Durum Response to Soil Water Depletion Levels

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Abstract

Research has not been conducted in Arizona 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 6479, 5099, 4283, and 4145 lbs/acre for the 35, 50, 65, and 80% depletion levels, respectively. The results of this study indicate that more frequent irrigations may be required than is typically practiced to optimize wheat grain yields in Arizona. This work will be repeated during the 1999-2000 growing season and the results from both years will be evaluated before general conclusions are drawn.

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.

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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 1998-99 growing season. Two durum varieties, Westbred 881 and Kronos, were planted on 1 December 98 at a rate of 175 lbs seed/acre in alternating strips the width of a grain drill. An irrigation to germinate the seed was applied on 2 December 98. The first post-emergence irrigation was applied uniformly over the entire field on 22 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 13.5 ft. wide and 430 ft. long. The main plots, or irrigation treatments, were 27 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 24 January 99, 2 days after an irrigation, 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 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 26 May 99 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.

Results and Discussion

The growing season weather compared to the long-term average is presented in Table 2. The lack of precipitation was the most striking characteristic of the 1998-99 wheat growing season. The growing season was also relatively warm from January through March and relatively cool in April, especially during the first half of the month.

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 35% for each variety and averaged over varieties. The lowest yield was obtained at 65 and 80% depletion averaged over varieties, and yield at 50% depletion was intermediate. Westbred 881 was more sensitive to slight water stress than Kronos. Irrigating at 50% rather than 35% depletion resulted in a 28% yield decline of Westbred 881 but only a 14% yield decline in Kronos. This is consistent with anecdotal evidence that Westbred 881 requires a higher level of management than other durum varieties to reach its yield potential.

Delaying irrigation until soil water reached 65 or 80% depletion had the effect of increasing grain protein content. This could have occurred due loss of nitrogen from the soil from leaching or denitrification with increased irrigation frequency. Protein dilution could have been a factor since grain yield at 35 and 50% depletion was greater than at 65 or 80% depletion. In fact, grain protein on a per acre basis of the 35 and 50% depletion levels was actually 18% greater than the 65 and 80% depletion levels. 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. Soil water depletion had a small and variable effect on test weight, but generally, irrigating at high depletion levels increased test weight. Test weight is an indirect measure of kernel size and density, and shriveled kernels can result in high test weight as these results demonstrate. Kernel weight was highest for the 50 and 65% depletion levels and lowest for the 35 and 80% depletion levels. The low kernel weight at 80% depletion could have occurred due to the direct effect of water stress on carbohydrate accumulation in the kernel. The low kernel weight at 35% depletion, however, occurred due to yield component compensation. Kernels per unit area was increased in this treatment either due to increased heads per unit area or increased kernels per head.

The results of this study indicate that more frequent irrigations may be required to optimize wheat grain yields in Arizona. On a practical level, this means that during peak water use, wheat may require water as often as every 10 days depending on soil type rather than every 2 weeks or longer as is commonly practiced. This work will be repeated during the 1999-2000 growing season and the results from both years will be evaluated before general conclusions are drawn.

Acknowledgements

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

		Irrigation water applied				Nitrogen fertilizer applied			
		Soil water depletion at irrigation (%)				Soil water depletion at irrigation (%)			
Date	Stage	35	50	65	80	35	50	65	80
		-------------------- inches --------------------				----------------- lbs N/acre -----------------			
01 Dec	Planting	4	4	4	4	106	106	106	106
22 Jan	Tiller	4	4	4	4	25	25	25	25
08 Feb	Joint	3	--	--	--	0	--	--	--
12 Feb	Joint	--	3	--	--	--	50	--	--
23 Feb	Joint	3	--	4	--	50	--	75	--
01 Mar	Joint	--	4	--	5	--	50	--	100
10 Mar	Boot	3	--	--	--	50	--	--	--
22 Mar	Flower	--	4	5	--	--	25	50	--
29 Mar	Flower	3	--	--	5	25	--	--	25
19 Apr	Dough	4	4	--	--	0	0	--	--
22 Apr	H. dough	--	--	5	--	--	--	0	--
26 Apr	H. dough	--	--	--	5	--	--	--	0
Sum		24	23	22	23	256	256	256	256
# of applications		7	6	5	5	5	5	4	4

Table 2. Climatic data for Maricopa for the 1998-99 growing season compared to the long-term average.

Climate variable	Year(s)	Dec	Jan	Feb	Mar	Apr	May
Max Temp. (ºF)	1998-99	66	70	73	78	78	93
	Avg. ‡	67	68	71	76	84	93
Min Temp. (ºF)	1998-99	34	35	39	44	46	57
	Avg. ‡	36	35	37	42	47	55
Ppt. (in)	1998-99	0.28	0.00	0.16	0.04	0.99	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 level at irrigation for Kronos and Westbred 881.

Variety	Soil water depletion at irrigation	Grain yield	Grain protein	Test weight	1000 kernel weight	HVAC
	% of plant available water	lbs/acre	%	lb/bu	g	%
Kronos	35	6736 a	11.19 a	62.5 ab	50.8 a	82.2 a
	50	5670 b	11.93 a	62.1 a	54.4 b	89.8 a
	65	4443 c	13.81 b	62.8 ab	54.5 b	99.5 b
	80	4131 c	13.53 b	63.1 b	51.6 a	98.2 b
Westbred 881	35	6222 a	12.28 a	61.9 ab	48.4 a	97.9 a
	50	4527 b	12.78 a	61.5 a	51.7 b	98.8 a
	65	4124 c	14.72 b	62.4 b	52.1 b	99.2 a
	80	4160 bc	14.08 b	62.6 b	50.2 ab	99.8 a
Average	35	6479 a	11.73 a	62.2 ab	49.6 a	90.1 a
	50	5099 b	12.35 a	61.8 a	53.0 bc	94.3 ab
	65	4283 c	14.26 b	62.6 ab	53.3 c	99.4 b
	80	4145 c	13.80 b	62.8 b	50.9 ab	99.0 b