Irrigation Studies of Grain Sorghum in the Oklahoma Panhandle 1958 to 1962

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Crop performance over the western portion of Oklahoma can be enhanced by timely additions of water. This appears to be true for most crops and for most years, so-called wet years included. This bulletin reports results of a study to determine the effect of timeliness in irrigating grain sorghum. Studies (1)[2] in the Texas Panhandle have given some information on the subject. The producer would like to hold inputs of water and labor to the minimum amounts required for optimum crop performance: there may be times to irrigate and times not to irrigate.

The study was conducted at Panhandle A. and M. College, Goodwell, Oklahoma. The crop studied was Westland variety of grain sorghum. This variety was widely grown at the time the study was initiated, but hybrid types now predominate. Westland variety was retained throughout the study to avoid undesired complications resulting from use of more than one type of sorghum. The results are expected to apply in relative fashion to hybrids, i.e., most results numerically reported should be proportionately higher for hybrids and occur in approximately the same order of ranking.

The soil type in the area of the study was Richfield silty clay loam except for a portion of the area which was classed Ulysses.

Procedures

The studies in 1958 and 1959 were similar in design. In 1960, 1961, and 1962 the design was similar, but slightly different than in the preceding two seasons. The results from the first two seasons are presented separately from the latter three throughout this bulletin. The 1958 and 1959 treatments are given W designations. The other treatments are given I designations.

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[2]Numbers in parentheses refer to Literature Cited.

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Land was prepared for irrigation and seeding by leveling with an Eversman land leveler and conventional tillage equipment. Irrigation water was applied through gated aluminum pipe. The amounts of water applied were metered with a Hersey-Sparling water meter coupled in the line. Row spacing was 28 inches and plant population was 64,000 plants per acre after thinning. The plots were 61 feet long and 9 rows wide. Nitrogen fertilizer was applied each year as anhydrous ammonia. Plant height measurements were made just prior to harvest. All studies were laid out in four replications. The plots were bordered such that all water applied, rainfall and irrigation, was confined to the plots.

At harvest, weight of grain from the various harvest areas was recorded. Yield and test weight of grain were calculated. Representative samples from each plot were ground for nitrogen analysis. Nitrogen determinations followed the Kjeldahl method.

Rainfall, evaporation and wind data for the 5 years are listed in Appendix Table 6.

1958-1959

Water treatments are listed in Table 1. All plots were given a preplant irrigation. In 1958, the preplant irrigation was a 3-inch application of water, in 1959 it was a 4-inch application. Treatments W-3, W-4, and W-5 approximate the conditions of maintaining soil moisture at levels above 25, 50, and 75 percent of the total possible available moisture capacity, respectively. Available moisture levels were approximated by the interval between the ⅓ atmosphere and the 15 atmosphere tension

Table 1. Schedule for application of irrigation water, 1958 and 1959 All plots received a preplant irrigation.

	Time of Irrigation (growth stage)			
Treatment	8-inch	boot	dough	other
W-1	x	-	-	
W-2	x	x	-	
W-3	x	-	-	Irrigate every 14 days after 8-inch stage.
W-4	x	-	-	Irrigate every 7 or 8 days after 8-inch stage
W-5	x	-	-	Irrigate every 3 or 4 days after 8-inch stage
W-6*	-	x	-	
W-7*	x	x	x	

*These treatments were not included in the 1958 study.

moisture percentages. Unless otherwise noted, irrigation was applied at 4-inch rates. Plots were irrigated when at least half of the plants reached the indicated stage in Table 1. A soil sampling procedure aided in orienting the W-3, W-4 and W-5 treatments toward their respective available water levels. The plots were harvested by hand. Heads were threshed in a plot thresher.

Cultural data for the 1958 study are listed in Table 2. The harvest area for each plot was a block 4 rows in width by 19 feet in length.

Cultural data for the 1959 study are shown in Table 3. Water treatments consisted of the seven applications listed in Table 1. The planting of June 11 resulted in an inadequate stand. The final planting was accomplished July 8. A sprinkler irrigation (July 11) was needed to insure uniform emergence and stand. The harvest area for each plot was a block 4 rows wide and 6 feet long.

1960, 1961 and 1962

At the beginning of this period, the study was redesigned to permit closer evaluation of watering at various growth stages of the crop. Table 4 indicates the design followed. A preplant irrigation was applied in years where such was feasible.

Table 2. Cultural data for the 1958 study.

Land treatment and fertilization (ammonia)	May 31; 80 pounds nitrogen/acre
Preplant irrigation	June 11; 3-inch
Planting	June 14
8-inch stage	July 17
Boot stage	August 7
Dough stage	August 30 (approx.)
Frost	October 22; 29° F
Harvest	October 30

Differential irrigation dates and amounts (inches).

	Date															
	7-17	7-23	7-28	7-29	7-30	8-4	8-7	8-8	8-11	8-12	8-14	8-19	8-26	8-30	9-2	9-13
W-1	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W-2	4	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-
W-3	4	-	4	-	-	-	4	-	-	-	4	-	-	-	4	-
W-4	4	4	-	-	4	4	-	4	-	4	-	4	4	-	4	-
W-5	4	4	-	4	-	4	4	-	4	-	4	4	4	4	4	4

Table 3. Cultural data for the 1959 study.

Preplant irrigation	May 23; 4-inch
Land treatment & fertilization (ammonia)	June 4; 80 lb. nitrogen/acre
Planting	June 11
Corrugation and irrigation	June 30; 4-inch
Replanting	July 8
Irrigation (for germination)	July 11; 3-inch sprinkle
8-inch stage	Aug. 14
Boot stage	Aug. 31
Dough stage	Sept. 21
Frost	Oct. 27; 26° F.
Harvest	Nov. 4

Differential irrigation dates and amounts (inches)

	Date										
	8-14	8-22	8-29	8-31	9-2	9-7	9-9	9-15	9-19	9-21	9-22
W-1	4	-	-	-	-	-	-	-	-	-	-
W-2	4	-	-	4	-	-	-	-	-	-	-
W-3	4	-	4	-	-	-	-	-	4	-	-
W-4	4	4	4	-	-	4	-	4	-	-	4
W-5	4	4	4	-	4	-	4	4	-	-	4
W-6	-	-	-	4	-	-	-	-	-	-	-
W-7	4	-	-	4	-	-	-	-	-	4	-

Table 4. Schedule for application of irrigation water, 1960, 1961 and 1962.

	Time of Irrigation (growth stage)			
Treatment	7-inch	boot	heading	dough
I-1	x	x	x	x
I-2	x	x	x	-
I-3	x	-	x	-
I-4	-	x	x	x
I-5	-	x	x	-
I-6	-	x	-	x
I-7	-	x	-	-

Plots for this period were harvested with a combine harvester. The harvest area was the three center rows 50 feet long. The plots were 9 rows wide. The stand was adjusted to 64,000 plants per acre rate, usually in mid-July. Any measurements of height reported were made just prior to harvest.

Cultural data for the 1960 study are listed in Table 5. Rains early in the season delayed the planting date to June 18. The 7-inch stage irrigation was not practical due to rains in July. This made treatments I-1 and I-4 identical as well as I-2 and I-5. The first killing frost was Oct. 31, but late season rains delayed harvest until Nov. 15.

