Durum Response to Soil Water Depletion Levels, 2000

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Abstract

This research represents the second year of a project to determine when to irrigate wheat based on soil water depletion levels. The purpose of this work is to establish the optimum irrigation timing based on depletion of plant available water in the soil. A field experiment was conducted at the Maricopa Agricultural Center testing irrigation of wheat at 35, 50, 65, and 80% depletion of plant available water in the soil for two durum varieties, Kronos and Westbred 881. Grain yields averaged over the two varieties were 6787, 6494, 5460, and 3067 lbs/acre for the 35, 50, 65, and 80% depletion levels, respectively. The results of this study indicate irrigating at 50% soil water depletion or less is optimal for wheat grain yield.

Introduction

Wheat is an important crop in Arizona since it breaks insect and disease cycles, adds organic material to the soil due to its high straw content, and may actually increase yields of subsequent crops. Growing a crop of wheat can help control winter weeds since wheat is very competitive with other plants. Also, salts can be leached from the soil while growing wheat during the winter when water use is low.

Wheat should be irrigated when 55% of the plant available water is depleted in the root zone (Doorenbos and Pruit, 1977). When crop water use is less than 0.10 inches/day this value should be increased by 30% (to 72% allowable depletion) and when crop water use is greater than 0.30 inches/day this value should be decreased by 30% (to 38% allowable depletion). During ripening, the maximum allowable depletion of plant available water is 90%. These guidelines are not always used in commercial practice in Arizona due to practical considerations. During the winter when water use is low and water is not needed by other crops, growers sometimes apply irrigation water to relatively wet soils to leach salts and to wet the subsoil. On the other hand, during its peak water use period, irrigation intervals often increase when water is needed to pre-irrigate cotton.

Research on several aspects of wheat irrigation has been conducted in Arizona. Consumptive use curves for wheat have been developed and published (Erie et al., 1968). The concept of the Crop Water Stress Index (CWSI), which is based on measuring canopy temperatures with an infrared thermometer, is an irrigation scheduling tool that was developed in Arizona (Jackson, 1982). The CWSI has been tested on wheat in Arizona and validated as a viable irrigation scheduling tool (Garrot et al., 1994). The effects of water stress at various growth stages has been studied for wheat in Arizona (Day et al., 1970). Roth et al. (1981) studied the effects of nitrogen levels and water application amounts on wheat.

Apparently, research has not been conducted in Arizona to determine when to irrigate wheat based on the allowable soil water depletion levels. Therefore, the purpose of this work is to establish the optimum irrigation timing based on depletion of plant available water in the soil. This research presented in this report represents the results from the 2000 crop year, and the results from 1999 have been reported previously (Husman et al., 1999).

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Materials and Methods

A wheat irrigation study was conducted at the University of Arizona Maricopa Agricultural Center on Field 6 on a Casa Grande Sandy loam soil during the 1999-00 growing season. Two durum varieties, Westbred 881 and Kronos, were planted on 23 November 99 at a rate of 176 lbs seed/acre in alternating strips. An irrigation to germinate the seed was applied on 2 December 99. The first post-emergence irrigation was applied uniformly over the entire field on 25 January 99. Subsequently, irrigations were applied when 35, 50, 65, or 80% of the plant available soil water was depleted. Irrigations were applied using the border flood method and a ditch weir was used to measure the amount of water applied. The experimental design was split plot consisting of four irrigation treatments as main plots, two varieties as subplots, and four replications. The subplots comprising a single variety were 9 ft. wide and 430 ft. long. The main plots, or irrigation treatments, were 18 ft. wide and 430 ft. long.

Soil water content was measured using a Campbell Pacific 503 DR Hydroprobe. Two neutron access tubes were located in each irrigation treatment 150 ft. from the top end of the field in one variety and 150 ft. from the bottom end of the field for the other variety. Soil water content was measured using the neutron probe in the 0 to 12 inch depth increment and every 8 inches thereafter to a depth of 52 inches. Soil samples were removed on 13 January 2000 for determination of gravimetric soil water content and soil texture. The volumetric soil water content was calculated assuming bulk density values based on soil texture (USDA-SCS, 1991). The neutron probe was calibrated using the volumetric soil water content and the corresponding neutron probe readings for each depth increment. Plant available water content was calculated as the difference between soil water content at field capacity and permanent wilting point. The soil water content at permanent wilting point was determined based on its texture (USDA-SCS, 1991). Soil water content was measured with the neutron probe every 2 days until the targeted soil water depletion threshold was attained. The active root zone was expanded from the initial 0 to 12 inches when water use occurred in the next 8 inch increment since the previous irrigation. The amount of irrigation water applied was that necessary to refill the soil profile to field capacity.

The amount and timing of irrigation water and fertilizer is presented in Table 1. Fertilizer was broadcast preplant at a rate of 106 lbs N/acre as ammonium sulfate and 11-52-0 and 104 lbs P_2O_5/acre as 11-52-0. Postplant nitrogen fertilizer was applied as urea ammonium nitrate solution (32-0-0) injected into the irrigation water. The center 5 feet of each plot was harvested on 15 May 2000 with a small plot combine and grain yield was calculated. Grain protein was measured using near infrared reflectance (NIR). Kernel weight and hard vitreous amber count (HVAC) were determined from a 10 g sample and test weight was measured using a 1 pint container. Kernels per head was determined by weighing grain from 10 heads per plot, then dividing by kernel weight. Heads per unit area was calculated from grain yield, kernel weight, and kernels per head.

