Evapotranspiration and Soil Moisture-Fertilizer Interrelations With Irrigated Winter Wheat in The Southern High Plains

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Evapotranspiration and Soil Moisture-Fertilizer Interrelations With Irrigated Winter Wheat in the Southern High Plains

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Irrigated and dryland winter wheat is one of the major crops produced in the High Plains of Texas. As reported by the U.S. Census of Agriculture, the acreages of irrigated wheat harvested in the High Plains in 1950, 1954, and 1959 were 133,000, 179,000 and 380,000 acres, respectively. Additional irrigated wheat is used only for grazing purposes. The major part of the irrigated winter wheat harvested in the mid-1950's was in Castro, Deaf Smith, Floyd, Hale, Parmer, and Swisher Counties. The soils in these counties consist mostly of clay loams and silty clay loams (*10*).[2] Continued expansion in irrigated wheat acreage has occurred since 1959, especially north of the Canadian River.

Rapid development of irrigation in the area was aided by ideal topography. It is not uncommon to furrow-irrigate ½-mile fields without any land smoothing.

The source of water used for irrigation is an aquifer that underlies most of the area. The total water supply is extensive, but the rate of recharge by rainfall is very small compared to the current pumping rate.

The pumping lift ranges from about 100 to 400 feet in different areas of the High Plains. The high costs of pumping and the growing awareness that very little recharge is occurring have created an interest in maximizing economic returns per unit of irrigation water and precipitation.

Dryland wheat farming in the area follows either a continuous wheat, a wheat-fallow, or a wheat-sorghum-fallow system. Yields on the wheat-fallow and the wheat-sorghum-fallow systems produced more than 10 bushels per acre about 80 percent of the time, whereas continuous wheat produced more than 10 bushels only 50 percent of the time (*1*). Average dryland yields range from 10 to 15 bushels per acre because of limited precipitation. Application of commercial fertilizer is not needed. In some years with unusually favorable moisture, yields approach 40 bushels per acre. Yields increase to 50 to 60 bushels per acre during the first few years of irrigation.

The decline in yields after several years of irrigation and the expansion of liquid fertilizer facilities in the High Plains of Texas created a need for information on irrigation and fertilizer practices. The purpose of this study was to combine moisture and fertilizer levels in an experiment to provide irrigation and fertilizer recommendations for use by irrigation farmers in the area.

STUDY AREA

Location

The experiment was conducted on the USDA Southwestern Great Plains Field Station near Bushland, Tex., 14 miles west of Amarillo (latitude 35°15′ N., elevation 3,825 feet). The station is located near the northern edge of the major irrigated wheat growing counties. The soil is representative for these counties and areas north of the Canadian River. The Canadian River bisects the High Plains in an east-west direction north of the station.

Soil

The soil on the experimental site is Pullman silty clay loam (*3,11*). Organic matter content in the 0- to 6-inch depth after several years of tillage ranges from 1.6 to about 2.1 percent, compared to a native grass site of 2.6 percent. A caliche layer ($CaCO_3$) occurs at a depth of 3.5 to 4 feet. The proportion of $CaCO_3$ by weight in the caliche layer is as high as 45 percent (*11*). The soil of a given layer is extremely uniform in physical properties and moisture-holding characteristics over extensive areas.

Volume weight determinations to a depth of 5 feet on the experimental site were made in May 1957; two 1.85- by 4-inch cores per foot of depth at four locations were used. The standard error of the mean of four cores was 0.032, or 2.1 percent of the mean volume weight. These data and soil moisture characteristics are summarized in table 1. Field capacity values given are the mean of high values measured 5 to 10 days after an irrigation when evapotranspiration rates were very low. Wilting percentages are the mean of low values measured near harvest on the drier plots. Field capacity determined in this way would not be the maximum obtainable 1 to 2 days after excessive irrigation. The data represent available water-holding capacity under normal irrigation practices when evapotranspiration rates are low.

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[1] The authors gratefully acknowledge the computer services provided by the data processing center, Texas A & M University, College Station, and the assistance of Frank O. Wood, in carrying out field operations and processing the voluminous data.

[2] Italic numbers in parentheses refer to Literature Cited, p. 17.

The rate of internal drainage by gravity on this soil is very slow. Therefore, when evapotranspiration rates are high, the effective available water-holding capacity is greater than the values given in table 1 because evapotranspiration demands can be met with water that ordinarily drains from the profile in the 5- to 10-day period after irrigation.

TABLE 1.—*Soil density and moisture-holding characteristics, Pullman silty clay loam*

Depth increment	Bulk density	Field capacity [1]	Wilting point [1]	Available water
Inches	*G./cc.*	*Percent*	*Percent*	*Inches*
0–12	1.40	25.1	12.8	2.15
12–24	1.56	23.4	12.9	1.96
24–36	1.53	21.3	12.1	1.69
36–48	1.51	20.0	12.3	1.39
48–60 [2]	1.43	20.3	13.1	1.24
60–72 [2]	[3] 1.50	19.1	14.0	.97
Total, 0–72				9.40

[1] On an oven-dry weight basis.
[2] Contains as much as 45 percent $CaCO_3$ by weight.
[3] Estimated.

Low intake rates on these soils limit the amount of irrigation water that can be applied in 16 to 24 hours during the growing season to about 4 inches. A summary of intake measurements made in an adjacent experiment with level basins and tillage practices similar to those used in this experiment is presented in table 2. A 4-inch irrigation during the growing season requires about 20 to 24 hours to be absorbed. The intake from 0 to ⅓ hour ranges from 2.4 to 2.7 inches and the intake from 0.33 to 15.33 hours averages about 1.3 inches. Intake rates are higher during the preplanting irrigations. Intake rates in large furrows or corrugations on these soils should be similar, because of rapid lateral movement in the plow layer and dense soil below the plow layer extending to a depth of about 3 feet.

The soil on the experimental site had been irrigated to a limited extent since 1949. Continuous wheat was grown on the site prior to initiating this study.

Climate

The weather in the Great Plains is noted for its great variability and rapid changes. Extreme variations in monthly rainfall, daily temperature, and windspeed are normally expected, especially during the months of March, April, and May. Annual precipitation ranges from less than 10 inches to over 30 inches. Average annual precipitation is lower in the western part. A summary of average climatic conditions and weather conditions existing during this 3-year study is presented in table 3. The probabilities of receiving various amounts of rainfall are reproduced in figure 1 (7). The pattern of precipitation is similar for much of the area, but more precipitation occurs east of Amarillo.

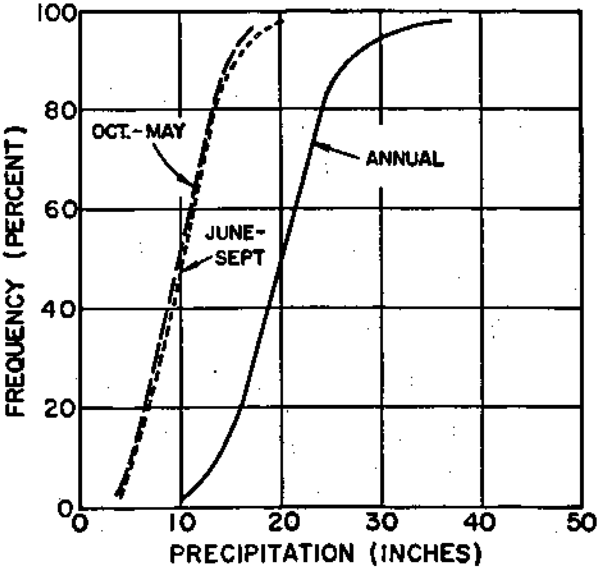

FIGURE 1.—Probability of receiving various amounts of annual, fallow period, and wheat-growing season precipitation at Amarillo, Tex.

TABLE 2.—*Average intake rates for 2 spring irrigations of winter wheat with sweep-chisel tillage used during the fallow period, Bushland, Tex.*

Year	Rates for a time interval of—									Weighted average
	0.33–0.67 hour	0.67–1.33 hours	1.33–2.00 hours	2.00–2.67 hours	2.67–3.33 hours	3.33–4.67 hours	4.67–7.33 hours	7.33–10.67 hours	10.67–15.33 hours	
	Inch/hour	*Inch/hour*	*Inch/hour*	*Inch/hour*	*Inch/hour*	*Inch/hour*	*Inch/hour*	*Inch/hour*	*Inch/hour*	*Inch/hour*
1957	0.576	0.264	0.156	0.132	0.108	0.090	0.069	0.050	0.044	0.087
1958	.624	.264	.156	.120	.084	.108	.066	.060	.043	.090

TABLE 3.—*Summary of weather data for the wheat-growing season at Bushland, Tex.*

Year	Preceding fallow period, July–September, average or total	Crop growing season										Annual [1] average or total
		October	November	December	January	February	March	April	May	June	Average or total	
	Precipitation (inches)											
1955–56	8.08	0.10	0.02	0.09	0.03	1.25	0.02	0.35	4.89	1.10	7.85	15.93
1956–57	5.33	.32	(2)	(2)	.43	.81	2.27	2.06	3.05	3.05	11.99	17.32
1957–58	6.97	2.55	1.23	.03	.86	.48	2.38	1.85	2.78	1.77	13.93	20.90
1939–61	7.03	1.87	.67	.71	.47	.44	.63	1.26	3.02	2.06	11.67	18.70
	Mean daily maximum air temperature (°F.)											
1955–56	89.3	78.5	64.3	60.5	55.9	49.2	70.0	74.9	87.8	88.7	70.1	75.0
1956–57	91.6	80.2	63.5	59.6	55.5	63.2	61.2	67.8	74.3	92.6	68.6	74.4
1957–58	90.0	69.9	54.6	62.4	52.3	52.3	48.8	66.0	81.1	88.6	64.1	70.6
1939–61	88.9	74.6	61.5	54.1	51.6	56.3	64.0	72.6	80.0	89.4	67.2	72.7
	Mean daily minimum air temperature (°F.)											
1955–56	61.2	43.0	27.1	26.0	23.4	22.2	29.4	36.0	52.3	57.0	35.2	41.8
1956–57	59.7	46.3	28.7	26.1	21.9	34.6	33.1	39.6	49.1	63.1	38.0	43.5
1957–58	59.8	44.6	31.7	27.0	24.1	26.8	28.3	39.2	52.5	57.4	36.9	42.7
1939–61	60.2	44.1	30.7	25.2	22.7	26.0	30.1	40.0	49.6	59.5	36.5	42.4
	Mean cloud cover (tenths) [3]											
1955–56	4.2	3.0	3.0	5.2	6.1	5.9	3.7	3.8	5.0	4.2	4.4	4.4
1956–57	3.3	2.8	2.3	3.3	7.5	7.8	6.7	7.0	5.9	4.3	5.3	5.3
1957–58	4.1	6.2	5.2	3.6	5.4	7.3	8.4	5.6	5.9	4.2	5.7	5.3
1955–60	3.9	4.0	3.6	4.5	5.8	6.1	5.4	5.2	5.4	4.3	4.9	4.7
	Estimated solar radiation (g. cal./cm.^{2}-day) [3]											
1955–56	566	419	324	245	270	350	519	599	606	677	446	477
1956–57	603	430	339	279	238	294	466	458	569	653	415	462
1957–58	573	321	266	274	282	307	335	517	566	661	392	438
Long-time average	583	390	305	259	274	342	451	532	589	652	422	462

See footnotes at end of table.