Cultural data for the 1961 study are listed in Table 6. The treatments were modified so that a plot scheduled for irrigation was not to stress before the next growth phase was reached. Thus, in a year of high evaporative demand a plot scheduled for irrigation at the beginning of the 7-inch stage might receive additional waterings before the boot stage. This change in procedure seemed necessary in order to more clearly

Table 5. Cultural data for the 1960 study.

Preplant irrigation	May 14, 4-inch
Fertilization (ammonia)	June 2, 80 lb. nitrogen/acre
Preplant irrigation	June 5, 4-inch
Planting	June 18
7-inch stage	July 25 & 26
Thinning	July 18
Boot stage	Aug. 2
Heading stage	Aug. 18
Dough stage	Sept. 8
Frost	Oct. 31, 29° F.
Harvest	Nov. 15

Differential irrigation dates and amounts (inches)

	Date		
	8-2	8-18	9-8
I-1	4	6	6
I-2	4	6	-
I-3	-	6	-
I-4	4	6	6
I-5	4	6	-
I-6	4	-	6
I-7	4	-	-

Table 6. Cultural data for the 1961 study.

Preplant irrigation	none
Land treatment & fertilization (ammonia)	June 10, 100 lb. nitrogen/acre
Planting	June 17
Irrigation (for stand uniformity)	July 1; 2.4-inch
7-inch stage	July 19
Boot stage	August 14
Heading stage	August 25
Dough stage	September 4
Frost	Nov. 3, 22° F. (31° Sept. 25)
Harvest	Dec. 8

Differential irrigation dates and amounts (inches)

	Date					
	7-19	8-1	8-14	8-25	8-31	9-4
I-1	3	3	-	3	-	-
I-2	3	3	-	3	-	-
I-3	3	3	-	3	-	-
I-4	-	-	3	-	3	-
I-5	-	-	3	-	3	-
I-6	-	-	3	-	-	3
I-7	-	-	3	-	-	-

Table 7. Cultural data for the 1962 study.

Preplant irrigation	April 25 and May 9, 4-inch each date
Fertilization (ammonia)	May 20; 100 lb. nitrogen/acre
Planting	May 29
7-inch stage	July 6
Boot stage	Aug. 8
Heading stage	Aug. 22
Dough stage	Aug. 30
Harvest	Oct. 12
Frost	Oct. 29; 29° F.

Differential irrigation dates and amounts (inches).

	Date					
	7-6	7-23	8-8	8-22	8-30	9-7
I-1	2	3.5	--	3.5	--	3.5
I-2	2	3.5	--	3.5	--	--
I-3	2	3.5	--	3.5	--	--
I-4	-	--	3.5	3.5	--	3.5
I-5	-	--	3.5	3.5	--	--
I-6	-	--	3.5	--	3.5	--
I-7	-	--	3.5	--	--	--

delineate any critical stages of plant growth for soil moisture. Note that the fertilization rate was increased to 100 pounds of nitrogen per acre.

Cultural data for the 1962 study are listed in Table 7. The modified irrigation treatments of 1961 were employed for the 1962 study.

Results

The experimental layouts in this study were designed so that the principal results might be analyzed statistically and thus be assigned a degree of confidence. Range tests were applied to most of the means reported and the results of the range tests are noted in most of the following tables of results. Means considered different at the 95 percent level of confidence will not have the same letter following in the tables. All range comparisons apply to the given year, i.e., no comparisons between years are valid for the range tests. In some cases the tests were applied at the 90 percent level of confidence, but these are not presented in the tables (only referred to in the discussion).

1958-1959

Yields for the 1958 and 1959 studies are shown in Table 8. In 1958, highest yields were on plots in which soil water content was maintained above the 50 percent available point (W-4). The yields for W-3, W-4 and W-5 should not be regarded as different, according to statistical analysis. These treatments represent the comparison between 25, 50 and 75 percent available soil moisture capacity.

Table 8. Yield of grain sorghum as influenced by timing of irrigation, 1958 and 1959.

Treatment	Average yield (pounds per acre)	
	1958	1959
W-1	3040 B	1690 B
W-2	4730 A B	3000 A
W-3	5650 A	3220 A
W-4	5860 A	2840 A
W-5	5340 A	2880 A
W-6	----	2720 A
W-7	----	2880 A

In 1959, the W-1 treatment was significantly lower than the others; no other differences were considered significant. All other treatments received water at the boot stage, which appeared critical for this year. The W-1 treatment appeared drouthy through September and October. Variability was high in the 1959 study; the coefficient of variation was 19 percent.

The effect of irrigation treatment on test weight of the grain is shown in Table 9. Test weight appears to be unaffected by the various irrigation treatments, except for a possible lowering for the W-1 treatment.

The effect of irrigation treatment on the nitrogen content of the grain is shown in Table 10. Nitrogen content seems to follow an inverse relation with the amount of water applied.

The effect of irrigation treatment on plant height is shown in Table 11. Plant height appears to bear a direct relationship to amount of water applied. It was noted that the number of heads per plot was greatest for the W-1 plots due to a great number of sucker heads.

1960, 1961 and 1962

Although the studies for these years were designed in accordance with Table 4, these irrigation schedules could not be strictly followed due to weather conditions. Consequently, some of the differences in timing called for in Table 4 were not attainable and therefore some of the seven treatments indicated were treated alike. This is seen in Tables

Table 9. Test weight of grain sorghum as influenced by timing of irrigation, 1958 and 1959.

Treatment	Average Test Weight (pounds per bushel) 1958	1959
W-1	52.3 A	46.0 A
W-2	56.8 A	48.3 A
W-3	57.0 A	50.6 A
W-4	56.8 A	49.8 A
W-5	56.5 A	49.0 A
W-6	---	47.9 A
W-7	---	49.1 A

Table 10. Nitrogen content of grain sorghum as influenced by timing of irrigation, 1958 and 1959.

Treatment	Nitrogen in Grain (percent) 1958	1959
W-1	2.21 A	1.97 A
W-2	2.05 B	1.73 C D
W-3	1.79 C	1.68 D
W-4	1.68 C D	1.69 D
W-5	1.60 D	1.65 D
W-6	---	1.87 A B
W-7	---	1.77 B C

Table 11. Height of grain sorghum plants at harvest as influenced by timing of irrigation, 1958 and 1959.

Treatment	Average Height (inches) 1958	1959*
W-1	33.1 C	39.0
W-2	41.8 B	45.1
W-3	43.8 A B	44.8
W-4	44.8 A	46.2
W-5	45.1 A	46.2
W-6	---	42.8
W-7	---	42.8

*The 1959 plant height data were not compared statistically.

5, 6 and 7. In the analyses of the results, treatments were pooled and the analyses of variance were modified accordingly. In 1960, I-1 and I-4 were treated alike and are herein referred to as I-1&4. The same was true for I-2 and I-5, called I-2&5. For 1961, treatments were I-1,2&3, I-4&5, I-6 and I-6. In 1962, I-2 and I-3 were treated alike, herein called I-2&3.

Table 12 shows yield results for 1960, 1961 and 1962. Considering 1960, yields from the I-7 treatment which received the most severe moisture treatment appear to be different from the first two treatments. However, 30 to 50 percent levels would have to be accepted for the differences to be significant.