Results and Discussion

The 1999-00 wheat growing season can be characterized as warm and dry compared to normal (Table 2). March was the only month where rainfall was recorded. The growing season had above average temperature except for December.

The effect of irrigation timing based on soil water depletion levels on grain yield and kernel characteristics is presented in Table 3. The optimum soil water depletion level according to grain yield was 50% for each variety and averaged over varieties. The lowest yield was obtained at 80% depletion averaged over varieties, and yield at 65% depletion was intermediate. Westbred 881 and Kronos responded similarly to soil water depletion.

Delaying irrigation had the effect of increasing grain protein content. This could have occurred due to loss of nitrogen from the soil from leaching or denitrification with increased irrigation frequency. Protein dilution could have been a factor since grain yield increased with more frequent irrigation. Soil water depletion had a similar effect on HVAC as grain protein for Kronos, but not for Westbred 881, which is inherently high in HVAC. Irrigating at higher depletion levels decreased test weight kernel weight. Test weight is an indirect measure of kernel size and density, and shriveled kernels can result in low test weight as these results demonstrate. More frequent irrigation resulted in more kernels per head. Irrigation at 80% soil water depletion resulted in the lowest number of heads per square foot.

In conclusion, irrigating at 50% soil water depletion or less was required to optimize wheat grain yield in this study.

Acknowledgements

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Table 1. Irrigation and nitrogen application dates and amounts for the various soil water depletion levels.

Treatment	Date	Irrigation Applied	Nitrogen Applied
		inches	lbs/acre
35% P.A.W. Depletion	12/2/99	4	106
	1/25/00	4	25
	2/7/00	3	0
	3/1/00	3	50
	3/24/00	3	25
	4/10/00	3	0
	4/24/00	4	0
	Total	24	206
50% P.A.W. Depletion	12/2/99	4	106
	1/25/00	4	25
	2/17/00	3	50
	3/21/00	4	25
	4/13/00	4	0
	4/24/00	4	0
	Total	23	206
65% P.A.W. Depletion	12/2/99	4	106
	1/25/00	4	25
	2/28/00	4	75
	4/6/00	5	0
	4/24/00	4	0
	Total	21	206
80% P.A.W. Depletion	12/2/99	4	106
	1/25/00	4	25
	3/8/00	4	100
	4/24/00	4	0
	Total	16	231

Table 2. Climatic data for Maricopa for the 1999 – 2000 growing season compared to the long-term average.

Climate variable	Year(s)	Dec	Jan	Feb	Mar	Apr	May
Max Temp. (ºF)	1999-00	67	71	73	75	89	99
	Avg. ‡	67	68	71	76	84	93
Min Temp. (ºF)	1999-00	32	36	39	44	52	61
	Avg. ‡	36	35	37	42	47	55
Ppt. (in)	1999-00	0.00	0.00	0.00	1.97	0.00	0.00
	Avg. ‡	1.53	0.59	0.83	0.67	0.39	0.11

‡Averages based on data summarized by Western Regional Climate Center from 1961-1990.

Table 3. Grain yield and kernel characteristics as affected by soil water depletion at irrigation (as a % of plant available water) for Westbred 881 and Kronos.

Variety	Soil water depletion	Grain yield	Grain protein	Test weight	Kernel weight	Kernels per head	Heads per ft^2	HVAC
	%	lbs/acre	%	lb/bu	g/1000			%
WPB881	35	6367 a*	12.1 a	62.8 a	51.2 a	39.0 a	35.1 a	98.9 a
	50	6332 a	14.0 b	61.0 b	47.1 ab	33.5 ab	40.9 a	99.5 a
	65	5165 b	14.0 b	61.7 b	46.1 b	29.0 ab	42.6 a	100 a
	80	2797 c	17.4 c	58.4 c	36.4 c	32.0 b	25.6 b	99.3 a
Kronos	35	7207 a	11.2 a	61.9 a	46.5 a	51.9 a	31.2 ab	82.0 a
	50	6656 a	12.1 ba	60.8 ab	44.6 ab	44.4 ab	34.4 ab	91.5 ab
	65	5755 b	13.0 b	61.0 a	42.8 ab	3636 b	40.3 a	98.9 b
	80	3336 c	16.7 c	59.4 b	39.6 b	32.0 b	30.1 b	100 b
Average	35	6787 a	11.61 a	62.3 a	48.8 a	45.4 a	33.1 bc	90.5 a
	50	6494 a	13.01 b	60.9 b	45.9 ab	38.9 ab	37.6 ab	95.5 ab
	65	5460 b	13.49 b	61.3 ab	44.4 b	32.8 b	41.5 a	99.5 b
	80	3067 c	17.04 c	58.9 c	38.0 c	32.0 b	27.8 c	99.6 b

* Means followed by the same letter are not significantly different according to an F-test protected LSD at P=0.05.