TABLE 3.—*Summary of weather data for the wheat-growing season at Bushland, Tex.*—Continued

Year	Preceding fallow period, July–September, average or total	Crop growing season										Annual [1] average or total
		October	November	December	January	February	March	April	May	June	Average or total	
	Pan evaporation (inches) [4]											
1955–56	30. 39	7. 28	5. 23	4. 14	3. 00	2. 10	8. 21	9. 66	11. 92	9. 95	61. 49	91. 88
1956–57	34. 45	8. 46	5. 49	4. 28	3. 91	3. 64	4. 41	5. 79	6. 37	11. 68	54. 03	88. 48
1957–58	30. 95	5. 15	2. 66	3. 80	1. 79	2. 01	1. 52	5. 29	6. 82	9. 54	38. 58	69. 53
1940–61 [5]	29. 58	6. 35	3. 77	2. 77	2. 12	2. 99	5. 69	7. 68	8. 86	10. 81	51. 04	80. 62
	Windspeed (miles/hour) [6]											
1955–56	5. 03	4. 92	5. 90	5. 81	5. 06	6. 44	7. 37	7. 12	8. 13	6. 06	6. 31	5. 99
1956–57	5. 29	5. 71	5. 32	5. 37	6. 69	6. 24	7. 63	7. 19	5. 90	6. 36	6. 27	6. 02
1957–58	4. 59	5. 68	5. 37	5. 64	4. 81	5. 99	5. 77	6. 47	5. 07	5. 91	5. 63	5. 37
1939–61	5. 87	5. 82	6. 00	6. 24	6. 50	7. 42	8. 20	8. 00	7. 25	7. 04	6. 94	6. 67
	Relative humidity (percent) [7]											
1955–56	57. 2	48. 3	46. 8	51. 7	58. 6	74. 4	42. 0	44. 6	46. 0	46. 8	50. 8	52. 4
1956–57	39. 5	42. 0	34. 9	37. 2	51. 5	57. 5	58. 7	43. 8	43. 0	39. 9	45. 3	43. 9
1957–58	53. 9	71. 9	71. 2	42. 1	53. 2	60. 1	66. 9	48. 9	45. 0	53. 9	57. 0	56. 2
1940–61	49. 1	51. 4	52. 1	56. 4	58. 2	57. 4	48. 5	46. 4	51. 2	48. 3	52. 2	51. 4

[1] Previous July through June.

[2] Trace.

[3] Amarillo, Tex.

[4] Young screened ground pan, 2 feet in diameter; 1940–53 U.S. Weather Bureau pan data converted to Young pan by a coefficient of 0.92.

[5] 11-year average for October through March.

[6] Height of anemometer, 1.75 feet.

[7] Average of 8:00 a.m., noon, and 4:30 p.m. values.

PROCEDURE

Experimental Design

The experimental design was a randomized complete block with split plots. Four replications of six soil moisture levels as main plots and six fertilizer treatments as subplots were used. Each moisture plot was included in a level basin, diked on all sides with level area dimensions of 24 by 210 feet. Depth of irrigation water applied was based on dimensions from center to center of the dikes, 27 by 212 feet. Fertilizer plots were 12 by 65 feet. The treatments were maintained on the same plots for the three seasons (farmers frequently grow wheat on the same field 3 to 5 years in succession).

Moisture Levels

A preplanting irrigation was applied each year 4 to 6 weeks before planting to wet the soil to a depth of 6 feet on all treatments. The amounts applied depended on the moisture status of each treatment. Moisture levels are described below.

Treatment No.	*Moisture level*
M_1	Preplanting irrigation only.
M_2	One 4-inch irrigation at the jointing stage in the spring.
M_3	Irrigated when the weighted mean soil moisture tension approached 9 atmospheres.
M_4	Irrigated when the weighted mean soil moisture tension approached 4 atmospheres.
M_5	Irrigated when the weighted mean soil moisture tension approached 1½ atmospheres.
M_6	Irrigations varied according to precipitation distribution during the season.

The weighted mean soil moisture tension was obtained by weighting tensions in successive quarters of the moisture depletion zone by 4, 3, 2, and 1. The weighting procedure was based on typical soil moisture extraction patterns. Soil moisture tension was measured indirectly by cured plaster of paris moisture blocks calibrated in a pressure membrane apparatus (2). Calibration consisted of placing six blocks selected at random in a special-built pressure membrane apparatus with 1 cm. of soil above and below the blocks. Individual leads for each block were used. The calibration curve was adjusted to 70° F. and used without further correction. The curing process consisted of at least two 24-hour soaking and drying cycles. The standard deviation of the resistance of individual cured blocks immersed in tap water was about 25 ohms. The curing process removed most of the drift in calibration that normally occurred in the field and some of the variability between blocks. New moisture blocks were installed each fall at depths of 4, 9, 16, 29, and 42 inches in the F_2 and F_6 fertilizer subplots of each moisture treatment. Readings were made three times a week during the spring season and less frequently in the winter.

A summary of the date and depth of irrigation water applied and the stage of growth at each irrigation is given in table 10 in the appendix. Water from a well was delivered and measured to each moisture plot by aluminum pipe and a flowmeter. A summary of precipitation by storms received during the growing season is presented in table 11 in the appendix.

Fertilizer Treatments

Nitrogen in the form of ammonium sulfate (20.6 percent N) was broadcast ahead of the furrow openers when seeding. Phosphorus (concentrated superphosphate, 45 percent P_2O_5) was placed below the seed in 1956 and with the seed in 1957 and 1958 when seeding. The rates for nitrogen and phosphorus used each season are given in table 4.

TABLE 4.—*Nitrogen and phosphorus applied at seeding for fertilizer treatments at Bushland, Tex., 1955–57*

Fertilizer treatment No.	Nitrogen		Phosphorus (45 percent P_2O_5), 1955–57
	1955	1956–57	
	Lb./acre	*Lb./acre*	*Lb./acre*
F_1	80	120	0
F_2	0	0	30
F_3	40	60	30
F_4	80	120	30
F_5	120	180	30
F_6	80	120	60

Cultural Practices

Tillage

Plots were either double-disked or sweep-plowed after harvest and chiseled during the summer to control weeds and work the stubble into the soil. In the fall, the plots were lightly smoothed with a leveler before the preplanting irrigation. A sweep-plow operated about 2 inches deep and a spike-toothed harrow were used before seeding to control volunteer growth.

Seeding and Harvesting

Plots were seeded each year to Concho wheat in rows spaced 10 inches apart. Seeding date and rate and the harvest dates are given in table 5.

TABLE 5.—*Seeding date, rate, and harvest date of wheat at Bushland, Tex., 1955–58*

Seeding date	Rate	Harvest date
	Lb./acre	
Oct. 10–12, 1955	112	June 15–19, 1956.
Oct. 11–12, 1956	112	July 1, 1957.
Oct. 8, 1957	100	June 25, 1958.

Yield Determination and Disposal of Straw

In 1956, four rows, 50 feet long, were cut, bundled, and later threshed. All straw was removed after combining the remaining portion of the plots. In 1957 and 1958, the plots were trimmed to 50-foot lengths and a self-propelled combine was used to harvest a swath 7 feet wide from each plot. After combining in 1957 and 1958, the straw and stubble were shredded and the plots chiseled to incorporate the straw into the soil, essentially returning the straw to each plot.

Evapotranspiration Determinations

Evapotranspiration (E_t) was determined from soil samples taken periodically from the F_2, F_4, and F_6 subplots of each moisture level to depths of 4 or 6 feet. Samples were taken by hand from 1955 to 1957 and by machine in 1957 and 1958 (*9*). Soil sampling sites were marked so that successive cores could be taken about 1 foot from the preceding location, moving in the same direction each time. After removing the core, all holes were filled with surface soil and tamped.

In 1955–56, the rate of E_t between sampling dates after an irrigation was projected back to the sampling date before irrigating. A different procedure was used in 1956–57 and 1957–58. Because of the low intake rates and limited depths of water applied, the rate of E_t during an irrigation period (from the date of sampling prior to an irrigation to the date of sampling after an irrigation) was calculated as follows:

$$\frac{\text{Inches}_1 + (\text{irrigation and rainfall}) - \text{inches}_2}{\text{Days between sampling dates}} = \text{inches per day}$$

where inches_1 and inches_2 represent the total water in the profile prior to and after irrigating. The depth of irrigation water applied was generally no greater and often less than the amount required to bring the soil to field capacity. Values obtained by this procedure for the irrigation period usually were somewhat larger than those obtained between sampling dates after an irrigation. This method of calculation for the irrigation period assumes that each subplot received the same depth of water and no deep percolation occurred. Small differences in intake between fertilizer subplots may have occurred because of small differences in soil moisture content. Constants used in 1955–56 for converting soil moisture percentage to inches of water per foot of depth were slightly different from those shown in table 1 because they were based on preliminary bulk density data.

Other Measurements

Samples of the wheat grain from the 36 treatments were analyzed by the Producers Quality Laboratory, Amarillo, Tex.,[3] and the Texas A. & M. Quality Laboratory, Arlington, Tex., for baking quality. Data from the Producers Quality Laboratory are reported.

Straw-grain ratios were determined for the 1955–56 crop by weighing the bundles before threshing and subtracting the weight of grain to obtain straw weight.

Hail damage corrections were made in 1957 based on an evaluation of 1 foot of row length for each subplot. The percentage of estimated damage was calculated as follows:

$$\text{Percentage of damage} = \left[1 - \frac{(\text{Heads standing} - \text{heads shattered})}{\text{Total stems}}\right] 100$$

This percentage indicates the number of heads not standing per 100 stems. However, some heads remained attached to the broken stems and all the grain was not completely missing from shattered heads. Therefore, yields were adjusted upward by an arbitrary one-third of the estimated hail damage.

Plant height was measured by using a stadia rod and observing the average height on each subplot at full height. Test weight of the grain was determined by using standard volumetric and weighing procedures.

RESULTS AND DISCUSSION

Evapotranspiration

The High Plains is not a large homogeneous irrigated area. Irrigated fields are intermixed with rangeland and nonirrigated farmland. The acreage of irrigated wheat in 1959 represented about 1.5 percent of the total land area in the High Plains. In the six-county area that had 76 percent of the irrigated winter wheat, the irrigated wheat acreage represented only 7.4 percent of the total

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[3] Commercial firms are included for the benefit of the reader and do not imply any endorsement or preferential consideration of the firm listed by the U.S. Department of Agriculture.

land area. Some additional wheat is irrigated for pasture during spring months. Evapotranspiration determinations made in this 2.8-acre experimental site should be representative of irrigated fields in the area that are surrounded by a high percentage of nonirrigated cropland.

Seasonal Evapotranspiration

A detailed summary of seasonal E_t and analysis of variance for the three fertility subplots on each moisture level is presented in table 12 in the appendix. Part of these data has been summarized and published earlier (*5, 8*).

The highest average grain yields and high water use efficiencies were obtained on the M_4 moisture level (see tables 6 and 20). Therefore, the M_4 moisture level will be referred to as the optimum moisture level in the rest of this report. Average cumulative E_t from the F_4 and F_6 fertilizer treatments on the M_4 moisture level is presented in figure 2. Cumulative E_t was above average in 1955-56 because of above normal solar radiation and air temperatures from March through May. Rainfall was below average during this time except during the latter part of May.

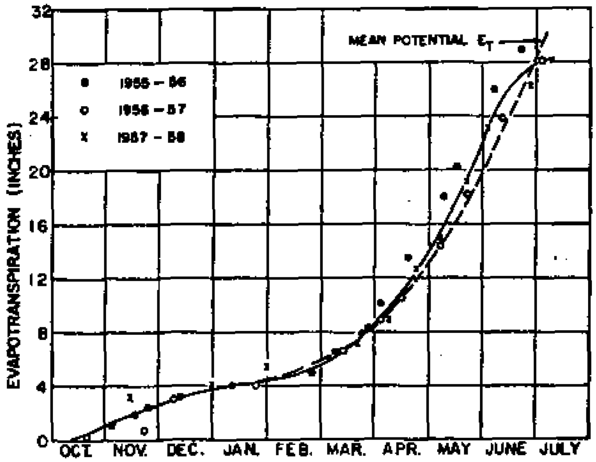

FIGURE 2.—Cumulative evapotranspiration for winter wheat at Bushland, Tex., with optimum soil moisture conditions and estimated mean cumulative potential E_t, 1955–58.