On the assumption that a correction for number of heads per plot would make yields more reliable, head counts were made in 1960 and 1961. No significant differences were observed either year. No improvements in yield data were obtained by making adjustments to common stand. The mean stand for 1960 was 113 heads per 50-foot row. The figure for 1961 was 128 heads per 50-foot row.

The data from 1962 were the most difficult to explain, probably because of the even spacing of rains in the summer months. Late irrigation appeared to be beneficial, as is indicated by comparing I-1, I-4 and I-6 with the remainder of the treatments. When comparing treatments I-1 with I-4 and I-2 & 3 with I-5 it was found that only a small amount of response was gained by adding water up to the boot stage. All treatments received water between boot and heading so no comparison can be made for the possible effect of drouth in this period.

Table 12. Yield of grain sorghum as influenced by timing of irrigation, 1960, 1961 and 1962.

Treatment	Yield (pounds per acre)
1960	
I-1 & 4	5180 A
I-2 & 5	5890 A
I-3	5640 A
I-6	5080 A
I-7	5390 A
1961	
I-1, 2 & 3	5870 A
I-4 & 5	4800 B
I-6	4340 B
I-7	4270 B
1962	
I-1	5016 A B
I-2 & 3	4667 B
I-4	4928 A B
I-5	4792 B
I-6	5190 A
I-7	4829 A B

Results of nitrogen analyses are presented in Table 13. These data for 1960 and 1961 show a definite trend for the nitrogen content to increase as the water stress increases. The 1962 data does not contain significant differences, but signs of this same trend are in evidence.

The results of the measurements on test weight are shown in Table 14.

Irrigation timing had an effect on test weight in 1960 and 1962. Some of the differences noted in 1961 were significant, 95 percent confidence.

The results of the measurements on plant height are shown in Table 15.

Discussion

The principal importance of this study is derived from the examination of results over a period of years. One can examine the results over a spectrum of climatic conditions. However, some of the results of individual years are peculiar and need individual analysis before the studies are considered as a whole.

Table 13. Nitrogen content of the sorghum grain as influenced by timing of irrigation, 1960, 1961 and 1962.

Treatment	Nitrogen in Grain (Percent)
1960	
I-1 & 4	1.67 A B
I-2 & 5	1.54 B
I-3	1.67 A B
I-6	1.76 A
I-7	1.72 A B
1961	
I-1, 2 & 3	1.86 D
I-4 & 5	2.13 B
I-6	2.01 C
I-7	2.33 A
1962	
I-1	1.37 A
I-2 & 3	1.38 A
I-4	1.45 A
I-5	1.49 A
I-6	1.45 A
I-7	1.43 A

Table 14. Test weight of grain sorghum as influenced by timing of irrigation, 1960, 1961, and 1962.

Treatment	Test weight (pounds per bushel)
	1960
I-1 & 4	57.0 A
I-2 & 5	57.2 A
I-3	56.7 A
I-6	56.9 A
I-7	56.9 A
	1961
I-1, 2 & 3	58.1 A
I-4 & 5	57.3 B C
I-6	57.0 C
I-7	57.5 B
	1962
I-1	57.8 A
I-2 & 3	58.0 A
I-4	57.8 A
I-5	57.3 A
I-6	57.5 A
I-7	57.3 A

Table 15. Height of grain sorghum plants at harvest as influenced by timing of irrigation, 1960 and 1961.*

Treatment	Height (inches)
	1960
I-1 & 4	43.1 A
I-2 & 5	43.4 A
I-3	39.2 B
I-6	40.2 B
I-7	40.9 B
	1961
I-1, 2 & 3	41.9 A
I-4 & 5	37.6 B
I-6	36.5 B
I-7	37.0 B

*No data for 1962
The wetter treatments show definite tendency for greatest height.

1958 and 1959

Effect of Irrigation on Yield

In 1958, the yields of the higher water rates held at a satisfactory level, but in 1959 yields were low due to late planting (Table 8). Data from both years indicate that yields from treatments W-3, W-4 and W-5 were not affected by the differences in water content of the soil brought about by holding the soil moisture condition in the top foot above 25, 50 and 75 percent available capacity, respectively. These comparisons were tested statistically at the 95 percent level of confidence (as were all comparisons reported in this series of studies, unless otherwise noted).

The principal difference in yield in 1958 and 1959 appears to be caused by the one factor not common to W-1 and the other treatments, that is, irrigation at the boot stage of plant development. The plants were preirrigated, providing a moisture reservoir against drought effects later in the season, but preirrigation was not used as a variable. The factor of early season moisture is important to get the plants established at an early date, the value of this is not questioned and is even evidenced in 1959 despite the late planting. Note that there is no evidence that the application of water every 3 or 4 days retarded growth, even though no great benefit of frequent irrigation was noted. Likewise, irrigation at the milk stage seems to cause no effect (compare W-2 and W-7).

It should be noted that while the yield of no two treatments are numerically the same, no reason can be offered as to their difference, except for the statement on W-1 mentioned previously. This does not guarantee that the other treatment results are not different but that they were not found to be so in this study with 95 percent confidence. This could be for two reasons: 1) there were no other differences, 2) the experimental material was too variable to make statements with the desired confidence.

Test Weight

Test weight appears constant over the moisture treatments (Table 9). It may be coincidental that the W-1 treatment was low each of the two years. Test weights were much lower in 1959 than 1958, but this factor alone is not enough to account for the low yields in 1959.

The tendency of low test weight on the W-1 in 1958 may be a reflection of the fact that these plots had a higher proportion of sucker heads, a condition brought on after the large rain in August. Prior to this period, the central shoot had been stunted by lack of water, despite the five inches of rain in July. The grain from W-1 appeared shriveled at harvest.

Nitrogen Content

Despite the level of variability in the 1958-59 studies, the data on nitrogen content of the grain give a clear picture of a relation between water treatment and nitrogen. The nitrogen content increases as the moisture decreases.

Percent nitrogen is plotted against inches of water applied before cessation of vegetative growth in Figure 1 and is plotted against yield in Figure 3. In Figure 1, cessation of vegetative growth is taken to mean the period of dough stage. Percent nitrogen effects will be discussed later, covering all years concurrently.

1960, 1961 and 1962

The data of 1960, Tables 12, 13, and 14, affords several comparisons of interest; 1) effect of irrigation at drouth stage by comparing I-1 & 4 with I-2 & 5 and comparing I-6 with I-7; here no evidence of a difference in favor of late irrigation is noted, 2) effect of irrigation at the boot stage by comparing I-3 with I-2 & 5; one sees no confident evidence of difference but possibly a tendency for boot irrigation to help, 3) effect of irrigation at heading by comparing I-1 & 4 with I-6; numerically, a difference appears to exist in favor of irrigation at heading, at the unacceptable level of 30 percent confidence.

Due to the wet season, differential treatments of irrigation were not started until August 2. All treatments, except I-3, were watered on this date. On August 18 all plots except I-6 and I-7 were watered. The first eight days of August were hot followed by three unseasonably cool days. August 16 and 17 were hot. The next irrigation came on September 8 when treatments I-1 and I-4 and I-6 received water. Any differences expected from this watering were probably erased by a 2-inch rain on September 9. A 2-inch rain fell September 23. The data seem to suggest that the irrigation of August 18 was of benefit. A gain of not more than one or two hundred pounds of grain per acre could confidently be claimed in view of statistical confidence.

