Late Season Water and Nitrogen Effects on Durum Quality, 1996

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Abstract

Durum grain quality is affected by many factors, but water and nitrogen are factors that the grower can control. The purpose of this research was to determine 1) the nitrogen application rate required at pollen shed to maintain adequate grain protein levels if irrigation is excessive or deficient during grain fill and 2) if nitrogen applications during grain fill can elevate grain protein. Field research was conducted at the Maricopa Agricultural Center using the durum varieties Duraking, Minos, and Turbo. The field was treated uniformly until pollen shed when nitrogen was applied at rates of 0, 30, and 60 lbs/acre. During grain fill, the plots were irrigated based on 30, 50, or 70% moisture depletion. In a separate experiment, nitrogen fertilizer was applied at a rate of 30 lbs N/acre at pollen shed only, pollen shed and the first irrigation after pollen shed, and pollen shed and the first and second irrigation after pollen shed. Increased irrigation frequency during grain fill decreased HVAC from 93 to 81%. Increasing nitrogen rate at pollen shed from 0 to 30 and 30 to 60 lbs N/acre increased protein from 11.6 to 12.5% and 12.5 to 13.3% and increased HVAC from 79 to 89% and 89 to 94%. Nitrogen fertilizer application at the first irrigation after pollen shed increased grain protein content from 12.9 to 13.6% and application at the first and second irrigation after pollen shed increased grain protein content further to 14.1% averaged over varieties. Nitrogen fertilizer application during grain fill may not be too late to increase grain protein content.

Introduction

The biggest problem facing the durum industry in Arizona is producing an acceptable quality of grain for pasta-making. Many factors influence durum grain quality such as the cultivar and growing season weather, but only nitrogen and water management can be controlled after planting by the grower. Nitrogen fertilizer management plays a major role in the production of high quality grain. Applications of nitrogen fertilizer during early stages affects yield while applications near pollen shed increase grain protein levels. An application of 30 pounds of nitrogen per acre is recommended near pollen shed to ensure acceptable grain protein levels according to current University of Arizona guidelines. This recommendation assumes that irrigations during the grain fill period will be applied according to crop requirements and that yields will be "normal". Excessive irrigations can reduce nitrogen availability due to leaching and lack of oxygen in the soil, and lead to reduced grain protein concentration. High yields tend to dilute the protein accumulated in the grain and reduce protein concentration.

This research was undertaken to answer the following questions: 1) Will an application of 30 pounds of nitrogen fertilizer per acre at pollen shed ensure acceptable grain quality if irrigations during grain fill are inadequate or excessive? and 2) Can nitrogen fertilizer applications during the grain fill period elevate grain protein concentration in anticipation of high yields?

Procedure

Field studies were conducted at the Maricopa Agricultural Center on Field 109, a Casa Grande Sandy Loam. The previous crop in the field was cauliflower on half and cantaloupe on the other half. Preplant fertilizer was applied at the rate of 60 lbs N/acre and 75 lbs P_2O_5/acre as 16-20-0. Duraking, Minos, and WestBred Turbo were planted into dry soil and irrigated up on November 17, 1995. The seed was planted with a grain drill in 12 ft. wide strips. The seeding rate was 120 pounds of seed per acre. The plots were 12 ft. x 50 ft.