The mean cumulative E_t curve, as shown, closely parallels the estimated mean cumulative potential E_t from October 20 through May 31 based on the equation $E_{tp} = (0.014T - 0.37)R_s$. In this equation T is the mean air temperature (° F.), R_s is total solar radiation expressed as evaporation equivalent, and E_{tp} is potential evapotranspiration (*6*). This equation was obtained by correlating E_t for several crops having good vegetative cover and soil moisture with solar radiation and mean air temperature. The mean E_t curve gives the average for 1955–58 and should represent average E_t in irrigated fields in the area if adequate soil moisture is maintained.

Nitrogen fertilizer increased the seasonal use of water a small amount when comparing the F_0 (zero nitrogen) treatment to treatments F_4 and F_6 (table 12). Nitrogen increased the 3-year average E_t from 25.4 to 27.8 inches, or about 10 percent, on the M_3, M_4, and M_5 moisture levels. Yields increased from 28.5 to 46.6 bu./acre, illustrating that E_t was only slightly affected by use of fertilizers even though yields were increased about 64 percent. There was no material difference in E_t between the 120- and 180-lb. N rate. Similar results would be expected on a field basis. Viets summarized a series of plot studies in other areas showing similar E_t and yield relations (*12*).

Soil moisture data also indicated that the soil moisture was always slightly higher on the 0-nitrogen treatments during April and May (table 13). Average values cannot be used to compare moisture levels directly, because different sampling dates were involved.

Rate of Evapotranspiration

The average rates of evapotranspiration for sampling periods on the M_4 moisture level for the 3 years are presented in figure 3. Estimated mean evaporative demand or potential E_t is also shown. Variations in E_t during the spring months are due to climatic variability. Above average radiation and air temperature in March through the first part of May in 1956 resulted in higher E_t rates. Pan evaporation was also considerably above normal during this period. Similarly, the influence of below normal solar radiation and air temperature is evident in the low rates during February and March 1958, and during April and early May in 1957. Very high E_t rates occurred on all mois-

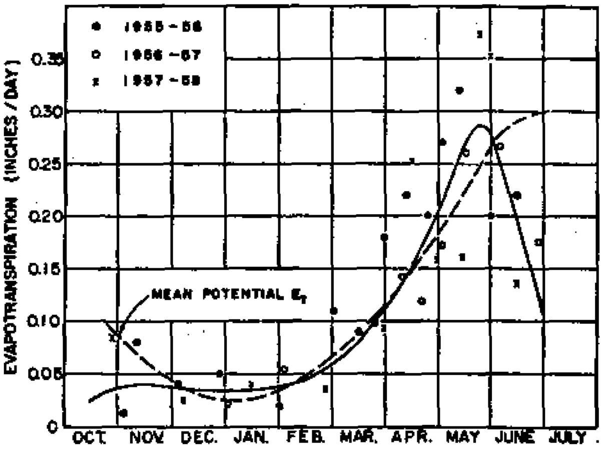

FIGURE 3.—Rate of evapotranspiration for winter wheat at Bushland, Tex., with optimum soil moisture conditions and estimated mean potential E_t.

TABLE 6.—*Effect of irrigation, nitrogen, and phosphorus treatments on the yield of winter wheat (one-third adjustment for hail damage in 1957), Bushland, Tex., 1956–58*

YIELD DATA

Year	Fertilizer treatment			Yields for moisture treatment—						
	No.	Nitrogen	P_2O_5	M_1	M_2	M_3	M_4	M_5	M_6	Average
		Lbs./acre	*Lbs./acre*	*Bu./acre*	*Bu./acre*	*Bu./acre*	*Bu./acre*	*Bu./acre*	*Bu./acre*	*Bu./acre*
1956	F_1	80	0	17.4	26.6	40.1	46.2	43.0	40.0	35.5
	F_2	0	30	16.9	22.3	29.3	33.6	30.5	32.0	27.4
	F_3	40	30	17.6	25.2	33.7	40.1	38.8	36.3	31.9
	F_4	80	30	18.1	26.2	41.5	45.9	44.2	38.9	25.8
	F_5	120	30	17.5	28.1	42.9	52.4	50.1	42.7	39.0
	F_6	80	60	18.9	25.5	38.0	45.3	45.0	41.3	35.7
Average				17.7	25.6	37.6	43.9	41.9	38.5	34.2
1957	F_1	120	0	45.9	55.1	54.6	50.8	54.2	54.2	52.5
	F_2	0	30	27.1	33.0	30.2	28.8	33.7	30.8	30.6
	F_3	60	30	40.6	47.8	43.0	44.0	47.3	47.1	45.0
	F_4	120	30	42.3	55.5	51.1	52.5	53.8	56.4	51.9
	F_5	180	30	44.4	50.9	59.8	48.9	44.7	47.4	49.4
	F_6	120	60	45.5	51.8	55.6	52.7	55.1	56.0	52.8
Average				41.0	49.0	49.0	46.3	48.1	48.7	46.7
1958	F_1	120	0	34.9	37.5	49.6	50.3	46.4	38.4	42.8
	F_2	0	30	20.2	22.2	22.8	26.3	21.0	21.4	22.3
	F_3	60	30	30.4	29.7	30.0	34.0	30.6	27.8	30.4
	F_4	120	30	33.9	38.1	40.4	49.8	44.2	44.1	41.7
	F_5	180	30	26.7	22.7	40.0	38.2	38.7	30.6	32.8
	F_6	120	60	34.8	36.4	49.6	52.8	40.0	39.2	42.0
Average				30.2	31.1	38.7	41.8	36.8	33.6	35.3
3-year average	F_1			32.7	39.7	48.1	49.1	47.9	44.2	43.6
	F_2			21.4	25.8	27.4	29.6	28.4	28.1	26.8
	F_3			29.5	34.2	35.6	39.4	38.9	37.1	35.8
	F_4			31.4	39.9	44.3	49.4	47.4	46.5	43.1
	F_5			29.5	33.9	47.6	46.5	44.5	40.2	40.4
	F_6			33.1	37.9	47.7	50.1	46.7	45.5	43.5
Overall average				29.6	35.2	41.8	44.0	42.3	40.2	38.9

ANALYSIS OF VARIANCE

Component	Degrees of freedom	Mean squares[1]		
		1956	1957	1958
Moisture (M)	5	2,539.80**	235.9 **	496.15**
Error (a)	15	19.19	27.76	19.34
Fertilizer (F)	5	384.45**	1,758.09**	1,644.30**
M x F	25	28.25**	33.80*	51.04**
Error (b)	90	5.68	19.19	15.67
Total	143			

[1] * = Significant at the 5-percent level; ** = significant at the 1-percent level.

ture levels during the latter part of May and first part of June 1958. These unusually high rates apparently were due to a combination of climatic factors—above normal air temperature and solar radiation, several days of high winds, and below normal relative humidity—that occurred during this time. These above normal climatic conditions are not evident in monthly means, because opposite climatic conditions occurred in early May and late June.

Mean potential E_t increases rapidly in April and May, approaching a maximum by late June. Mean E_t decreased rapidly in June because of crop maturation.

Attempts to relate available soil moisture to E_t rates were not successful, because sampling periods on the high and low moisture plots did not coincide. Also, frequent rainfall made the limited comparisons inconclusive. For example, when a 1-inch rain fell on all plots, the rate of E_t for several days would be similar on all plots regardless of the existing moisture level. However, a general trend indicated very little reduction in E_t occurred on the low moisture plots until the available soil moisture in the 6-foot profile dropped below 40 to 45 percent.

Total water in the 0- to 4-foot depth for all moisture levels by sampling dates is presented in table 14 (appendix). These values are the average of the F_4 and F_5 plots. Total water in the 4- to 6-foot depth increment is presented in table 15 (appendix). Soil moisture extraction from the the 4- to 6-foot depth increment was small; therefore, this increment was not sampled each time the 0- to 4-foot depth was sampled.

Grain Yield

Grain yield for each moisture level and fertility treatment is presented in table 6 with a summary of the analysis of variance. The 1957 yields include the adjustment for hail damage. The yields prior to hail damage adjustment and the percentages of hail damage are presented in tables 16 and 17 (appendix).

With high soil moisture, M_4 and M_5, yields increased linearly up to 120 lb. per acre of applied nitrogen. With 180 lb. nitrogen per acre, yields were reduced, primarily because of the effects of lodging before the grain matured. Similar results were obtained with medium soil moisture levels, M_3 and M_6, except the yields were lower.

Nitrogen was the primary factor limiting yields on the high moisture levels. Large year-to-year variation in yields occurred with limited irrigations because of the variations in amount and distribution of precipitation.

Nitrogen fertilizer did not affect yields as much on low moisture levels, M_1 and M_2. In 1956, a year with below normal rainfall from March to the latter part of May, nitrogen fertilizer did not materially affect yields. In 1957 and 1958, above normal rainfall was received from March through May. Yields were much higher in 1957 and 1958, and a significant response to nitrogen up to 120 lb. per acre was obtained.

On the M_4 moisture level (considered as the optimum soil moisture level), yields increased 0.2 bu. per acre for each pound of nitrogen applied up to 120 lb. per acre.

In 1958–59, the entire experimental site was irrigated uniformly, maintaining a high soil moisture level to evaluate the carryover or residual nitrogen effects. The yields obtained in 1959 are presented in table 7. Yields were greater on the previous F_4 treatment than the 0-nitrogen treatment: 30.7 vs. 27.2 bu. per acre. The largest average yield, 41.7 bu. per acre, was obtained on the previous F_5 fertilizer treatment. Also, larger yields due to residual nitrogen were obtained on the previous low moisture plots. Yields indicated that very little residual nitrogen re-

TABLE 7.—*Yield of irrigated winter wheat in 1959 as affected by previous fertilizer and moisture treatments, Bushland, Tex.*

YIELD DATA

Fertilizer treatment No.[1]	Yields for moisture treatment[2]—						
	M_1	M_2	M_3	M_4	M_5	M_6	Average
	Bu./acre	*Bu./acre*	*Bu./acre*	*Bu./acre*	*Bu./acre*	*Bu./acre*	*Bu./acre*
F_1	32.5	31.2	28.8	27.8	29.4	30.7	30.1
F_2	25.4	26.8	27.9	28.5	26.6	28.3	27.2
F_3	28.2	27.2	26.8	27.6	27.3	25.2	27.0
F_4	36.8	31.0	27.3	29.0	29.9	30.3	30.7
F_5	45.9	44.6	39.5	38.8	39.2	42.0	41.7
F_6	35.1	32.1	28.0	29.2	27.3	30.6	30.4
Averages	34.0	32.1	29.7	30.2	30.0	31.2	31.2

ANALYSIS OF VARIANCE

Component	Degrees of freedom	Mean squares[3]
Moisture (M)	5	64.54**
Error (a)	15	8.62
Fertilizer (F)	5	694.25**
M x F	25	13.77**
Error (b)	90	6.80
Total	143	

[1] Applied in previous years; no fertilizer applied in 1959.

[2] Previous levels, irrigated uniformly, maintaining a high soil moisture level in 1959.

[3] ** = Significant at the 1-percent level.

mained on the M_3, M_4, M_5 and M_6 plots where 120 lb. N per acre had been applied in 1957 and 1958. No significant yield response to phosphorus occurred.

Delaying irrigations until small amounts of available water remained in the upper layers of the soil decreased total seasonal E_t, but the resulting yields decreased by a greater proportion. This relation was evaluated by considering the average seasonal E_t on the M_4 moisture level as E_t with optimum soil moisture (E_{to}). The yield on the M_4 moisture level was used as the maximum (Y_4) (fig. 4). Yields from the subplots receiving 120 lb. nitrogen per acre were used for this comparison. In the dry year, a 20-percent reduction in E_t resulted in a 45-percent reduction in yield. Maintenance of available soil moisture for high yields was more critical in a dry year than in a wet year.