Irrigation data of 1961 suggest that the need for irrigation just prior to the boot stage is critical. This is evidenced by comparing I-1, 2 & 3 to the other treatments and this is the only difference regarded as significant. There is no evidence that the irrigation at the dough stage was beneficial (compare I-6 with I-7). It would be fair to speculate on treatments I-6 and I-7 that the damage was already done at the time of irrigation and no amount of water would save the situation.

A more valid comparison for evaluation of the irrigation would have been to irrigate I-1 at the dough stage, as set forth in the original plan. Note that I-1, I-4 and I-6 were scheduled for the late irrigation but the latter two did not receive the water. This season the waterings at heading carried the plants through maturity. Note that the time lapse between heading and dough was only 10 days. Wind and evaporation conditions were not severe during this period. Any water added to plots in I-1 and I-4 at this time would have been excessive. With the exception of August 31, (96° maximum temperature, 375 miles of wind and .51 inch of evaporation) severe conditions did not prevail until the five-day period September 16-20, when wind and evaporation were high but temperatures moderate. (See Appendix Table 6)

Plots in I-4 & 5 were scheduled for water during the heading stage but waterings at the boot stage carried till the irrigation at August 31. Allowing for effect of the rains around the boot stage one notes that the treatment I-1, 2 & 3 was watered amply throughout the entire season, with an unknown amount of drying out near the end of the season. The low temperature on September 25 would tend to reduce soil drying and may have caused some damage to leaves.

Effects of Irrigation on Yield

The principal differences in yield noted in 1962 are between I-2 & 3 and I-5 compared to I-6. Yields from I-2 & 3 and I-5 cannot be confidently considered different. This implies that the effect of irrigations on July 6 and July 23 applied to I-2 & 3 were masked by the numerous small rains in July, and the effect of the large rains in June, namely June 26, carried the nonirrigated treatments for an extended period. Hence, the difference noted between I-2 & 3 and I-5 compared with I-6 is attributed to the late irrigation applied to I-6 on August 6, the beginning of the soft dough stage. Note that no comparison of treatments would lead one to believe that the irrigations of July or early August caused significant differences in yield, a result not consistent with past experience. This will be further discussed later.

Differences due to other late waterings in 1962 are significant at between 90 and 95 percent confidence. I-6 would differ from I-7 and here the comparison is clear: the August 30 watering is the only difference in treatment. I-1 differs from I-2 & 3 if one is willing to accept the 90 percent level. The trend in these comparisons is clear. Late watering appeared to be of benefit in 1962. Note that I-4 does not appear to differ from I-5, the treatments differed by the late watering on I-4. Here it is suggested that the two waterings in August carried the plants into the dough stage with adequate water supply in the soil.

The tendency for a rain or irrigation to carry plants for extended periods was noted during the course of the 1962 study. Notes in the field books indicated that plots which were not allowed to stress before the boot stage did not stress prior to the heading stage; plots that were not allowed to stress before the heading stage did not stress prior to the soft dough stage. Considering the experimental plan, this would tend to make I-6 resemble I-4, and I-7 resemble I-5. As expected, statistical analysis reveals that these cannot be considered different, even at the 90 percent level of confidence. In effect, due to irrigation similarity (I-2 being identical to I-3) and patterns of rainfall and of low evaporative demand, one might consider that the 1962 study had only four treatments: I-1, I-2&3, I-4&6, and I-5&7.

With the rains of June and July smoothing out any expected effect of irrigation just prior to the boot stage, one might ask: why the favorable response to the late irrigation? Perhaps this favorable response is due to the uniformity of water application through the season prior to the dough stage. If the rooting habit of the plants were confined to regions abnormally near the soil surface, any drying trend at the latter part of the season might cause a plant stress. The only significant August rains came the first (1.91 inches) and the 13th (2.28 inches). Between these rains were two consecutive days of 106° temperature with 443 miles of wind. Between August 13 and 31, were 10 days of 94° or higher with high wind and high evaporation. These conditions are more severe than for the comparable period in 1961, when only two days of over 94° were recorded with less wind and lower evaporation. The figures are similar to the 1960 records except the maximum temperatures for 1960 were lower. Ten days in this same period in August were over 94° in 1960.

The overall effect in 1961 was to favor the irrigation prior to boot since the months of June and July were dry. The 1960 data did not show response to irrigation despite the drying conditions because the months of June and July had over 7 inches of rainfall. A two-inch rain followed the dough stage irrigation in Sept. 1960. In 1960, treatments I-6 and I-7 had opportunity for greatest moisture stress. As it turned out, they did yield the lowest but not enough to be called significant at reasonable levels of certainty.

In considering the yield data for the five years, the effect of adequate water present at the period preceding the boot stage dominates the results. Other irrigation patterns studied show less effect. Whenever possible, a preplant irrigation was applied. This water was held in the profile and was available to the plant later in the season. This water no doubt helped carry the plants over periods when no irrigation was scheduled and tended to smooth the spread in yield. The only effect of the late season watering was noted in 1962 when frequent rainfall in June and July carried the plants to the severe drying conditions of August. Possibly these plants were rooted closer to the surface and were not able to adequately use the water in the second to fourth foot of the soil profile; hence, an irrigation response at the soft dough stage was found.

Conditions in 1962 were similar to 1960 but no response to the late irrigation was noted, possibly because of a two-inch rain the day following the late irrigation. The data of Jensen and Sletten (1), obtained in 1956, indicate response to a late irrigation. However, irrigation timing and period of high atmospheric moisture demand were confounded because the growth stages for the various irrigation treatments occurred at different dates. Their data showed the irrigations prior to the boot stage gave highest yield.

Test Weight

Test weight was recorded each year. No effect of irrigation timing on test weight was apparent (Tables 9 and 16). Data in 1959 appeared to differ from the other years, no doubt due to the short growing season that year. Differences of small magnitude were noted in 1961.

Plant Height

Plant heights were not measured in 1962 but data from the other four years indicates that height at harvest appears to vary in the same manner as yield of grain (Table 15). The more water available during the period just preceding the boot stage, the higher the plants. Late waterings appear to have no effect on plant height.

Nitrogen Content

Percent nitrogen of grain appears to vary markedly with irrigation treatment. In 1958 and 1959 (Figure 1) the trend was for the dryer treatments to have the highest percent nitrogen, although one might suspect that the effect noted might be due to an inverse effect with yield.

In considering all the data in Tables 10 and 13, no clear cut effect relating nitrogen percentage to water timing is evident.

In 1961 the late watering gives a decrease (comparing I-6 and I-7) but no other year shows significant effect of late irrigation. The ideal comparison for this effect might be I-1 with I-2 where one could avoid the possibility of early drought having done irreparable damage before the late irrigation. However, this comparison is possible only for the 1962 data and no difference was noted. The comparison of the W-2 and W-7 data from 1959 should afford a similar comparison, and again, no difference.