Irrigation water and nitrogen fertilizer were applied at similar rates until pollen shed (see Tables 1 and 2). Starting at pollen shed, two experiments were conducted to determine: 1) the influence of irrigation during grain fill on the effectiveness of nitrogen applications at pollen shed and 2) the influence of nitrogen applications during grain fill on grain protein. Experiment 1 was designed as a split-split plot with four replications and irrigation levels during grain fill as main plots, varieties as subplots, and nitrogen rate at pollen shed as sub-subplots. Irrigation levels maintained during grain fill were 30, 50, and 70% soil moisture depletion as determined by neutron probe readings. The amount of water applied for each irrigation level during grain fill was based on the soil moisture depletion and assuming an irrigation efficiency of 0.7. A larger volume of water than necessary to replace depleted moisture was applied to the 30% treatment in order to get water down to the end of the field. Duraking, Minos, and Turbo were the varieties and nitrogen was applied at pollen shed at rates of 0, 30, and 60 lbs N/acre. Experiment 2 was designed as a split plot with varieties as main plots and nitrogen application during grain fill as subplots. Nitrogen was applied at a rate of 30 lbs N/A at pollen shed only, pollen shed plus the first irrigation after pollen shed, and pollen shed plus the first and second irrigation after pollen shed.

The plots were harvested with a small plot combine on May 28, 1996. The harvested area was 5 ft. x 45 ft. The grain was weighed, moisture determined, and grain yield was calculated on a 10% moisture basis. Grain protein was estimated by multiplying 5.7 by total grain nitrogen determined by the Kjeldahl method and adjusting to 12% moisture. Hard vitreous amber count was determined from a 10 g sample and expressed as % by weight. Plant height and lodging were measured before harvest. Pollen shed was defined as the first day of pollen shed and physiological maturity date was defined as the point when the glumes turn color. Whole plant samples were removed from an 8 ft^2 area for the variety Turbo. Harvest index was determined from these samples, and straw, total yields, and nitrogen uptake calculated.

Discussion

Increased frequency of irrigation during grain fill increased test weight, decreased HVAC, increased lodging, and delayed maturity (Table 3). In an identical study conducted last year, irrigation had no effect on HVAC and nitrogen at pollen shed increased HVAC and protein as occurred this year. Turbo was especially susceptible to low HVAC with increased irrigation frequency during grain fill. Varietal differences were detected for grain yield and various kernel and plant characteristics. Nitrogen rate at pollen shed increased protein, HVAC, and lodging and decreased plant height. Grain protein in Turbo did not increase as much with nitrogen rate as other varieties, especially at medium and high water frequencies. Grain protein in Duraking did not increase with nitrogen rate as much as the other varieties especially at long irrigation intervals. Total and grain nitrogen uptake for the variety Turbo were increased by nitrogen rate at anthesis (Table 4).

Nitrogen application during grain fill increased test weight, grain protein content, and hard vitreous amber count, but did not affect grain yield (Table 5). Late season nitrogen application did not affect HVAC of Minos or Duraking, but did affect HVAC of Turbo. Straw and total plant yield and nitrogen uptake for the variety Turbo were not affected by late season nitrogen application (Table 6).

Acknowledgments

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Table 1. Schedule of nitrogen fertilizer application.

			Irrigation x Nitrogen Experiment			Late Season Nitrogen Experiment		
			lbs N/acre at pollen shed			30 lbs N/acre at		
Date	Stage	Form of nitrogen	0	30	60	Pollen shed only	Pollen shed and 1st irrigation after pollen shed	Pollen shed and 1st and 2nd irrigation after pollen shed
			---------- lbs N/acre ----------					
17 Nov	Planting	16-20-0	60	60	60	60	60	60
11Jan	5-6 leaf	$CaNO_3$	100	100	100	100	100	100
21 Mar	Pollen shed + 3 d	$CaNO_3$	0	30	60	30	30	30
01 Apr	+ 14 d	$CaNO_3$	0	0	0	0	30	30
15 Apr	+ 28 d	$CaNO_3$	0	0	0	0	0	30
SUM	Season		160	190	220	190	220	250

Table 2. Irrigation schedule.