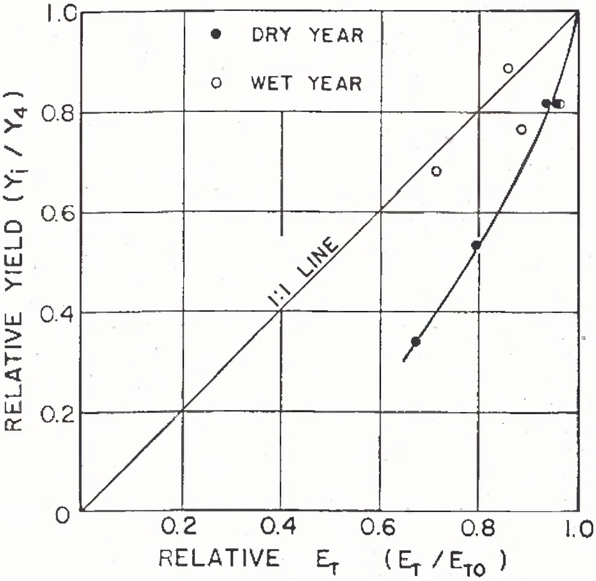

FIGURE 4.—Relative yield decreased more rapidly than relative seasonal evapotranspiration in a dry year (1956) when irrigations were delayed. In a wet year (1958) a definite trend was not apparent.

Maximum yields were obtained when the average available soil moisture in the 6-foot profile before irrigation remained above 45 to 50 percent. The upper layers were considerably drier than the lower depths. Allowing the available soil moisture to drop to 30 to 40 percent for the last irrigation in the spring did not materially affect yields.

Grain Quality [4]

Quality characteristics of wheat as influenced by available soil moisture and fertilizer applications are important. Milling and baking characteristics, including protein quantity and quality, and other grain characteristics such as test weight may all be influenced by soil moisture and fertility levels. Quality evaluations were made of the Concho wheat produced on the various soil moisture and fertilizer treatments. Although the average level for a given characteristic might have been different had another variety been used, it is believed that the influence of soil moisture and soil fertility on quality characteristics would have been similar to those obtained with Concho.

Test weight

The 3-year average test weights are presented in figure 5. The test weights for all moisture levels were normal at the lower rates of nitrogen applications. Test weights decreased when nitrogen applications exceeded 120 lb. per acre. On the high moisture levels (M_4 and M_5) and with 180 lb. per acre of N the reduction was apparently caused by the effects of lodging. The highest average test weights were obtained on the M_4 moisture level.

Protein

Protein content of wheat grain is an important factor affecting baking quality. Variations in protein content as affected by applied nitrogen on the high and medium soil moisture levels, and with limited irrigation, are presented in figures 6, 7, and 8.

With limited irrigation and low yields, protein content of the grain the first year increased linearly with applied nitrogen. In the second and third year, protein content increased nonlinearly with applied nitrogen, apparently because of residual or carryover nitrogen (fig. 6).

With medium soil moisture, nitrogen applications up to 120 lb. per acre did not increase protein content materially because yields increased. Yields did not increase significantly at 180 lb. N per acre, but protein content increased (fig. 7). Residual nitrogen apparently affected protein content at high nitrogen rates during the 2d and 3d year.

On the high soil moisture level, protein content was not materially affected by applied nitrogen except at the highest N levels, primarily because yields increased with more applied nitrogen (fig. 8). Figure 9 is presented to illustrate the interrelation between applied nitrogen, yields, and protein content. This figure clearly illustrates that when average yields increased with a given average rate of nitrogen application, the weighted average protein content decreased rapidly. Weighted average protein content $= \Sigma$ (yield x percent)/Σ yield. This figure also illustrates that if a specific protein content is desired, both yield and applied nitrogen must be controlled. Yield can

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[4] Prepared jointly with K. B. Porter, agronomist, Texas Agricultural Experiment Station, Bushland.

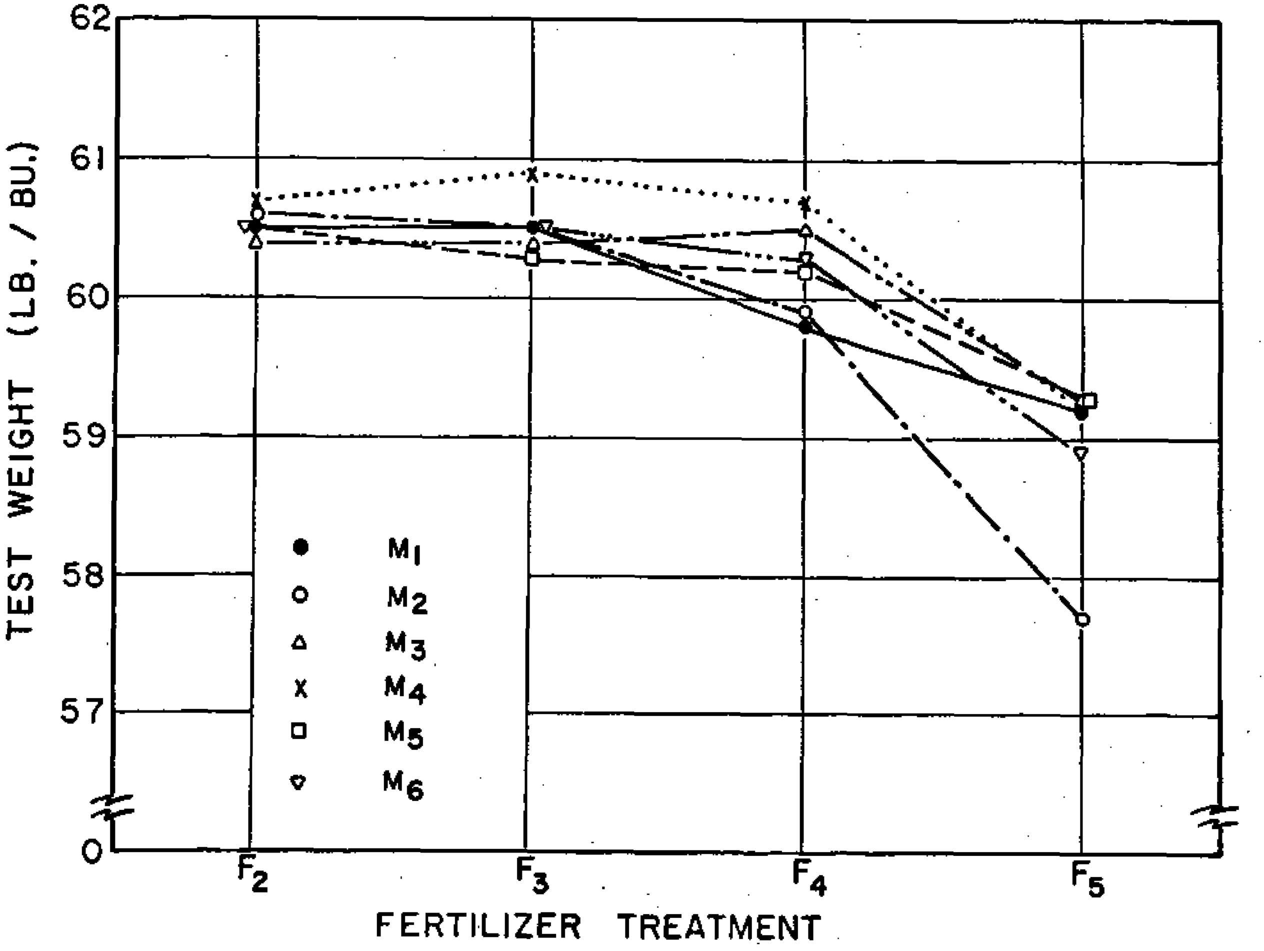

FIGURE 5.—Three-year average test weights were less with 180 lb. N per acre.

be controlled by irrigation practices except in years with above normal and well-distributed rainfall.

Milling and Baking Characteristics

A summary of grain and flour quality, and baking characteristics for each year is presented in table 18 in the appendix. In 1956 and 1958, doughs produced from wheat grown on the lower moisture levels, M_1 and M_2, were stronger than those of higher moisture levels. Likewise, the baking scores were generally higher for loaves baked from the wheat grown on these treatments. The more desirable quality characteristics of the M_1 and M_2 treatments as compared to those of the higher moisture treatments could have been the result of more and a better quality protein in the grain produced on the lower moisture treatments. Differences in quantity of protein in the grain from different fertility treatments within moisture treatments appeared to have less effect on baking characteristics than protein differences between different moisture treatments. Differences in baking characteristics of grain from the various treatments were less distinct in 1957 than in the other years, even though the M_1 and M_2 treatments produced grain with a higher protein content than other moisture treatments. In 1957, a high mean maximum air temperature of 92.6° F. for June (the last part of the fruiting period), or other environmental factors, may have adversely affected the quality of the protein (*4*).

The relations of baking score to yield, straw-grain ratio, nitrogen fertilizer, and wheat protein for 1956 and 1957 are given in table 19 in the appendix.[5]

Results of these studies indicate that quality characteristics were affected by soil moisture and nitrogen levels as well as environmental factors.

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[5] JENSEN, M. E., PORTER, K. B., SLETTEN, W. H., and CLYMA, W. THE EFFECT OF IRRIGATION WATER MANAGEMENT AND FERTILIZER ON QUALITY CHARACTERISTICS OF WINTER WHEAT AT BUSHLAND, TEX., IN 1956 AND 1957. (Mimeo.) Presented at the Hard Red Wheat Workers' Conference at Stillwater, Okla., Feb. 10-13, 1958.

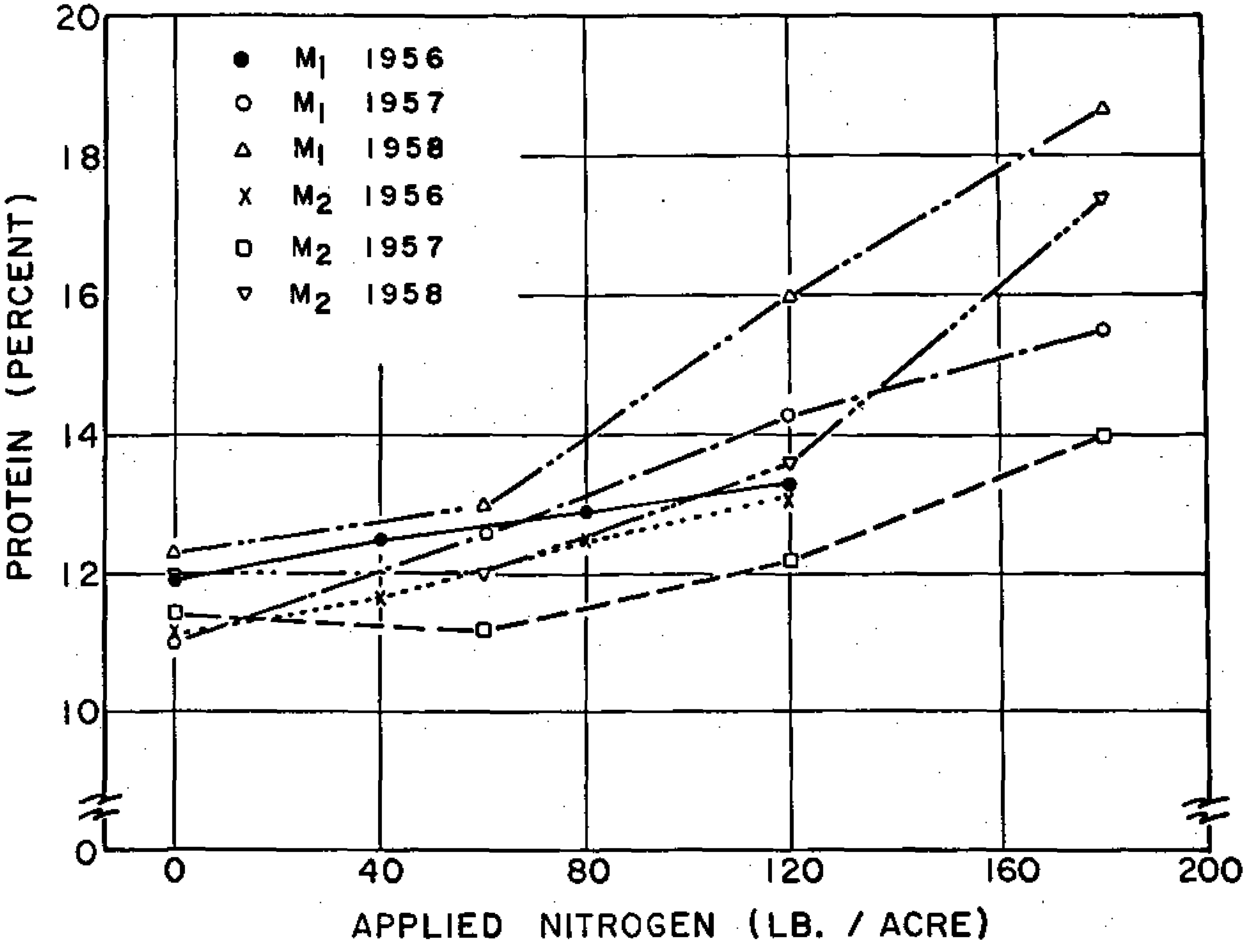

FIGURE 6.—When yields were restricted with limited irrigation, protein content increased with higher rates of applied nitrogen.