The data for all five years is shown in Figure 1. Here data are plotted against the total amount of water added including rainfall, prior to the time vegetative growth stopped, i.e., in the late dough stage. The points for W-4 and W-5 are omitted for the years of 1958 and 1959 since there was no recorded close estimate of the date vegetative growth was effectively terminated, and with the frequent watering, the amount of

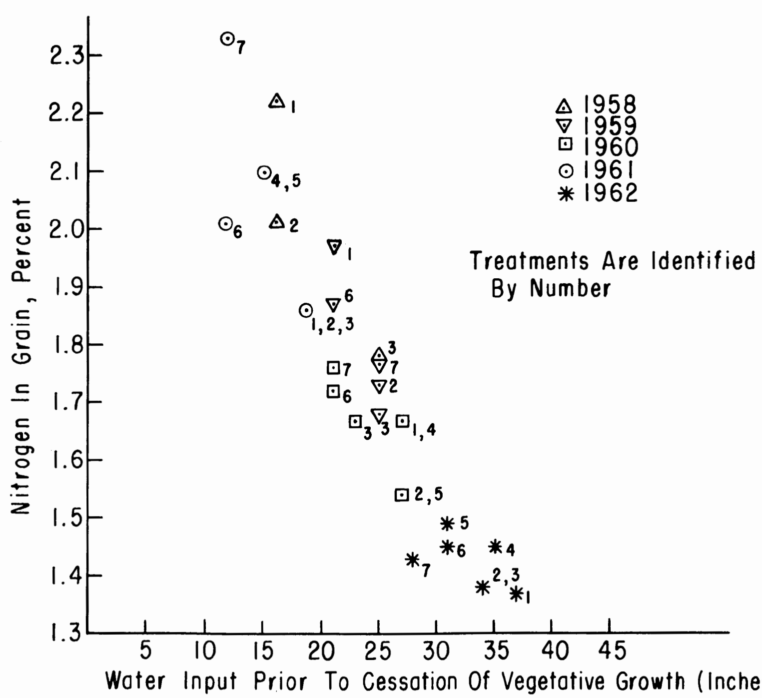

Figure 1. The effect of irrigation water applied during the vegetative growth upon the nitrogen content of the grain.

water added prior to cessation of vegetative growth is uncertain. This limitation does not occur in the remainder of the data. A close linear relationship is seen to exist between percent nitrogen and this added water. That this percentage is related more to the total amount of water added than to the timing might suggest an effect due either to leaching or to change in soil environment and resultant effect on soil microorganisms.

Since the nitrogen is added in the form of ammonia, anything which affects the nitrifying organisms might affect the nitrogen percentage in the grain. The observed relationship in Figure 1 might be due to effect of water on yield reflected in the percent nitrogen. For comparison, Figure 2 shows the relationship between yield and water added during vegetative growth, and Figure 3 shows the effect of yield on percent nitrogen in the grain. Some of the years show definite effect of one variable on the other but there is certainly no effect which follows true for all five years as was seen in Figure 1. Percent nitrogen times yield is yield of nitrogen or nitrogen removed from the plots. This is shown in Figure 4. Again some years show a trend within the year but no effect bridging all years is noted. Data from this study are too insufficient to explain this phenomenon.

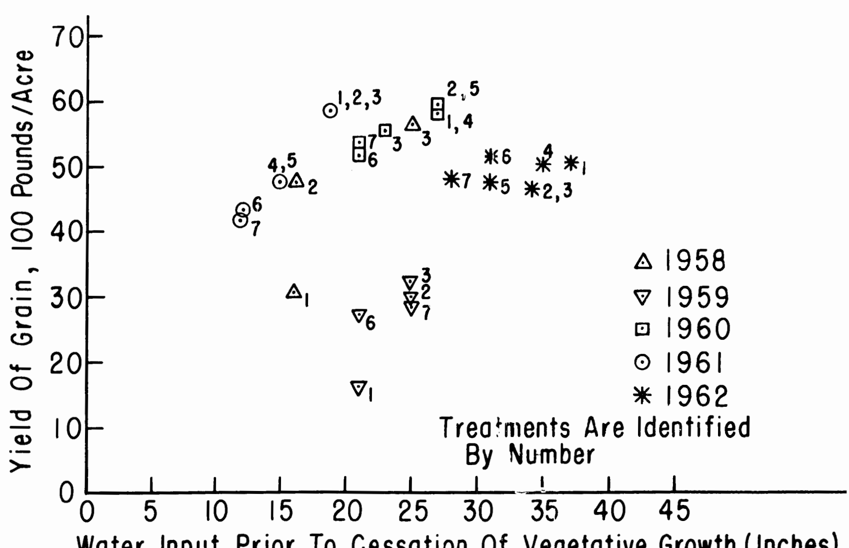

Figure 2. The effect of irrigation water applied during the vegetative growth upon the yield of the grain.

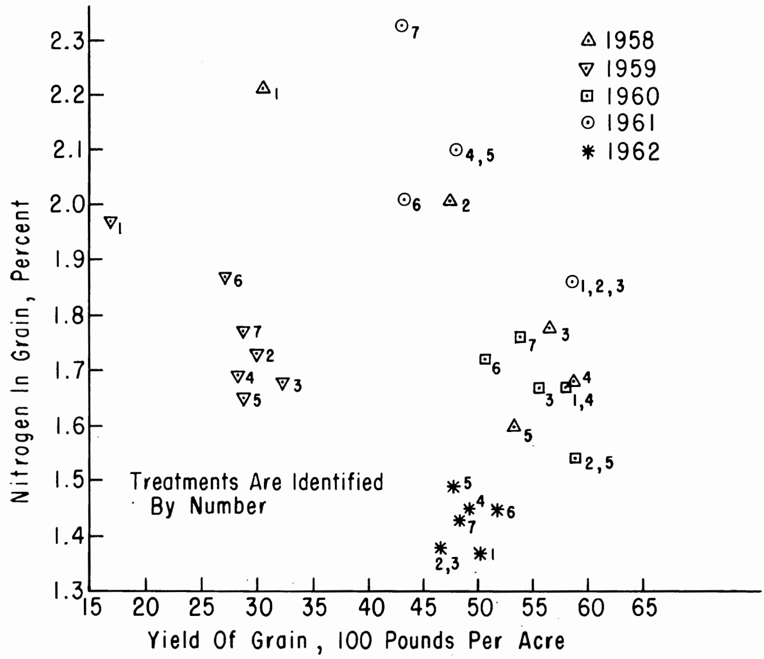

Figure 3. The effect of yield of grain on the nitrogen content of the grain.

Water Use Efficiency

The matter of water use efficiency has attracted interest in the past and deserves some comment here. This efficiency is usually defined as the ratio of useable dry matter produced (grain in the case of these studies) to the amount of water which passed from soil to plant, i.e., that water going to carbohydrate production in the plant and that going to transpiration. Since it was not possible to make detailed soil moisture measurements during the study, the best estimate of water use during the study is that water which fell as rain plus that water which was added by irrigation. This assumes that the water left in the soil at the end of the season is the same as that present in the soil at the start of the season.

