Critical Growth Stages for Water Stress in Durum, 2001

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Abstract

The purpose of this research was to determine which durum growth stage is most responsive to additional irrigations (based on 35% depletion) when grown at a slightly suboptimal irrigation level of 65% plant available soil water depletion at other growth stages. A field experiment was conducted at the Maricopa Agricultural Center testing the effects of additional irrigations applied during tillering, jointing, or grain fill. Additional irrigations during tillering, jointing, grain fill, or no additional irrigations resulted in grain yields of 5964, 5419, 6301, and 4200 lbs/acre for Kronos and 5440, 5990, 5030, and 4019 lbs/acre for Westbred 881, respectively. The most responsive stage to additional irrigation was grain fill for Kronos and jointing for Westbred 881. The yield response of Kronos to additional irrigation during jointing may have been reduced by severe (78%) lodging in this treatment.

Introduction

Previous work has suggested that durum yield is optimized when irrigation water is applied at plant available soil water depletion of 35% (Husman et al., 1999) or 50% (Husman et al., 2000). Irrigation water may be saved if soil water could be depleted to a greater extent during certain growth stages without reducing yield. The growth of small grains may be divided into three major stages: planting to jointing, jointing to flowering, and flowering to physiological maturity. The most critical growth stage for wheat as far as water stress is concerned may be the jointing stage (Day and Intalap, 1970). Irrigation after flowering had little or no effect on yield in the study of Ottman et al. (2000). The purpose of this research was to determine which major growth stage is most responsive to additional irrigation water when grown at a slightly suboptimal irrigation level of 65% plant available soil water depletion.

Materials and Methods

A durum irrigation study was conducted at the University of Arizona Maricopa Agricultural Center on Field 6 on a Casa Grande Sandy loam soil during the 2000-01 growing season. Two durum varieties, Kronos and Westbred 881, were planted on 29 November 00 at a rate of 155 lbs seed/acre in alternating strips. An irrigation to germinate the seed was applied on 1 December 00. Subsequently, irrigations were applied when 65% of the plant available soil water was depleted except for the period from planting until jointing (tillering), jointing to flowering (jointing), and flowering to physiological maturity (grain fill) when irrigations were applied based on 35% depletion for each of three treatments. The fourth treatment was a control irrigated at 65% depletion throughout the season. 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

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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. A neutron probe calibration obtained in the same field the previous year was used for the experiment this year. 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 of irrigation water applied is presented in Table 1 and the soil water depletion before irrigation is presented in Table 2. Fertilizer was broadcast preplant at a rate of 98 lbs N/acre as ammonium sulfate and 11-52-0 and 100 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 at a rate of 100 lbs N/acre on 13 Feb 2001 (except for the plots where an additional irrigation was applied at tillering which received 50 lbs N/acre on 23 Jan 2001 and 50 lbs N/acre on 13 Feb 2001) and 50 lbs N acre on 28 March 2001. The center 5 feet of each plot was harvested on 24 May 2001 with a small plot combine and grain yield was calculated. Kernel weight was determined from a 10 g sample and test weight was measured using a 1 pint container. Kernels per head were 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 2000-01 durum growing season can be characterized as cool (initially) and wet except for December (Table 2). Precipitation was above average in January, March, and April. The maximum daily temperature was below average in January and February, near average in March and April, and above average in May. Minimum daily temperature was within 1 to 2°F of the long term average except in March, April, and May where it was more than 2°F above average. The relatively cool early season temperatures delayed early crop development.

Additional irrigation increased grain yield and affected other characteristics. Additional irrigation during tillering resulted in an intermediate response, but the response at jointing and grain fill depended on the variety. For Kronos, additional irrigation during grain fill increased grain yield the most while additional irrigation during jointing increased grain yield the least. Additional irrigation during jointing increased height of Kronos; caused severe lodging; reduced test weight, kernel weight, and heads per square foot; and increased kernels per head. For Westbred 881, additional irrigation during grain fill increased grain yield the least and additional irrigation during jointing increased grain yield the most, in contrast to Kronos. Additional irrigation during jointing increased height of Westbred 881 and reduced test weight and kernel weight similar to the response for Kronos, but had no effect on lodging or kernels per head and increased heads per square foot in contrast to Kronos. Grain protein content was highest without additional irrigations, and additional irrigation during grain fill resulted in lower protein than additional irrigation during tillering for Kronos.