They also suggest the need for shorter varieties having strong gluten and resistance to lodging to permit nitrogen fertilization levels adequate for maintaining the quantity and quality of grain protein without increasing the lodging hazard.

Other Crop Characteristics

Straw-Grain Ratio

The influence of the soil moisture levels and fertilizer on the straw-grain ratio (by weight) in 1956, a dry year, is presented in table 8. The ratio of straw to grain was higher with limited irrigation and with higher rates of applied nitrogen.

Plant Height

The influence of soil moisture levels and fertilizer on plant height in 1958 is presented in table 9. Limited irrigation reduced plant height even in a wet year. Plant height increased substantially with higher rates of applied nitrogen. Lodging was closely associated with greater plant height. Excessive plant height and lodging occurred when both soil moisture and soil fertility were at or above optimum levels during the stem elongation period.

Water Use Efficiency

Water use efficiency, expressed in units of marketable products per unit of water evaporated and transpired during the growing season, is frequently used to indicate the effectiveness of agronomic and irrigation practices for maximum utilization of water supplies. A summary of water use efficiencies (bushels per acre-inch) for the 3 years is presented in table 20 in the appendix.

Fertilizer Effects

Fertilizers are extremely important in obtaining maximum utilization of water supplies. The use

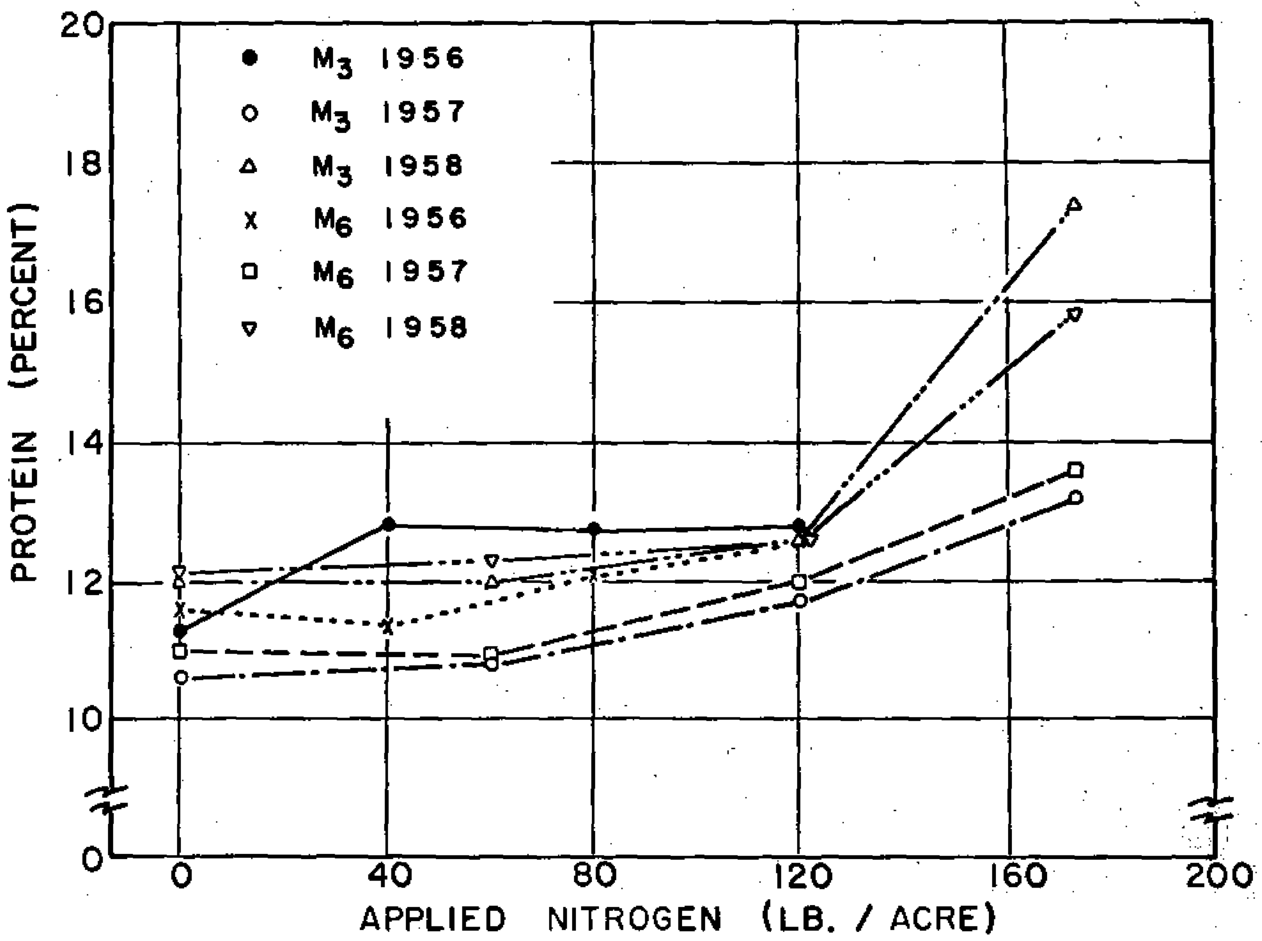

FIGURE 7.—Protein content of grain was not influenced materially by applied nitrogen with medium soil moisture because yields increased with higher applications (less than 120 lb. N per acre).

of nitrogen fertilizer did not greatly affect evapotranspiration but increased yields considerably, resulting in higher water use efficiencies (table 20).

Seasonal Variation

In a dry year such as 1956, water use efficiency was very low with limited irrigation, but in years with normal or above normal well-distributed precipitation, high water use efficiencies also occurred with limited irrigation treatments. In contrast, high water use efficiencies occurred in both wet and dry years on the medium and optimum soil moisture levels (table 20).

Irrigation Water Use Efficiency

Irrigation water use efficiency was evaluated by considering yield increases over nonirrigated crop yields per unit of total irrigation water applied annually (prior to seeding and during the growing season).

In 1956, the dryland wheat yield was zero. In 1958, the dryland yield was 14.9 bushels per acre under similar tillage practices and under continuous cropping. These yields were subtracted from those on the irrigated plots with optimum fertilizer treatments giving the approximate increase in yields attributed to applied irrigation water. In the dry year, irrigation water use efficiency increased as more irrigation water was applied, up to 25 inches (fig. 10). The total irrigation water applied for the 1956 yield includes the two light irrigations given in the fall of 1955 to improve the stand of wheat. Therefore, the curve for the dry year may be several inches too far to the right and too low under normal irrigation practices. In the wet year, irrigation water use efficiency decreased as more irrigation water was applied.

In an extremely dry year, no grain was produced without irrigation and small amounts of irrigation water resulted in only low grain yields. Thus ir-

TABLE 8.—*Effect of soil moisture, nitrogen, and phosphorus on the straw-grain ratio of irrigated winter wheat in 1956, Bushland, Tex.*

STRAW—GRAIN—RATIO DATA

Fertilizer treatment			Straw per pound grain for moisture treatment—						
No.	N	P_2O_5	M_1	M_2	M_3	M_4	M_5	M_6	Average
			Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
F_1	80	0	1.86	1.88	1.66	1.64	1.76	1.65	1.74
F_2	0	30	1.68	1.78	1.43	1.37	1.62	1.51	1.56
F_3	40	30	1.88	1.74	1.47	1.46	1.63	1.55	1.62
F_4	80	30	1.83	1.85	1.52	1.59	1.67	1.57	1.67
F_5	120	30	1.94	1.92	1.52	1.61	1.70	1.76	1.74
F_6	80	60	1.87	2.07	1.53	1.59	1.66	1.58	1.72

ANALYSIS OF VARIANCE

Component	Degrees of freedom	Mean squares [1]
Moisture (M)	5	0.533**
Error (a)	15	.037
Fertilizer (F)	5	.129**
M x F	25	.015
Error (b)	90	.015
Total	143	

[1] ** = Significant at the 1-percent level.

rigation water use efficiency was low for the first increments of water added. Additional increments increased yields substantially, resulting in higher irrigation water use efficiencies (fig. 10).

Irrigation water use efficiencies were higher in the wet year (1958). In 1958 the total E_t was lower than in 1956 and the increase in yield averaged about 2.25 bushels per acre-inch of applied irrigation water, decreasing with greater amounts of applied water.

With the irrigation practice used in this study, which included preplanting irrigations, about 20 to 24 inches of irrigation water were needed in a dry season and only 4 to 8 in a wet season to give high yield increases per unit of irrigation water applied.

Fallow Period Irrigations

In this experiment one or two irrigations were necessary before planting to wet the soil to a depth of 6 feet. Storage of rainfall during the fallow period under dryland conditions is only 15 to 20 percent of the total off-season precipitation. Storage efficiency of rainfall plus irrigation water applied off season was also low. For example, the 3-year average rainfall from harvest to seeding was 6.50 inches. A major part of this was lost by evaporation, and preplanting irrigations were needed to wet the soil profile. The average depth of preplanting irrigations on the higher moisture levels was 6.75 inches, for a total of 13.25 inches applied during the fallow period. Of this 13.25 inches, an average of only 5.3 inches, or 40 percent, remained in the soil at seeding.

Irrigation Water Management

Irrigation water management practices for winter wheat will vary with each farm unit, depending upon crops grown, available water supply, grazing needs, general level of production desired, and facilities and labor for irrigating. Some general irrigation guidelines can be derived from the results of this study.

Preplanting Irrigations

The decision of whether or not to give a preplanting irrigation would depend to a large extent on whether germination and stand establishment could be obtained without irrigating. If wheat is dry-seeded in shallow beds between small furrows or corrugations and irrigated up, preplanting irrigations usually are not needed. On the other hand, if seeding is to be done in moist soil with germination and stand establishment dependent on existing soil moisture then preplanting irrigations will be needed if summer precipitation does not provide adequate soil moisture.