Viets (2) has given the matter of efficiency extensive consideration and points out that the denominator of the efficiency ratio cannot be completely controlled. In general, field crops will use a minimum amount of water as determined by environmental conditions. At the

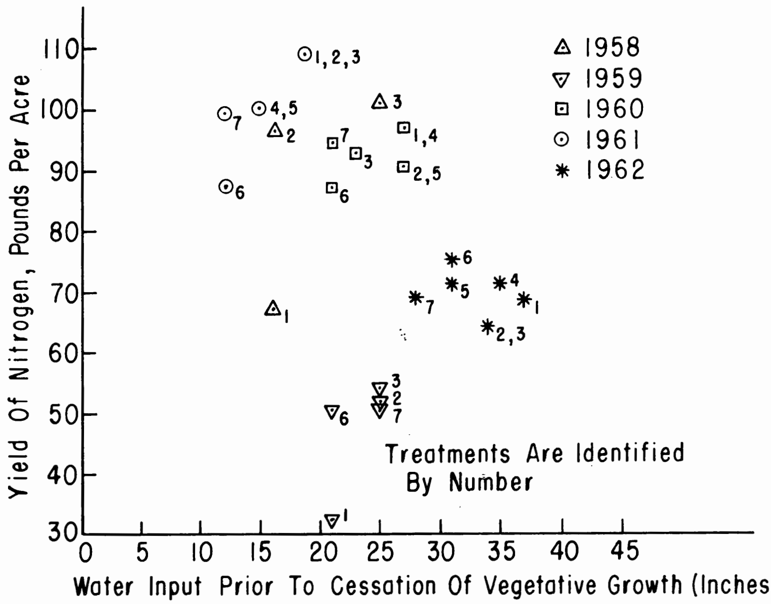

Figure 4. The effect of irrigation water applied during the vegetative growth upon the yield of nitrogen.

present no practical means is known by which to reduce this minimum amount of water and by this means increase efficiency. The numerator of this ratio is dependent upon water available as well as fertility of the soil. One does not desire to maximize this ratio by maximizing the numerator since this leads to uneconomical yields. Hence, the utility of maximum water use efficiency concept is limited. Since all water taken by the plant is figured in the efficiency, the efficiency can be decreased by natural rainfall which occurs at times when water may be already present in the soil in adequate amounts.

The efficiency will be increased in years when only that water needed by plants and only in quantities useable and only at times needed are added to the soil. The year 1961 is an example. Treatment I-6 yielded 4340 pounds of grain per acre with 10 inches of water estimated as being consumed by the plants. Efficiency here is 434 pounds of grain per acre per inch of water. The figure for I-1, 2 & 3 would be 293 pounds of grain per inch of water, still a respectable figure. While efficiency appears to decrease, the additional 7 inches of water on I-1, 2, 3 produced 1530 pounds of grain per acre.

In view of the foregoing one might question the value of the concept of water use efficiency, and the foregoing analysis considered only some of the vagaries of the denominator. The numerator is affected by variety as well as fertility level. Evidence exists that had one of the adapted hybrids been used in place of the variety Westland, yields might have been raised about one third with the same moisture and fertility. This would have raised the efficiency proportionately.

While water use efficiency may never be a useful guide for production, some useful information may come from research studies on efficiency. The principal purpose of this study was to learn something of the effect of timing of irrigations on yield of grain sorghum. Here one is interested in maximizing yield by varying timing without changing too much the total quantity of water applied, i.e., maximizing water use efficiency with given water inputs. Thus one could consider that this was a study of water use efficiencies.

Summary

The purpose of this work was to study effects of timing of irrigation on the production of grain sorghum. The assumption was made that, other things being equal, the minimization of total water applied is desirable, and so there are times to irrigate and times not to irrigate.

The study was conducted for five years, 1958 to 1962, at Panhandle A. & M. College, Goodwell, Oklahoma. Irrigations were timed by a pattern based on growth stages of the plants. The study was designed to reveal whether certain growth stages were critical for water application and whether other growth stages were not critical.

The results indicate that yields suffer if plants stress for water prior to and during the boot stage of development. There is indication that if the growing season starts wet and rains are frequent enough to keep the surface moist, late irrigation (dough stage) may be of value when drought occurs late in the season.

The nitrogen content of the grain seems to be influenced more by the total amount of water added during vegetative growth than by water timing

Plant height appeared to vary with favorable timing of irrigation. Timing which enhanced yield enhanced plant height.

Literature Cited

1. Jensen, M. E. and W. H. Sletten. Good irrigation management brings increased sorghum yields. *Soil and Water,* July 1957, p. 8-9.

2. Viets, F. G., Jr. Fertilizers and the efficient use of water. *Advances in Agronomy* 14:223-264. 1962 Academic Press, New York.

Appendix

Appendix Table 1. Rainfall and cultural data for 1958.

Date	May	June	July	August	September
1	--	--	.23	.96	.09
2	--	--	T	--	W-3, 4 & 5
3	.19	--	.92	--	--
4	.03	--	--	W-4 & 5	2.25
5	--	--	.59	--	.19
6	--	--	.73	--	--
7	--	--	--	W-2, 3 &5; boot stage	--
8	T	--	--	W-4	--
9	--	--	--	--	--
10	.03	--	--	--	--
11	--	3" preplant irrig.	--	W-5	--
12	.51	T	.54	W-4	--
13	1.02	--	T	--	W-5
14	--	T planted	T	W-3 & 5	.20
15	--	--	--	--	--
16	T	--	1.32	--	.31
17	.41	.07	.08 8-inch stage (All irrig.)	--	--
18	--	--	T	--	--
19	--	--	T	W-4 & 5	--
20	--	.41	.07	1.40	--
21	--	T	.21	--	--
22	--	.12	--	.03	--
23	--	.26	.14 W-4 & 5	--	T
24	.01	--	--	--	--
25	.13	--	.09	--	.11
26	--	--	.42	W-4 & 5	T
27	.14	--	.14	--	--
28	--	--	W-3	--	--
29	--	--	W-5	--	--
30	--	.17	W-4	W-5, dough stage	.02
31	fertilize	--	--	--	--
Total Rain	2.33	1.03	5.48	2.39	3.28

Period	*Rain* (inches)	*Large Rains* (inches)	*Date*
October	.10	.07	Oct. 26

Frost: Oct. 22 — 29° F.
Harvest: Oct. 30

Appendix Table 2. Rainfall and cultural data for 1959.

Date	May	June	July	August	September
1	--	--	.44	--	--
2	--	.19	--	--	W-5
3	--	T	--	--	.07
4	.19	.18 (level & fert.)	--	T	--
5	.02	T	T	--	--
6	--	--	T	.17	--
7	.82	--	--	3.86	W-4
8	.97	--	replant	T	--
9	--	--	--	--	W-5
10	--	--	--	--	--
11	--	planted	emerg. sprinkle irrig.	--	--
12	--	T	.44	--	--
13	--	--	--	--	--
14	--	--	.74	.16 8-inch stage	--
15	--	--	1.45	1.34 (W-1,2,3,4,5,&7)	W-4&5
16	--	T	.11	--	--
17	.21	T	.05	--	.11
18	--	--	--	--	--
19	--	.04	T	.02	W-3
20	T	--	T	--	--
21	--	.03	.95	.04	W-7 dough stage
22	.24	.08	--	W-4&5	W-4&5
23	preplant irrig.	.09	--	.01	.08
24	--	--	--	.06	T
25	.52	--	.11	--	--
26	.04	--	--	--	--
27	--	--	--	--	--
28	--	--	--	--	--
29	--	T	--	W-3,4&5	--
30	T	T(corrugate & water)	--	--	.49
31	--	--	--	W-2,6&7 boot stage	--
Total Rain	3.01	.61	4.29	5.66	.75

Period	*Rain* (inches)	*Large Rains* (inches)	*Date*
October	2.59	.82	Oct. 1

Freeze date: Oct. 27—26° F.
Harvest: Nov. 4

Appendix Table 3. Rainfall and cultural data for 1960.