Based on previous work, irrigating at 65% depletion was yield-limiting (Husman et al., 1999; Husman et al., 2000). If only a particular growth stage were sensitive to water stress, then irrigating at 65% depletion except at the sensitive stage would reduce water applications. However, the results of this research suggest that all growth stages are responsive to additional irrigation if irrigations are otherwise applied at 65% soil water depletion. The most responsive stage to additional irrigation was grain fill for Kronos and jointing for Westbred 881. One additional irrigation was applied during tillering, whereas two additional irrigations were applied during jointing and grain fill, which may have limited the response at tillering. If Kronos had not lodged, the most responsive stage may have been jointing since the heads were huge in this treatment but the number of heads that developed was reduced.

Acknowledgements

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Table 1. Irrigation dates and amounts for growth stages when additional irrigations applied.

		Irrigation water applied			
		Stages when additional irrigations applied			
Date	Stage	Tillering	Jointing	Grain Fill	None
		---------- inches ----------			
12/1/00	Planting	4	4	4	4
1/23/01	4-5 leaf	4	--	--	--
2/13/01	1 node	3	4	4	4
3/2/01	3 nodes	--	4	--	--
3/22/01	Heading	--	4	--	--
3/29/01	Flowering	4	4	4	4
4/5/01	Watery kernel	--	--	4	--
4/17/01	Milk	--	--	4	--
4/24/01	Soft dough	4	4	4	4
TOTAL		19	24	24	16

Table 2. Plant available soil water depletion levels before irrigation for growth stages when additional irrigations applied.

		Soil water depletion before irrigation			
		Stages when additional irrigations applied			
Date	Stage	Tillering	Jointing	Grain Fill	None
		---------- % of plant available water ----------			
1/22/01	4-5 leaf	37	--	--	--
2/13/01	1 node	44	63	63	63
2/28/01	3 nodes	--	25	--	--
3/21/01	Heading	--	36	--	--
3/28/01	Flowering	63	26	70	64
4/4/01	Watery kernel	--	--	45	--
4/16/01	Milk	--	--	35	--
4/23/01	Soft dough	60	55	29	60

Table 3. Climatic data for Maricopa for the 2000-01 growing season compared to the long-term average.

Climate variable	Year(s)	Dec	Jan	Feb	Mar	Apr	May
Max Temp. (ºF)	2000-01	69	63	68	77	83	100
	Avg. ‡	67	68	71	76	84	93
Min Temp. (ºF)	2000-01	34	36	37	45	51	63
	Avg. ‡	36	35	37	42	47	55
Ppt. (in)	2000-01	0	1.30	0.63	1.06	1.02	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 4. Grain yield and kernel characteristics as affected by additional irrigation at various stages for Kronos and Westbred 881.

Variety	Additional irrigation	Grain yield	Test weight	Grain protein	HVAC	Kernel weight	Kernels per head	Heads per ft^2	Plant Height	Lodging
	stage	lbs/acre	lb/bu	%	%	g/1000			inches	%
Kronos	Tillering	5964 ab	61.0 b	15.2 a	100 a	51.2 b	35.1 c	34.7 a	31.8 b	0.0 a
	Jointing	5419 b	57.4 c	14.8 ab	100 a	38.9 d	66.8 a	21.9 c	37.8 a	77.5 b
	Grain fill	6301 a	62.6 a	14.3 b	100 a	55.7 a	45.5 b	25.9 bc	29.5 c	1.3 a
	None	4200 c	58.3 c	16.7 c	100 a	45.3 c	36.8 bc	27.3 b	30.0 c	0.0 a
WPB 881	Tillering	5440 ab	61.7 a	15.2 a	100 a	52.4 b	37.6 a	29.3 a	32.5 b	0.0 a
	Jointing	5990 a	58.5 c	15.4 a	100 a	41.5 d	41.8 a	36.4 b	39.0 a	5.0 a
	Grain fill	5030 b	61.8 a	15.0 a	100 a	57.3 a	34.9 a	26.5 a	30.5 c	0.0 a
	None	4019 c	60.0 b	16.7 b	100 a	48.0 c	35.5 a	24.9 a	31.3 bc	0.0 a
Avg.	Tillering	5702 a	61.3 a	15.2 a	100 a	51.8 b	36.3 a	32.0 a	32.1 a	0.0 a
	Jointing	5704 a	58.0 c	15.1 a	100 a	40.2 d	54.3 b	29.2 ab	38.4 b	41.3 b
	Grain fill	5665 a	62.2 a	14.7 a	100 a	56.5 a	40.2 a	26.2 b	30.0 a	0.6 a
	None	4110 b	59.2 b	16.7 b	100 a	46.7 c	36.1 a	26.1 b	30.6 a	0.0 a

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