Irrigation of other crops such as grain sorghum is generally not needed after September 10. Thus irrigation facilities would be available for

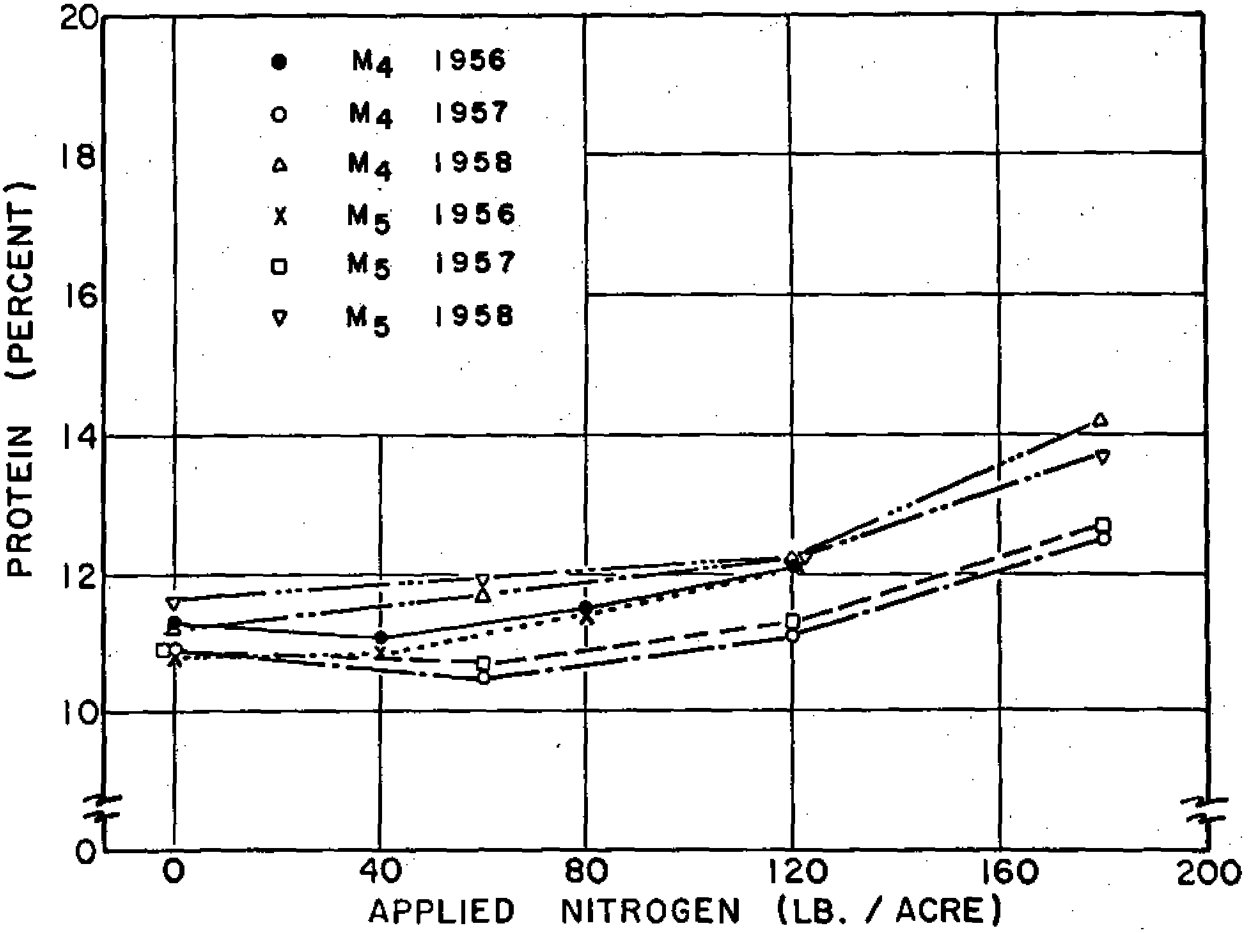

FIGURE 8.—Protein content of grain was not greatly affected by applied nitrogen with high soil moisture because yields increased.

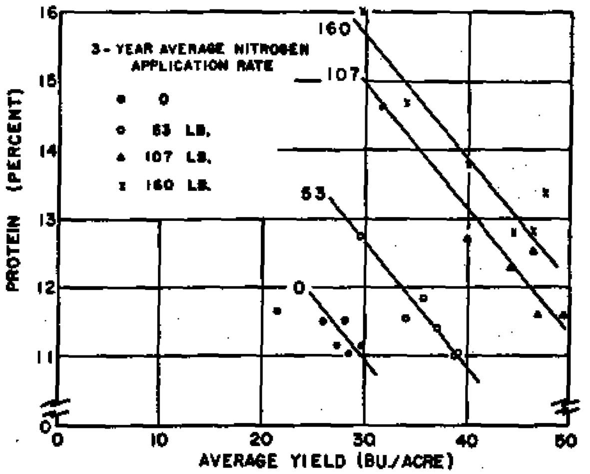

FIGURE 9.—The 3-year weighted average protein content of wheat decreased with higher average yields and increased with higher average rates of applied nitrogen.

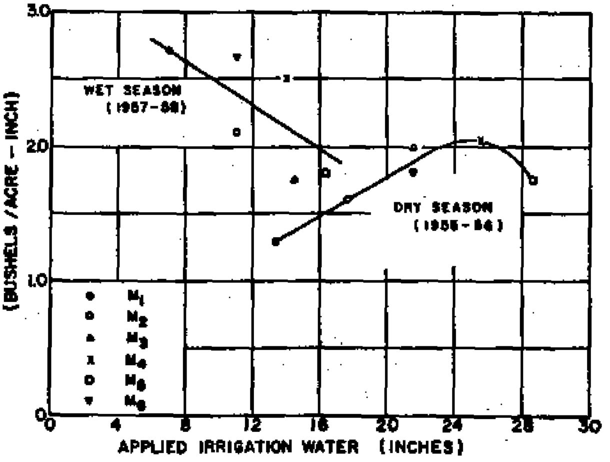

FIGURE 10.—Irrigation water use efficiency is dependent on season.

TABLE 9.—*Effect of moisture and fertilizer treatments on the plant height of irrigated winter wheat in 1958, Bushland, Tex.*

PLANT HEIGHT DATA

Fertilizer treatment			Height at moisture treatment—						
No.	N	P_2O_5	M_1	M_2	M_3	M_4	M_5	M_6	Average
	Lb./acre	*Lb./acre*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*	*Ft.*
F_1	120	0	3.4	3.8	3.8	3.9	3.9	3.7	3.8
F_2	0	30	2.5	2.5	2.6	2.6	2.6	2.6	2.6
F_3	60	30	3.0	3.2	3.2	3.4	3.1	3.2	3.2
F_4	120	30	3.3	3.8	3.7	3.9	3.9	3.7	3.7
F_5	180	30	3.3	3.8	4.0	3.9	4.0	3.9	3.8
F_6	120	60	3.3	3.8	3.8	3.9	3.8	3.7	3.7
Averages			3.2	3.5	3.6	3.6	3.6	3.5	3.5

ANALYSIS OF VARIANCE

Component	Degrees of freedom	Mean squares [1]
Moisture (M)	5	0.580**
Error (a)	15	.039
Fertilizer (F)	5	5.667**
M x F	25	.042**
Error (b)	90	.015
Total	143	

[1] ** = Significant at the 1-percent level.

preplanting irrigations about a month prior to seeding.

Under normal conditions, with a preplanting irrigation, precipitation after seeding would be sufficient for the wheat to establish secondary roots and to sustain plant growth until spring. If summer rains wet the soil 2 to 3 feet, a preplanting irrigation may not be necessary but a fall irrigation may be needed after seeding, to allow the wheat plants to establish secondary or crown roots and to maintain the crop until spring.

High Production Level

Assume that adequate but not excessive nitrogen fertilizer was provided for near maximum production. Irrigations can be scheduled by observing rainfall that occurred, estimating probable rainfall based on current forecasts, and using the mean cumulative E_t or E_t rate curve of figures 2 or 3.

If a preplanting irrigation had been given to wet the soil to a depth of 6 feet, the first irrigation should be given when no more than 4.5 to 5 inches of water had been removed from the soil. With normal rainfall, the first irrigation will be needed about March 20 to April 1. The second irrigation will be needed about April 20 to May 1 and the third about May 15 to May 20.

A season with below normal precipitation may require four spring irrigations with the first beginning about March 1. Conversely, a season with above normal precipitation may require only two spring irrigations. These irrigations should apply 3.5 to 4 inches of water.

Medium Production Level

Assuming a preplanting irrigation was given and adequate nitrogen fertilizer was provided, the first irrigation should be given before 5.5 to 6.0 inches of water have been used from the soil. With normal precipitation, the first irrigation will be needed about April 1 to April 10. The second irrigation will be needed about May 5 to May 10. An extremely dry spring may require three spring irrigations; a wet spring only one.

Low Production Level

Efficient production can be made with either a preplanting irrigation or irrigating for germination plus one irrigation in the spring. The spring irrigation should be delayed until about May 5 to May 15 if possible, but no later, so that soil moisture will be available during the peak use period, which is also the fruiting period. Fertilizer requirements would be much less under this level of production.

SUMMARY AND CONCLUSIONS

The results of a 3-year study of soil moisture levels and fertilizer treatments on winter wheat in the High Plains of Texas showed that the seasonal evapotranspiration (E_t) with optimum soil moisture averaged about 28 inches. Delaying irrigations until the soil moisture was depleted to low levels reduced seasonal E_t, but yields were reduced by a proportionately greater amount. Delayed irrigations that decreased seasonal E_t 10 percent reduced yields about 20 percent.

Nitrogen fertilizers increased seasonal E_t only about 10 percent over the nonfertilized plots, but yields were increased over 60 percent.

The rate of E_t during the fall and winter months averaged about 0.04 inch per day. The rate increased rapidly in the spring as solar radiation increased and air temperature rose. Evapotranspiration reached a mean maximum of 0.28 inch per day during the heading stage (about May 15–20). From heading to maturity, potential E_t increased, but E_t decreased because of crop maturation.

Grain yields were increased substantially with the addition of nitrogen up to 120 lb. per acre when medium and high moisture levels were maintained. Lodging and reduced yields occurred with nitrogen rates of 180 lb. per acre. Test weights also were lowest with 180 lb. N per acre.

Protein content of grain increased with high rates of applied nitrogen but decreased as yields were increased by irrigation at a given rate of nitrogen application. The results indicated that protein content of grain could be controlled within limits by controlling nitrogen application and controlling grain yields by irrigation practices.

Water use efficiency (pounds of grain per unit of E_t) increased when nitrogen fertilizer was used. Yields were increased over dryland yields by 2 bu. per acre-inch of irrigation water applied in a dry season and 2 to 3 bu. per acre-inch in a wet season.

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APPENDIX

TABLE 10.—*Record of irrigations of moisture treatments for winter wheat in 1955–56, 1956–57, and 1957–58, Bushland, Tex.*

Time of irrigation		Depth of water for moisture treatment—					
Date	Stage of growth	M_1	M_2	M_3	M_4	M_5	M_6
		Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
1955:							
Sept. 1	Preplanting	9.5	9.5	9.5	9.5	9.5	9.5
Oct. 28	Emergence	2.3	2.3	2.3	2.3	2.3	2.3
Nov. 18	do	1.8	1.8	1.8	1.8	1.8	1.8
1956:							
Mar. 16	Tillering					3.0	
Mar. 28	do		4.0		4.0		4.0
Apr. 13	Jointing					4.0	
Apr. 16	do			4.0			
Apr. 30	Boot				4.0		4.0
May 7	Flower					4.0	
May 15	Milk			4.0			
May 17	do				4.0		
May 23	Soft dough					4.0	
1955–56 total		13.6	17.6	21.6	25.6	28.6	21.6
1956:							
Aug. 25	Preplanting	5.6	5.6	5.6	5.6	5.6	5.6
Sept. 1	do	2.0	2.0	2.0	2.0	2.0	2.0
Nov. 26	Emergence	3.0	3.0	3.0	3.0	3.0	3.0
1957:							
Apr. 9	Jointing					3.5	3.5
Apr. 16	do		3.7		3.7		
Apr. 24	Boot			3.7			
May 10	Flower					4.0	
May 22	Milk				4.0		
1956–57 total		7.6	14.3	14.3	18.3	18.1	14.1
1957:							
Sept. 14	Preplanting	7.0	7.0	7.0	6.0	6.0	7.0
1958:							
Apr. 11	Jointing					3.3	
Apr. 25	Boot		4.0		4.0		
Apr. 30	do			4.0			
May 8	Flower					4.0	4.0
May 22	Milk				4.0		
May 29	Soft dough			3.5		3.0	
1957–58 total		7.0	11.0	14.5	14.0	16.3	11.0
Overall average		9.4	14.3	16.8	19.3	21.0	15.6

TABLE 11.—*Precipitation received from planting to harvest, 1955–56 to 1957–58, Bushland, Tex.*