Date	May	June	July	August	September	October
1	--	--	T	--	--	--
2	--	fertilize	--	I-1,2,4,5,6&7 boot	--	--
3	--	--	T	--	--	--
4	T	--	1.35	--	--	--
5	.23	preplant irrig.	T	--	--	--
6	--	T	.45	--	--	--
7	--	.65	.60	--	--	--
8	T	.03	.45	.09	I-1,4&6 dough	--
9	--	.15	.20	T	1.96	--
10	--	.08	--	--	--	--
11	--	1.86	--	--	--	.18
12	--	.07	--	--	--	T
13	--	.05	1.34	.09	--	.13
14	preplant irrig.	--	--	--	--	--
15	T	--	--	--	--	1.43
16	--	--	--	--	.13	.03
17	T	--	--	--	--	.37
18	--	planted	--	I-1,2,3,4,&5 heading	.24	.29
19	--	T	--	--	--	.15
20	.24	--	--	--	--	--
21	--	--	.60	T	--	--
22	--	--	--	--	--	--
23	--	--	--	--	2.33	--
24	--	--	--	--	.72	--
25	--	--	--	--	--	--
26	--	--	--	--	--	--
27	--	--	--	--	--	--
28	T	--	T	--	--	--
29	--	--	1.09	--	--	--
30	--	--	--	--	--	.32
31	--	--	--	--	--	T killing frost (29°F.)
Total Rain	.47	2.89	6.08	.18	5.56	2.90

Period	*Rain* (inches)	*Largest Rain* (inches)	*Date*
November 1-15	.01	.01	Nov. 9

Harvest Date: Nov. 15

Appendix Table 4. Rainfall and cultural data for 1961.

Date	May	June	July	August	September
1	--	--	I-1,2,3,4,5,6,7; 7-in. stage	T, I-k,2&3	--
2	--	--	1.44	.29	--
3	--	--	--	T	.01
4	.53	.12	--	--	I-6; dough
5	--	--	--	--	--
6	--	.44	--	--	--
7	--	.43	.23	--	.36
8	.35	T	1.17	--	--
9	--	--	.30	--	--
10	--	fertilization	--	T	--
11	--	--	.02	.12	.09
12	--	--	.05	.20	.19
13	--	--	T	.23	--
14	--	.30	T	I-4,5,6,&7 boot	--
15	--	.10	--	.11	Irrigation cut-off
16	.02	.08	--	.18	--
17	--	planted	--	--	--
18	--	--	--	--	--
19	--	T	7-inch; I-1,2&3	.18	.32
20	.87	T	.18	--	.03
21	T	--	.14	--	--
22	--	--	.12	--	--
23	--	--	--	--	--
24	--	--	--	--	--
25	--	.25	--	I-1,2&3 heading	--
26	--	.02	--	--	--
27	--	--	--	--	--
28	.13	--	--	--	--
29	--	--	--	--	--
30	.08	--	--	--	--
31	T	--	--	I-4&5	--
Total Rain	1.98	1.74	3.65	1.31	1.00

Period	*Rain* (inches)	*Large Rains* (inches)	Date *Large Rain*
October	2.37	.73 & 1.19	Oct. 9 and Oct. 31
November	1.04	.98	Nov. 15
December	no rain prior to harvest, Dec. 8.		

Killing frost: Nov. 3—22°F (31° Sept. 25, 29° Oct. 23)

Appendix Table 5. Rainfall and cultural data for 1962.

Date	May	June	July	August	September
Note:	preplant irrig. Apr. 25.				
1	--	1.83	--	1.91	--
2	--	.38	--	--	.35
3	--	T	--	--	--
4	--	--	.36	--	T
5	--	--	--	--	T
6	--	--	I-1,2,&3 7-inch	--	--
7	--	--	--	--	T, I-1&4
8	--	T	--	I-4,5,6&7 boot	.94
9	preplant irrig.	.49	.12	--	--
10	--	.79	--	--	--
11	--	.09	.45	--	--
12	--	--	--	--	--
13	T	--	--	2.28	irrig. cut-off
14	--	.07	--	--	.41
15	--	--	--	T	.05
16	.46	--	.02	--	.26
17	--	--	--	--	--
18	.46	.23	--	--	--
19	T	--	.22	--	--
20	fertilization	--	.08	--	.07
21	--	--	--	T	T
22	--	.34	--	I-1,2,3,4&5 heading	T
23	--	.99	I-1,2&3	--	.17
24	--	T	.18	--	.06
25	--	T	--	--	--
26	--	3.51	--	--	--
27	--	--	.09	--	--
28	T	--	.18	--	--
29	planted	--	.43	--	--
30	--	--	.13	T, I-6 soft dough	--
31	--	--	.42	.12	--
Total Rain	.92	8.72	2.68	4.31	2.31

Period	*Rain* (inches)	*Largest Rain* (inches	Date *Largest Rain*
October 1-12	.14	.14	Oct. 5

Harvest date: Oct. 12.
Earliest frost: Oct. 29—29°F.

Appendix Table 6. Selected record of temperature, wind and evaporation*, Goodwell, Oklahoma, July 15 to Sept. 20, 1958 to 1962 inclusive.

	July																	August					
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6
											1958												
Temp. max.	92	90	93	95	97	87	87	89	92	90	87	90	85	88	94	97	92	88	92	94	95	97	95
min.	66	62	68	69	68	64	59	61	64	67	64	65	62	61	62	70	66	59	66	65	68	66	67
Evaporation	.25	.55	.39	.48	.50	.22	.32	.02	.52	.35	.35	.64	.26	.32	.42	.57	.37	--	.28	.32	.68	.51	.28
Wind	165	185	191	148	171	77	84	95	200	160	117	178	88	77	183	201	82	88	88	89	165	133	91
											1959												
Temp. max.	87	86	84	85	85	89	87	93	91	91	89	87	85	94	95	94	98	98	104	103	102	101	94
min.	58	64	64	60	64	62	57	63	65	65	66	56	58	62	71	68	68	67	70	69	68	68	67
Evaporation	--	.19	.32	.30	.32	.42	.38	.37	.36	.37	.39	.52	.05	.27	.64	.33	.20	.53	.60	--	--	--	.36
Wind	106	150	13	26	103	89	54	58	84	81	62	*	52	51	140	72	64	142	231	111	109	103	124
											1960												
Temp. max.	84	92	91	85	86	85	92	86	88	95	95	98	102	99	98	92	95	96	98	100	97	98	98
min.	57	62	64	63	54	58	60	60	68	61	64	68	66	70	63	61	64	66	66	64	63	69	70
Evaporation	.34	.34	.44	.40	.24	.35	.52	.23	.34	.36	.37	.46	.56	.48	.52	.30	.49	.37	.64	.44	.39	.59	.58
Wind	94	110	81	143	47	64	169	126	48	29	51	73	143	105	88	51	120	162	149	77	36	137	175
											1961												
Temp. max.	94	98	99	102	97	95	79	80	95	97	95	95	97	98	94	94	97	93	86	93	94	98	97
min.	62	65	62	67	66	64	60	60	58	65	66	66	68	67	64	67	69	68	67	62	62	69	62
Evaporation	.31	.41	.36	.42	.80	.59	.21	.19	.53	.62	.49	.56	.53	.38	.54	.54	.52	.32	.19	.26	.50	.33	.57
Wind	48	84	63	167	119	232	143	82	153	178	189	205	223	195	222	199	207	104	98	82	78	40	113
											1962												
Temp. max.	88	87	94	94	97	93	96	100	87	79	84	79	89	84	87	83	81	80	84	93	97	98	96
min.	62	64	61	62	67	64	64	69	66	54	54	64	63	63	62	64	62	56	62	65	65	61	63
Evaporation	.46	.22	.48	.48	.64	.36	.39	.50	.21	.22	.39	.21	.35	.30	.28	.28	.21	--	.30	.40	.43	.40	.48
Wind	174	130	114	210	211	105	79	167	126	117	60	140	95	82	123	80	144	97	94	190	93	55	138

*Data taken from Climatological Data, Oklahoma, Weather Bureau, U. S. Department of Commerce, Washington, D. C. Temperatures are °F., evaporation is in inches measured in a standard Weather Bureau type pan, four feet in diameter, wind is in miles per day measured over the pan. * means amount included in following measurement. -- means no record for the date.