Irrigation x Nitrogen Experiment									Late Season Nitrogen Experiment		
Post pollen shed soil moisture depletion											
30%			50%			70%			50%		
Date	Stage	Inches	Date	Stage	Inches	Date	Stage	Inches	Date	Stage	Inches
17 Nov	Planting	4.0	17 Nov	Planting	4.0	17 Nov	Planting	4.0	17 Nov	Planting	4.0
11 Jan	5-6 leaf	3.4	11 Jan	5-6 leaf	3.4	11 Jan	5-6 leaf	3.4	11 Jan	5-6 leaf	3.4
15 Feb	2 nodes	4.0	15 Feb	2 nodes	4.0	15 Feb	2 nodes	4.0	15 Feb	2 nodes	4.0
04 Mar	Late boot	4.0	04 Mar	Late boot	4.0	04 Mar	Late boot	4.0	04 Mar	Late boot	4.0
13 Mar	Heading	4.0	13 Mar	Heading	4.0	13 Mar	Heading	4.0	13 Mar	Heading	4.0
21 Mar	Pollen shed + 3d	4.0	21 Mar	Pollen shed + 3d	4.0	21 Mar	Pollen shed + 3d	4.0	21 Mar	Pollen shed + 3d	4.0
29 Mar	+11 d	3.0	01 Apr	+ 14 d	4.0	08 Apr	+ 21 d	5.6	01 Apr	+ 14 d	4.0
04 Apr	+ 17 d	3.0	15 Apr	+ 28 d	4.0	24 Apr	+ 36 d	5.6	15 Apr	+ 28 d	4.0
11 Apr	+ 24 d	3.0	25 Apr	+37 d	4.0				25 Apr	+37 d	4.0
18 Apr	+ 30 d	3.0									
25 Apr	+ 37 d	3.0									

Table 3. Irrigation, variety, and nitrogen application at pollen shed effects on grain yield and various grain and plant characteristics.

Irrigation during grain fill	Variety	Nitrogen at Pollen shed	Grain Yield[1]	Test Weight	1000 Kernel Weight	Grain Protein[2]	Hard Vitreous Amber	Plant Height	Lodging	Pollen shed	Physio-logical Maturity
% depletion		lbs/acre	lbs/acre	lb/bu	g	%	%	inches	%		
30	Duraking	0	7752	63.7	49.8	11.6	77	36.4	0	3/17	4/29
30	Duraking	30	7468	63.6	47.7	12.0	88	35.4	0	3/17	4/29
30	Duraking	60	7496	63.8	50.0	12.3	92	35.9	0	3/17	4/29
30	Minos	0	6164	64.3	52.0	12.3	82	39.9	68	3/12	4/27
30	Minos	30	6424	63.9	53.3	13.4	88	38.9	68	3/12	4/27
30	Minos	60	5680	63.8	42.1	14.4	92	38.4	68	3/12	4/27
30	Turbo	0	7520	62.8	54.3	10.4	58	41.8	5	3/22	5/02
30	Turbo	30	8662	63.1	53.3	11.3	72	41.3	3	3/22	5/02
30	Turbo	60	7747	63.0	56.1	12.3	84	41.8	13	3/22	5/02
50	Duraking	0	6870	63.5	47.7	11.2	74	35.4	0	3/17	4/29
50	Duraking	30	7240	63.9	50.0	12.1	84	35.4	0	3/17	4/29
50	Duraking	60	7287	63.5	48.5	13.5	97	34.4	0	3/17	4/29
50	Minos	0	6377	64.4	51.9	12.0	87	40.4	18	3/14	4/27
50	Minos	30	6230	64.2	53.2	13.5	95	40.4	23	3/14	4/27
50	Minos	60	6216	63.7	51.5	14.0	98	39.4	50	3/14	4/27
50	Turbo	0	7818	63.2	53.7	11.5	74	41.8	8	3/24	5/03
50	Turbo	30	7932	63.0	53.7	11.6	83	40.4	5	3/24	5/03
50	Turbo	60	7373	63.2	55.4	12.2	92	40.8	5	3/24	5/03
70	Duraking	0	6486	63.2	44.7	11.7	85	36.4	0	3/20	4/27
70	Duraking	30	6533	63.0	46.7	12.5	98	36.3	0	3/20	4/27
70	Duraking	60	7126	62.9	47.5	13.6	99	35.4	0	3/20	4/27
70	Minos	0	6320	63.7	50.1	12.4	88	41.3	13	3/15	4/22
70	Minos	30	5694	63.7	49.0	13.4	97	41.3	35	3/15	4/22
70	Minos	60	5860	63.0	49.5	14.6	98	40.4	40	3/15	4/22
70	Turbo	0	6846	61.9	49.2	11.3	85	41.3	0	3/23	4/29
70	Turbo	30	7164	61.8	50.0	12.3	96	40.8	3	3/23	4/29
70	Turbo	60	6937	62.3	50.6	12.7	97	41.3	5	3/23	4/29
LSD (5%)[3]			728	0.6	6.5	1.4	13	3	17	—	—
30	All	All	7213	63.5	50.9	12.2	81	38.9	25	3/17	4/30
50	All	All	7038	63.6	51.7	12.4	87	38.7	12	3/18	4/30
70	All	All	6552	62.8	48.6	12.7	93	39.4	11	3/20	4/26
LSD (5%)			NS	0.5	NS	NS	5	NS	6	NS	3
All	Duraking	All	7140	63.4	48.1	12.3	88	35.7	0	3/18	4/28
All	Minos	All	6107	63.8	50.3	13.3	92	40.0	42	3/14	4/25
All	Turbo	All	7556	62.7	52.9	11.7	82	41.3	5	3/23	5/01
LSD (5%)			266	0.5	3.0	0.5	6	0.6	11	2	1
All	All	0	6906	63.4	50.4	11.6	79	39.4	12	3/18	4/28
All	All	30	7039	63.4	50.8	12.5	89	38.9	15	3/18	4/28
All	All	60	6858	63.3	50.1	13.3	94	38.7	20	3/18	4/28
LSD (5%)			NS	NS	NS	0.2	3	0.5	5	—	—