Date	Amount	Date	Amount	Date	Amount
1955–56:	*Inches*	1956–57—Continued	*Inches*	1957–58—Continued	*Inches*
Nov. 7	0.02	Apr. 20	0.08	Jan. 19	0.40
Dec. 5	.09	Apr. 22	.80	Jan. 28	.03
Jan. 17	.03	Apr. 27	.03	Feb. 7	.08
Feb. 2–4	[1]1.77	Apr. 28	.57	Feb. 11	.08
Mar. 15	.02	Apr. 29	.27	Feb. 12	.02
Apr. 15	.28	May 1	.03	Feb. 14	.01
Apr. 19	.07	May 2	.01	Feb. 26	.29
May 24	1.52	May 8	.03	Mar. 4	.09
May 25	1.88	May 11	.89	Mar. 6	.88
May 27	.22	May 13	.11	Mar. 7	.05
May 30	1.27	May 15	.24	Mar. 8	.60
June 4	.19	May 16	.02	Mar. 12	.19
June 5	.01	May 20	.09	Mar. 23	.18
June 9	.17	May 24	.85	Mar. 27	.22
June 13	.27	May 27	.46	Mar. 28	.17
June 17	.09	May 28	.04	Apr. 8	.15
June 18	.03	May 31	.28	Apr. 9	.06
		June 1	2.12	Apr. 11	.06
Total	7.93			Apr. 12	.80
		Total	11.06	Apr. 13	.13
1956–57:				Apr. 17	.18
Oct. 18	0.26	1957–58:		Apr. 18	.07
Oct. 20	.06	Oct. 12	0.27	Apr. 20	.40
Jan. 4	.04	Oct. 13	1.02	May 2	.06
Jan. 30	.39	Oct. 17	.02	May 3	.67
Feb. 4	.03	Oct. 20	.15	May 4	.07
Feb. 18	.59	Oct. 21	.02	May 9	.15
Feb. 19	.02	Oct. 22	.30	May 10	.15
Feb. 22	.15	Oct. 23	.02	May 13	.26
Feb. 28	.02	Oct. 25	.37	May 17	.28
Mar. 2	.35	Nov. 3	.19	May 19	.03
Mar. 3	.03	Nov. 4	.03	May 25	.40
Mar. 4	.10	Nov. 5	.38	May 28	.71
Mar. 5	.13	Nov. 6	.08	June 6	.03
Mar. 6	.01	Nov. 17	.12	June 13	.01
Mar. 20	1.00	Nov. 18	.05	June 17	.13
Mar. 21	.25	Nov. 21	.23	June 19	.11
Mar. 23	.22	Nov. 22	.20	June 21	.28
Mar. 24	.17	Dec. 24	.08	June 22	.03
Mar. 30	.01	Jan. 4	.08		
Apr. 3	.26	Jan. 5	.35	Total	12.82
Apr. 12	.05				

[1] Water equivalent of snow measured on the plots, 0.52 inch more than recorded by nearby rain gage.

TABLE 12.—*Effect of irrigation and nitrogen treatment on total water use by irrigated winter wheat, Bushland, Tex., 1956–58*

EVAPOTRANSPIRATION DATA

Harvest year	Fertilizer treatment			E_t for indicated fertilizer treatment at moisture treatment—						
	No.	N	P_2O_5	M_1	M_2	M_3	M_4	M_5	M_6	Average
		Lb./acre	*Lb./acre*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
1956	F_3	0	30	19.4	21.6	22.9	23.6	27.5	26.3	23.6
	F_4	80	30	19.7	24.2	24.9	30.4	31.4	28.7	26.5
	F_5	120	30	20.3	23.9	28.3	30.2	34.0	28.9	27.6
Average				19.8	23.2	25.4	28.1	31.0	28.0	25.9
1957	F_3	0	30	17.1	23.4	23.8	24.1	26.3	23.6	23.0
	F_4	120	30	18.1	24.9	24.3	28.4	27.3	24.5	24.6
	F_5	180	30	17.3	24.6	25.1	27.4	27.3	24.3	24.4
Average				17.5	24.3	24.4	26.6	27.0	24.3	24.0
1958	F_3	0	30	18.4	22.4	25.0	26.6	28.9	22.9	24.0
	F_4	120	30	19.4	23.7	26.0	27.0	29.0	23.2	24.7
	F_5	180	20	19.1	23.2	25.5	26.2	27.4	23.1	24.1
Average				19.0	23.1	25.5	26.6	28.4	23.1	24.3
3-year average	F_3		30	18.3	22.5	23.9	24.8	27.6	24.3	23.6
	F_4		30	19.1	24.3	25.1	28.6	29.2	25.5	25.3
	F_5		30	18.9	23.9	26.3	27.9	29.6	25.6	25.4
Average				18.8	23.6	25.1	27.1	28.8	25.1	24.7

ANALYSIS OF VARIANCE

Component	Degrees of freedom	Mean squares[1]		
		1956	1957	1958
Moisture (M)	5	95.38**	140.93**	132.59**
Error (a)	15	4.23	.48	.73
Fertilizer (F)	2	52.90**	17.58**	3.23*
M x F	10	4.39**	2.29	1.14
Error (b)	36	.94	1.32	.83
Total	71			

[1] * = Significant at the 5-percent level; ** = significant at the 1-percent level.

TABLE 13.—*Average soil moisture percentage on an oven-dry weight basis for 3 levels of fertilization for sampling periods in April and May 1956–58, Bushland, Tex.*

Harvest year	Depth	M_1			M_2			M_3			M_4			M_5			M_6		
		F_2	F_4	F_6	F_2	F_4	F_6	F_2	F_4	F_6	F_2	F_4	F_6	F_2	F_4	F_6	F_2	F_4	F_6
	Ft.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
1956	0–1	14.1	13.6	14.2	17.3	16.8	16.5	17.3	16.2	16.8	19.7	19.1	18.5	18.5	17.5	17.1	18.5	17.8	17.3
	1–2	15.6	16.2	15.5	19.4	18.0	17.6	18.8	17.8	18.3	20.7	19.4	18.7	20.9	18.8	18.0	20.0	18.3	17.9
	2–3	14.9	15.0	13.7	17.2	16.1	15.6	16.2	15.5	15.5	17.5	16.6	16.2	18.0	16.2	16.1	17.2	16.0	15.6
	3–4	15.8	15.1	14.7	17.0	16.4	15.6	16.4	15.2	15.1	17.0	16.0	15.9	17.3	16.4	16.2	16.7	15.4	15.2
Average		15.1	15.0	14.5	17.7	16.8	16.3	17.2	16.2	16.4	18.7	17.8	17.3	18.7	17.2	16.8	18.1	16.9	16.5
1957	1	18.7	17.2	17.2	(1)	(1)	(1)	22.0	20.1	19.3	21.5	19.0	18.7	23.6	22.1	20.5	22.8	20.7	19.4
	2	17.4	17.7	17.4	(1)	(1)	(1)	20.4	18.5	18.4	20.2	18.2	18.0	21.9	20.6	19.6	20.4	18.3	17.8
	3	15.5	15.8	14.9	(1)	(1)	(1)	17.4	15.6	16.0	17.4	16.0	16.1	17.5	17.0	17.2	17.4	15.5	15.0
	4	15.2	15.3	15.2	(1)	(1)	(1)	16.2	15.5	16.0	16.8	15.6	16.0	16.2	15.9	15.8	16.5	15.2	15.2
Average		16.7	16.5	16.2	(1)	(1)	(1)	19.0	17.4	17.4	19.0	17.2	17.2	19.8	18.9	18.3	19.3	17.4	16.8
1958	1	22.7	17.2	17.0	23.4	21.7	20.8	22.4	20.3	19.4	23.6	20.9	20.8	23.7	21.8	21.2	(1)	(1)	(1)
	2	20.4	16.2	16.6	22.3	20.0	19.4	21.2	18.7	18.4	21.7	20.2	20.0	22.1	20.8	20.4	(1)	(1)	(1)
	3	16.9	14.7	14.6	19.3	16.6	16.7	19.4	16.2	15.0	19.5	17.9	17.2	19.8	18.5	18.5	(1)	(1)	(1)
	4	15.9	14.4	14.7	18.6	15.2	15.2	18.2	14.8	14.6	18.5	16.9	16.4	19.0	16.7	16.7	(1)	(1)	(1)
Average		19.0	15.6	15.7	20.9	18.4	18.0	20.3	17.5	16.8	20.8	19.0	18.6	21.2	19.4	19.2	(1)	(1)	(1)
Overall average		16.9	15.7	15.5	19.3	17.6	17.2	18.8	17.0	16.9	19.5	18.0	17.7	19.9	18.5	18.1	18.7	17.2	16.7

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[1] No sampling periods in April.

TABLE 14.—*Total water in the 0- to 4-foot soil profile for each date of sampling (average of the F_4 and F_5 fertilizer subplots), Bushland, Tex., 1956–58*[1]

Harvest Year	Total water at moisture level—											
	M_1		M_2		M_3		M_4		M_5		M_6	
	Date	*Inches*	*Date*	*Inches*	*Date*	*Inches*	*Date*	*Inches*	*Date*	*Inches*	*Date*	*Inches*
1956	Mar. 23	10.7	Mar. 23	10.7	Mar. 23	10.7	Mar. 23	10.7	Mar. 16	14.1	Mar. 23	10.7
	Apr. 5	12.5	Mar. 28	13.7	Apr. 5	12.5	Mar. 28	13.7	Mar. 23	15.8	Mar. 28	13.7
	Apr. 19	11.3	Apr. 4	15.7	Apr. 16	12.1	Apr. 4	15.7	Apr. 5	13.8	Apr. 4	15.7
	May 4	9.7	Apr. 19	13.0	Apr. 25	14.3	Apr. 19	13.0	Apr. 12	12.2	Apr. 19	13.0
	May 18	9.1	May 4	10.1	May 8	11.1	Apr. 30	11.3	Apr. 23	14.4	Apr. 30	11.3
	June 26	10.2	May 18	9.0	May 15	9.9	May 8	13.0	May 7	10.8	May 8	13.0
			June 27	10.1	May 22	10.6	May 16	10.7	May 15	12.2	May 16	10.7
					June 7	12.4	May 22	12.1	May 22	10.2	May 23	9.0
					June 22	11.1	June 7	12.9	June 7	14.1	June 8	11.3
							June 22	10.6	June 20	12.0	June 25	10.8
1957	Oct. 26	14.7	Oct. 26	14.7	Oct. 20	15.0	Oct. 20	15.0	Oct. 20	15.0	Oct. 20	15.0
	Nov. 21	14.1	May 8	13.5	Apr. 4	13.5	Nov. 23	14.4	Apr. 25	14.1	Apr. 25	13.6
	Dec. 10	13.2	May 23	10.6	Apr. 17	11.8	Dec. 10	15.2	May 9	11.7	May 9	12.5
	Jan. 24	12.8	June 12	9.4	Apr. 24	14.7	Jan. 24	14.2	May 23	13.0	May 28	10.9
	Mar. 13	12.8	July 5	9.5	May 10	13.5	Mar. 13	13.5	June 7	13.9	June 13	9.8
	Apr. 4	13.1			May 28	11.8	Apr. 4	13.2	July 3	10.4	July 8	9.5
	Apr. 16	11.5			June 13	13.0	Apr. 16	11.8				
	May 10	10.7			July 5	9.5	May 7	13.4				
	June 5	11.2					May 22	11.0				
	July 8	9.5					June 11	13.5				
							July 3	10.3				
1958	Sept. 12	10.9	Nov. 14	15.8	Nov. 14	15.3	Sept. 12	12.1	Nov. 14	14.6	Nov. 14	16.0
	Nov. 14	15.3	Apr. 23	12.0	Apr. 29	11.5	Nov. 14	15.6	Apr. 8	13.6	May 6	11.0
	Dec. 30	14.6	May 7	14.4	May 8	13.8	Dec. 30	15.1	Apr. 24	14.5	May 20	14.9
	Jan. 31	14.4	May 20	12.8	May 20	13.0	Jan. 31	14.5	May 6	13.3	June 9	9.2
	Mar. 21	14.3	June 9	8.8	May 27	10.9	Mar. 21	14.9	May 21	15.4	June 27	9.7
	Apr. 8	13.1	June 27	9.6	June 5	12.1	Apr. 8	14.3	May 27	12.6		
	Apr. 24	11.6			June 27	9.9	Apr. 23	12.0	June 5	13.8		
	May 6	10.2					May 7	14.6	June 27	10.6		
	May 20	10.3					May 21	13.2				
	June 9	8.6					June 3	12.6				
	June 27	8.9					June 27	10.9				

[1] Each value is based on 8 soil cores except in 1956, when several moisture levels sampled the same day are averaged together. Water content at wilting point is about 8.9 inches.

