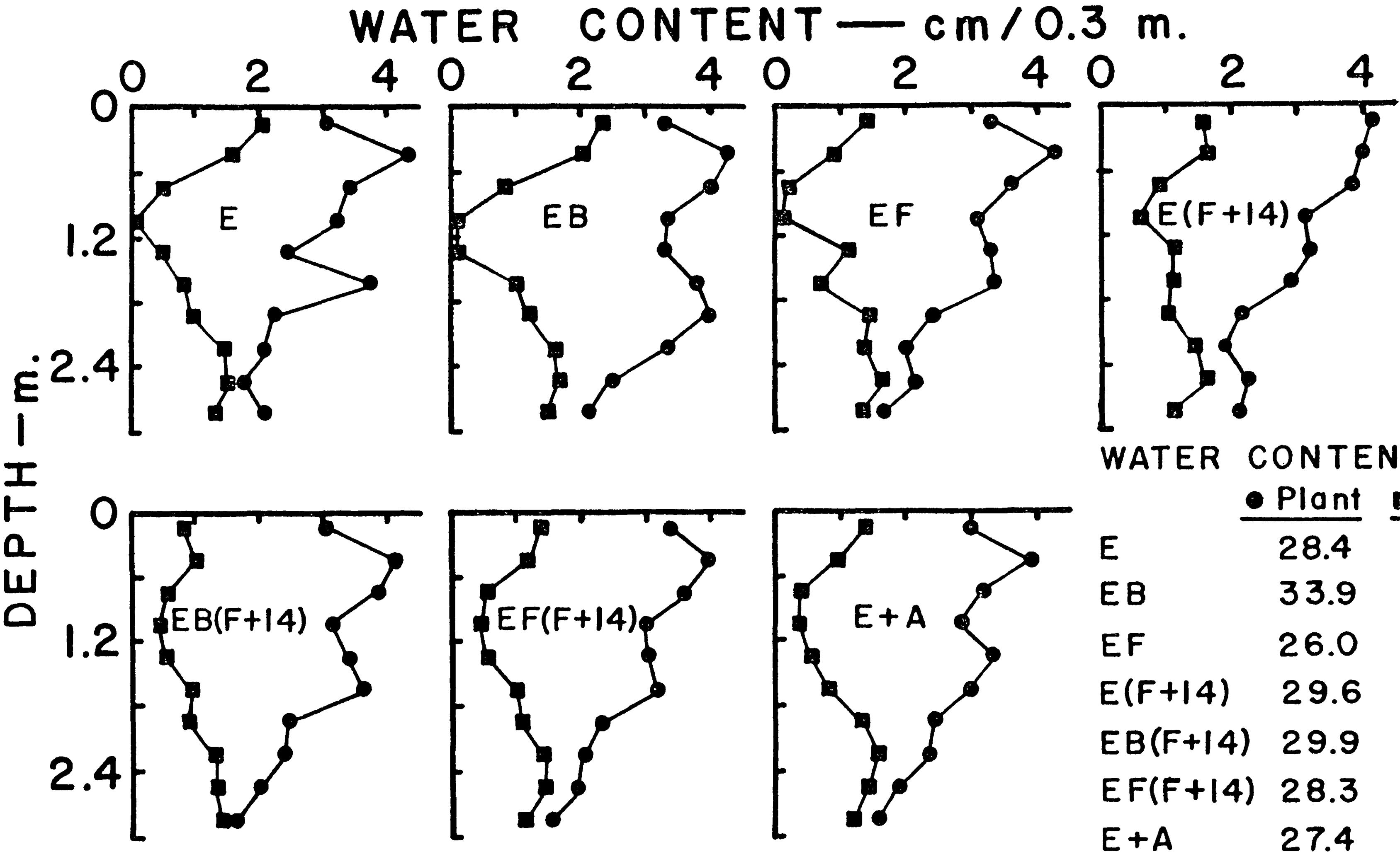
	● Plant	■ Harv.
E	21.4	4.0
EB	22.5	2.8
EF	22.4	3.4
E(F+14)	24.8	4.2
E + A	23.2	4.4

Figure 1. Available soil water contents at planting and harvest of irrigated sunflowers at Bushland, Texas, in 1975. Irrigation treatments were: E -- emergence only, EB -- emergence and early budding, EF -- emergence and start of flowering; E(F + 14) -- emergence and 14 days after start of flowering, and E + A -- emergence and adequately during the growing season.