Table 3. (con'd) Irrigation, variety, and nitrogen application at pollen shed effects on grain yield and various grain and plant characteristics.

	Grain Yield[1]	Test Weight	1000 Kernel Weight	Grain Protein[2]	Hard Vitreous Amber	Plant Height	Lodging	Pollen shed	Physio-logical Maturity
Effect					Significance of Effects[4]				
Irrigation	NS	*	NS	NS	**	NS	**	NS	*
Variety	**	**	*	**	*	**	**	**	**
Variety x Irrigation	NS	NS	NS	NS	*	**	**	NS	NS
Nitrogen	NS	NS	NS	**	**	**	**	—	—
Nitrogen x Irrigation	NS	NS	NS	NS	NS	NS	NS	—	—
Nitrogen x Variety	*	*	NS	*	NS	NS	**	—	—
Nitrogen x Irrigation x Variety	NS	NS	NS	**	NS	NS	NS	—	—

1 Grain yield calculated on a 10% moisture basis.

2 Grain protein calculated on a 12% moisture basis.

3 LSD (5%) = least significant difference at the 5% probability level.

4 NS, *, and ** = not significant at the 5% probability level, and significant at the 5% and 1% probability level, respectively.

Table 4. Irrigation, variety, and nitrogen application at pollen shed effects on total yield and nitrogen uptake for the variety Turbo.