TABLE 15.—*Total water in the 4- to 6-foot increment of the soil profile for each date of sampling (average of F_4 and F_5 fertilizer subplots), Bushland, Tex., 1956–58*[1]

Harvest year	Total water at moisture level—											
	M_1		M_2		M_3		M_4		M_5		M_6	
	Date	*Inches*	*Date*	*Inches*	*Date*	*Inches*	*Date*	*Inches*	*Date*	*Inches*	*Date*	*Inches*
1956	Apr. 19	5.5	May 18	5.7	Apr. 16	6.8	June 22	5.6	June 20	5.8	June 25	5.4
	May 18	5.4	June 27	5.6	June 22	5.6						
	June 26	5.6										
1957	Oct. 26	5.6	Oct. 26	5.6	Oct. 20	6.4	Oct. 20	6.4	Oct. 20	6.4	Oct. 20	6.4
	Jan. 24	5.7	May 8	6.6	Apr. 4	6.6	Jan. 24	6.4	Apr. 25	6.3	Apr. 25	6.3
	Apr. 4	6.0	June 12	5.0	July 5	5.0	Apr. 4	6.3	July 3	5.4	May 28	5.4
	May 10	5.7	July 5	4.7			July 3	5.2			July 8	4.9
	July 8	4.8										
1958	Sept. 12	4.8	Nov. 14	6.0	Nov. 14	5.5	Sept. 12	5.8	Nov. 14	6.2	Nov. 14	5.5
	Nov. 14	5.3	Apr. 23	5.5	Apr. 29	5.8	Nov. 14	6.3	Apr. 8	6.3	May 6	5.4
	Jan. 31	5.5	May 20	5.6	May 20	5.8	Jan. 31	6.5	May 21	6.5	May 20	5.8
	Apr. 8	5.5	June 27	5.8	June 27	5.3	Apr. 8	6.7	June 27	5.4	June 27	8.1
	May 20	5.1					May 21	6.1				
	June 27	4.6					June 27	5.5				

[1] Each value is based on 8 soil cores except in 1956, when several moisture levels sampled on the same day were averaged together. Water content at wilting point is about 4.8 inches.

TABLE 16.—*Effect of irrigation treatment, nitrogen, and phosphorus on the yield of irrigated winter wheat (after hail damage) in 1957, Bushland, Tex.*

YIELD DATA

Fertilizer treatment			Yields for moisture treatment—						
No.	N	P_2O_5	M_1	M_2	M_3	M_4	M_5	M_6	Average
	Lb./acre	*Lb./acre*	*Bu./acre*	*Bu./acre*	*Bu./acre*	*Bu./acre*	*Bu./acre*	*Bu./acre*	*Bu./acre*
F_1	120	0	37. 8	46. 1	44. 0	41. 5	42. 9	44. 7	42. 8
F_2	0	30	23. 8	28. 5	25. 5	24. 7	28. 8	26. 0	26. 2
F_3	60	30	35. 3	39. 7	38. 0	36. 1	38. 7	40. 0	38. 0
F_4	120	30	35. 2	46. 3	42. 9	41. 6	43. 2	46. 7	42. 7
F_5	180	30	35. 5	40. 1	47. 7	35. 8	34. 3	39. 1	38. 7
F_6	120	60	38. 4	43. 5	45. 6	42. 5	43. 5	46. 3	43. 3
Average			34. 3	40. 7	40. 6	37. 0	38. 6	40. 5	38. 6

ANALYSIS OF VARIANCE

Component	Degrees of freedom	Mean squares [1]
Moisture (M)	5	156. 20**
Error (a)	15	18. 02
Fertilizer (F)	5	1,011. 82**
M x F	25	21. 10*
Error (b)	90	11. 46
Total	143	----------

[1] *= Significant at the 5-percent level; **= significant at the 1-percent level.

TABLE 17.—*Effect of irrigation treatment, nitrogen, and phosphorus on the percentage*[1] *of hail damage to winter wheat in 1957, Bushland, Tex.*

DATA FOR PERCENTAGE OF HAIL DAMAGE

Fertilizer treatment			Hail damage for moisture treatment—						
No.	N	P_2O_5	M_1	M_2	M_3	M_4	M_5	M_6	Average
	Lb./acre	*Lb./acre*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
F_1	120	0	53.2	48.7	58.2	54.2	62.7	52.5	54.9
F_2	0	30	37.2	40.5	46.5	42.2	43.2	49.0	43.1
F_3	60	30	38.5	50.2	34.2	54.0	55.0	44.7	46.1
F_4	120	30	49.7	49.2	47.7	62.0	58.5	51.0	53.0
F_5	180	30	59.7	64.0	60.5	80.7	69.2	51.7	64.3
F_6	120	60	46.0	48.2	53.5	58.0	63.2	52.0	53.5
Average			47.4	50.1	50.1	58.5	58.6	50.1	52.5

ANALYSIS OF VARIANCE

Component	Degrees of freedom	Mean square[2]
Moisture (M)	5	539.60*
Error (a)	15	105.20
Fertilizer (F)	5	1,324.40**
M x F	25	115.64
Error (b)	90	113.39
Total	143	

[1] Percentage of damage $=\left[1-\frac{(\text{Heads standing}-\text{heads shattered})}{\text{Total stems}}\right]100.$

[2] * = Significant at the 5-percent level; ** = significant at the 1-percent level.

TABLE 18.—*Effect of soil moisture on the quality of Concho winter wheat, Bushland, Tex., 1956–58*

Harvest year	Moisture level	Grain			Flour		Farinograph				Baking	
		Protein	Ash	Flour yield	Ash	Protein	Hydration	Peak	Stability	Mixing time index	Loaf vol.	Total rating
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Min.*	*Min.*	*Min.*		*Cc.*	
1956	M_1	12.8	1.85	59.9	0.50	------	2.7	4.5	5.5	56	718	74
	M_2	12.3	1.81	60.8	.50	11.0	2.5	4.3	6.1	51	667	63
	M_3	12.4	1.86	59.4	.48	11.1	2.4	3.5	3.2	77	658	44
	M_4	11.6	1.76	58.7	.48	10.5	2.1	3.3	3.1	76	646	43
	M_5	11.3	1.81	59.7	.45	10.1	2.1	3.2	4.5	71	671	56
	M_6	11.9	1.77	60.1	------	10.7	2.3	3.5	3.3	67	675	51
1957	M_1	13.3	1.78	65.9	.41	12.6	2.6	3.3	4.6	45	646	48
	M_2	12.2	1.84	65.6	.42	11.2	2.3	4.2	4.1	50	679	48
	M_3	11.8	1.84	65.1	.43	10.8	2.6	3.9	3.9	57	625	48
	M_4	11.3	1.86	66.8	.42	10.1	2.6	4.3	4.4	56	679	50
	M_5	11.4	1.86	65.6	.43	10.5	2.5	4.0	4.5	53	683	47
	M_6	12.0	1.81	66.1	.45	10.8	2.5	3.7	3.8	62	638	43
1958	M_1	15.5	1.95	65.0	.49	13.8	2.9	4.3	5.9	43	675	57
	M_2	13.3	1.99	66.6	.45	12.1	2.5	4.1	5.6	44	700	58
	M_3	12.6	1.99	66.2	.43	10.9	2.1	3.0	2.8	70	618	42
	M_4	12.3	1.85	62.0	.44	10.6	2.0	3.2	3.9	68	650	49
	M_5	12.3	1.95	------	.45	10.6	1.8	2.9	3.3	67	683	51
	M_6	13.4	1.95	67.3	.44	11.3	2.1	3.5	4.0	57	754	52
Average	------	12.5	1.86	63.6	.45	11.1	2.4	3.7	4.3	59	664	51

TABLE 19.—*Relationship between yield of irrigated winter wheat (Concho) and baking score,*[1] *straw-grain ratio and baking score, nitrogen fertilizer and wheat protein, and wheat protein and baking score, Bushland, Tex., 1956–57*[2]

Relationship	r	Regression equation
Yield vs. baking score, 1956	−0.710**	$y=258.1/x$ [illegible]
Yield [3] vs. baking score, 1957	.011	$y=46.48+0.004x$
Straw-grain ratio vs. baking score, 1956	.797**	$y=-44.09+59.32x$
Nitrogen fertilizer vs. wheat protein, 1956	.599*	$\text{Log}_{10}\, y=\text{Log}_{10}\, 11.28+0.000423x$
Nitrogen fertilizer vs. wheat protein, 1957	.673**	$\text{Log}_{10}\, y=\text{Log}_{10}\, 10.66+0.000521x$
Wheat protein vs. baking score, 1956	.437**	$y=-29.34+7.02x$
Wheat protein vs. baking score, 1957	.216	$y=39.38+0.61x$

[1] Producers Quality Laboratory, Amarillo, Tex.

[2] *=Significant at the 5-percent level, $n=36$; **=significant at the 1-percent level, $n=36$.

[3] Yield adjusted for ⅓ of measured hail damage.

TABLE 20.—*Effect of irrigation and fertilizer treatments on the efficiency, bushels per acre-inch of water, of producing wheat, Bushland, Tex., 1956–58*

DATA FOR BUSHELS PER ACRE-INCH OF WATER

Harvest year	Fertilizer treatment			Yields per acre-inch of water for moisture treatment—						
	No.	N	P_2O_5	M_1	M_2	M_3	M_4	M_5	M_6	Average
		Lb./acre	*Lb./acre*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
1956	F_2	0	30	0.94	1.14	1.29	1.48	1.12	1.24	1.20
	F_4	80	30	.88	.98	1.68	1.43	1.40	1.36	1.28
	F_5	120	30	.85	1.16	1.56	1.66	1.48	1.38	1.35
Average				.89	1.08	1.51	1.50	1.33	1.32	1.27
1957	F_2	0	30	1.59	1.41	1.27	1.19	1.28	1.32	1.34
	F_4	120	30	2.34	2.23	2.10	1.85	1.98	2.30	2.13
	F_5	180	30	2.56	2.07	2.39	1.79	1.64	1.92	2.06
Average				2.16	1.90	1.92	1.61	1.63	1.84	1.84
1958	F_2	0	30	1.09	.99	.91	.99	.73	.94	.94
	F_4	120	30	1.75	1.61	1.55	1.84	1.52	1.90	1.70
	F_5	180	30	1.49	.98	1.56	1.46	1.41	1.33	1.37
Average				1.45	1.19	1.34	1.43	1.22	1.39	1.34
3-year average	F_2		30	1.21	1.18	1.16	1.20	1.04	1.17	1.16
	F_4		30	1.66	1.59	1.78	1.71	1.63	1.85	1.70
	F_5		30	1.63	1.40	1.84	1.64	1.51	1.54	1.59
Average				1.50	1.39	1.59	1.51	1.39	1.52	1.48

ANALYSIS OF VARIANCE

Component	Degrees of freedom	Mean squares[1]		
		1956	1957	1958
Moisture (M)	5	0.3623*	0.5058**	0.1418*
Error (a)	15	.0370	.0476	.0362
Fertilizer (F)	2	.0701*	4.5486**	3.4265**
M x F	10	.0322	.1130*	.0986**
Error (b)	36	.0136	.0420	.0276
Total	71			

[1] *=Significant at the 5-percent level; **=significant at the 1-percent level.

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