WATER CONTENT-cm	● Plant	■ Harv.
E	15.9	8.4
EB	20.1	11.0
EF	16.2	9.0
E(F+14)	21.3	13.7
EB(F+14)	23.7	12.8
EF(F+14)	20.2	12.5
E+A	16.0	9.8

Figure 2. Available soil water contents at planting and harvest of irrigated sunflowers at Bushland, Texas, in 1976. Irrigation treatments were: E -- emergence only, EB -- emergence and early budding, EF -- emergence and start of flowering, E(F + 14) -- emergence and 14 days after start of flowering, and E + A -- emergence and adequately during the growing season.



WATER CONTENT—cm	● Plant	■ Harv.
E	28.4	10.8
EB	33.9	12.3
EF	26.0	10.4
E(F+14)	29.6	11.9
EB(F+14)	29.9	9.2
EF(F+14)	28.3	10.4
E+A	27.4	10.0

Figure 3. Available soil water contents at planting and harvest of irrigated sunflowers at Bushland, Texas, in 1977. Irrigation treatments were: E -- emergency only, EB -- emergence and early budding, EF -- emergence and start of flowering, E(F + 14) -- emergence and 14 days after start of flowering, and E + A -- emergence and adequately during the growing season.

for that year. Although the emergence irrigation increased the soil water content soon after planting, water contents below about the 1-meter depth remained low. One irrigation normally does not increase water contents below 1 meter because of the very slowly permeable subsoil of Pullman clay loam. The generally low soil water content at planting and failure of the crop to use water from depths greater than about 1.2 meters (Figure 2) contributed to the low total water use in 1976 (Table 1). In contrast, soil water contents at planting and use during the growing season were higher in 1975 and 1977 (Figures 1 and 3). This resulted in higher total water use and yields for these years.

Water-Use Efficiency

Water use efficiency (WUE) values (Table 1) were based on achene yields and total growing-season water use. In 1975 and 1976, WUE's were higher when growing-season irrigations were applied than when not applied (E treatment). However, in both years, the E + A treatment resulted in lower WUE's than treatments with one or two well-timed growing-season irrigations. In 1977, several treatments with growing-season irrigations (EB, EF, and EB(F + 14) resulted in WUE's lower than or similar to those of the E treatment. The E(F + 14) and EF(F + 14) treatments resulted in higher WUE's than the E + A treatment.

Conclusions

Sunflower plant height and achene yield, test weight, and oil content were significantly affected by irrigation timing and frequency. Growing-season water use and water-use efficiency were also affected by the treatments, but these factors were not analyzed statistically.

Besides adequate irrigation (E + A treatment), an irrigation at early budding had the greatest effect on plant height. Later irrigations (EF and E(F + 14) treatments) had no, or relatively little, effect on plant heights when compared with the emergence only (E) irrigation.

Achene yields generally were significantly higher with growing-season irrigations than with the E treatment. Responses to one or two growing-season irrigations were largely influenced by the frequency and amount of growing-season precipitation. With generally adequate early rainfall, irrigation at early to late flowering (EF, E(F + 14), and EF(F + 14) treatments) resulted in substantial yield increases as compared with the E treatment. With limited early growing-season rainfall, like in 1976, sunflowers irrigated at early budding or early flowering and at late flowering yielded more than those irrigated at late flowering only (E(F + 14) treatment).

For near maximum achene yields, results of this study suggest that sunflowers on Pullman clay loam should receive water by irrigation or effective rainfall at least every 14 days throughout the period from early budding to late flowering. Treatments that provided such conditions (EF(F + 14) in 1975, EB(F + 14) in 1976, and EF(F + 14) in 1977) resulted in yields that were not significantly different from those of the adequate irrigation (E + A) treatment. Because of fewer irrigations and similar yields, these treatments resulted in higher water-use efficiencies than those of the E + A treatments. If sunflowers produce satisfactory yields with limited irrigations, their adaptation will be greatly enhanced in regions where water for irrigation is limited, like the Southern Great Plains of the USA.

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