Appendix Table 6. (Continued.)

	August 7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
												1958													
Temp. max.	98	99	95	97	99	96	100	101	102	90	88	92	97	86	86	80	84	82	89	91	100	102	99	88	95
min.	63	64	61	61	68	64	63	65	66	62	60	62	67	63	64	63	65	55	56	61	58	59	68	66	57
Evaporation	.24	.47	.43	.29	.47	.30	.33	.41	.70	.62	.52	.25	.47	.25	.28	.33	.23	.22	.40	.38	.40	.37	.45	.46	.43
Wind	73	40	216	10	89	69	54	78	30	116	139	100	160	90	75	90	145	40	97	99	95	44	190	169	90
												1959													
Temp. max.	85	85	89	90	94	95	95	88	78	88	94	92	92	92	100	93	87	88	86	87	94	96	100	92	93
min.	64	64	65	65	64	65	69	66	65	65	63	65	67	68	67	67	65	63	64	66	65	66	65	63	53
Evaporation	--	.24	.45	.40	.50	.53	.65	.23	.09	.20	.26	.47	.45	.35	.47	.39	.26	.36	.44	.38	.42	.46	.35	.34	.40
Wind	149	22	116	98	151	171	258	201	75	84	74	141	228	167	192	166	67	119	209	170	180	157	78	109	70
												1960													
Temp. max.	99	100	78	80	83	88	94	92	90	90	90	88	93	94	92	99	97	97	97	92	98	95	90	97	97
min.	71	64	69	58	58	61	62	62	61	65	63	55	54	67	61	66	70	63	69	66	65	67	64	64	62
Evaporation	.28	.33	.25	.22	.26	.40	.39	.43	.50	.54	.37	.44	.41	.46	.36	.17	.40	.42	.53	.41	.50	.48	.17	.46	--
Wind	114	102	109	84	67	99	137	245	156	170	298	148	71	152	147	164	208	134	178	113	328	116	82	143	149
												1961													
Temp. max.	92	--	101	100	91	86	79	84	89	92	92	93	81	83	89	87	86	92	93	88	92	95	92	91	96
min.	60	--	60	60	59	59	60	60	66	66	64	64	63	58	64	61	50	59	62	60	62	61	58	61	65
Evaporation	.33	*	.84	.34	.31	.25	.23	.18	.30	.45	.36	.26	.10	.23	.27	.32	.25	.31	.57	.46	.48	.46	.41	.48	.51
Wind	85	*	248	78	99	56	103	55	91	136	146	132	129	78	137	134	67	190	213	173	187	136	100	168	375
												1962													
Temp. max.	94	99	106	106	90	97	85	90	94	90	100	100	97	94	91	95	100	89	89	95	98	93	100	91	87
min.	62	68	72	64	75	60	58	65	66	61	63	65	63	63	66	64	68	60	52	56	59	66	62	67	60
Evaporation	.30	.37	--	--	.35	.14	--	--	.34	.37	.55	*	*	.68	*	.63	.54	.47	.27	.51	.51	.57	--	.36	.29
Wind	50	106	196	247	87	81	132	83	99	93	180	246	206	76	157	187	197	187	86	139	126	209	69	251	163

Appendix Table 6. (Continued.)

	September 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
									1958											
Temp. max.	98	99	98	94	88	85	83	83	93	87	84	89	88	81	80	71	83	85	85	94
min.	66	70	69	66	64	65	64	66	67	63	67	64	61	68	51	54	53	49	56	56
Evaporation	.33	.94	.51	- -	.27	.22	.21	.29	.28	.27	.18	.29	.30	.41	.32	.28	.25	.34	.25	.38
Wind	173	287	221	143	144	54	78	110	161	87	85	117	212	165	73	163	132	186	65	132
									1959											
Temp. max.	89	87	82	93	102	100	96	92	84	80	81	79	80	86	90	89	86	77	93	94
min.	61	46	61	58	67	62	62	63	66	39	44	38	37	42	46	52	52	53	56	64
Evaporation	.56	.21	.38	.39	.56	.57	.55	.60	.41	.20	.32	.19	.40	.36	.43	.21	.37	.29	.61	.58
Wind	141	148	128	164	181	122	151	90	401	45	39	58	32	71	97	80	66	139	186	250
									1960											
Temp. max.	100	99	96	94	99	93	93	87	68	77	87	78	85	95	87	82	87	88	85	86
min.	66	63	62	63	61	66	65	64	54	49	51	51	55	57	65	53	55	56	56	58
Evaporation		.52	.49	.49	.51	.12	.38	.25	- -	.12	.41	.28	.33	.20	.43	.25	.26	.25	.16	.11
Wind	209	186	114	145	171	246	213	103	132	71	51	77	79	62	106	66	53	73	46	96
									1961											
Temp. max.	95	100	84	74	86	92	84	90	88	91	86	84	78	65	75	87	87	87	79	78
min.	60	62	49	36	43	61	61	61	61	62	63	58	44	43	49	51	56	56	56	55
Evaporation	.49	.44	.32	.19	.33	.40	.29	.38	.25	.29	.12	.38	.31	.28	.34	.41	.52	.52	.26	.26
Wind	95	181	265	103	81	169	176	182	179	192	113	69	266	85	100	275	264	266	284	202
									1962											
Temp. max.	89	84	93	66	68	84	80	86	71	81	95	91	92	90	85	91	84	93	78	61
min.	62	59	61	50	50	55	60	54	43	43	60	63	62	58	61	61	55	60	60	49
Evaporation	.29	.14	.25	.27	.10	.20	.13	.06	.06	.19	.26	.59	.37	.31	.20	.39	.23	.40	.32	.04
Wind	120	187	169	168	93	139	131	67	228	85	234	230	143	60	59	109	84	149	202	117

Oklahoma's Wealth in Agriculture

Agriculture is Oklahoma's number one industry. It has more capital invested and employs more people than any other industry in the state. Farms and ranches alone represent a capital investment of four billion dollars—three billion in land and bulidings, one-half billion in machinery and one-half billion in livestock.

Farm income currently amounts to more than $700,000,000 annually. The value added by manufacture of farm products adds another $130,000,000 annually.

Some 175,000 Oklahomans manage and operate its nearly 100,000 farms and ranches. Another 14,000 workers are required to keep farmers supplied with production items. Approximately 300,000 full-time employees are engaged by the firms that market and process Oklahoma farm products.

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