Irrigation during grain fill	Nitrogen at Pollen shed	Total Yield[1]	Grain Yield	Straw Yield	Harvest Index	Straw Nitrogen	Total N Uptake	Grain N Uptake	Straw N Uptake	Nitrogen Harvest Index
% deplet.	lbs/acre	lbs/acre	lbs/acre	lbs/acre	%	%	lbs/acre	lbs/acre	lbs/acre	%
30	0	19236	7520	11717	39.2	0.34	179	141	38	78.6
30	30	20984	8662	12321	41.3	0.29	210	176	34	83.7
30	60	20103	7747	12356	38.6	0.38	215	171	44	79.3
50	0	20088	7818	12270	39.0	0.26	191	161	30	84.2
50	30	19701	7932	11769	40.3	0.32	202	165	36	82.1
50	60	17947	7373	10574	41.1	0.27	188	162	27	85.9
70	0	17755	6846	12089	38.8	0.26	166	138	27	83.6
70	30	18929	7164	11973	38.0	0.30	191	157	34	82.5
70	60	18188	6937	11172	38.4	0.34	194	157	36	81.4
LSD (5%)[2]		NS	792	NS	NS	NS	NS	NS	NS	NS
30	All	20108	7976	12131	39.7	0.34	201	162	39	80.5
50	All	19246	7708	11538	40.1	0.28	194	163	31	84.1
70	All	18291	6982	11744	38.4	0.30	183	151	33	82.5
LSD (5%)		NS	734	NS	NS	NS	NS	NS	NS	NS
All	0	19027	7395	12025	39.0	0.29	179	147	32	82.1
All	30	19871	7920	12021	39.9	0.30	201	166	35	82.7
All	60	18746	7352	11367	39.4	0.33	199	163	36	82.2
LSD (5%)		NS	302	NS	NS	NS	13	11	NS	NS
Effect					Significance of Effect[4]					
Nitrogen x Irrigation		NS	NS	NS	*	NS	NS	NS	NS	*

[1] Total, grain, and straw yields calculated on a 10% moisture basis.

[2] LSD (5%) = least significant difference at the 5% probability level.

[3] NS = not significant at the 5% probability level.

[4] NS and * = not significant at the 5% probability level, and significant at the 5% probability level, respectively.

Table 5. Variety and late season nitrogen application effects on grain yield and various grain and plant characteristics.

Variety	Late season nitrogen[1]	Grain Yield[2]	Test Weight	1000 Kernel Weight	Grain Protein[3]	Hard Vitreous Amber	Plant Height	Lodging	Pollen shed	Physiological Maturity
	lbs/acre	lbs/acre	lb/bu	g	%	%	inches	%		
Duraking	30	7657	63.3	48.0	13.0	97	36.9	0	3/16	4/30
Duraking	30+30	7600	63.1	47.6	14.0	99	34.4	0	3/16	4/30
Duraking	30+30+30	7501	63.1	47.9	14.0	99	34.9	0	3/16	4/30
Minos	30	6050	63.9	50.4	13.9	98	38.9	53	3/12	4/26
Minos	30+30	6031	63.8	50.4	14.4	98	39.4	63	3/12	4/26
Minos	30+30+30	5557	63.3	50.6	14.9	99	39.4	58	3/12	4/26
Turbo	30	7890	63.0	53.0	11.8	81	40.8	13	3/24	5/03
Turbo	30+30	7785	63.1	54.0	12.5	94	41.3	20	3/24	5/03
Turbo	30+30+30	7439	62.6	52.0	13.4	98	40.8	13	3/24	5/03
LSD (5%)[4]		658	0.5	1.6	0.9	5	1.9	13	—	—
Duraking	All	7586	63.2	47.8	13.7	98	35.4	0	3/16	4/30
Minos	All	5879	63.6	50.5	14.4	98	39.2	58	3/12	4/26
Turbo	All	7705	62.9	53.0	12.5	91	41.0	15	3/24	5/03
LSD (5%)		603	0.5	1.3	0.5	4	1.7	31	5	3
All	30	7199	63.4	50.5	12.9	92	38.9	22	3/17	4/29
All	30+30	7139	63.3	50.7	13.6	97	38.4	28	3/17	4/29
All	30+30+30	6832	63.0	50.2	14.1	99	38.4	23	3/17	4/29
LSD (5%)		NS	0.2	NS	0.4	3	NS	NS	—	—
Effects						Significance[5]				
Variety		**	*	**	**	**	**	**	**	**
Nitrogen		NS	**	NS	**	**	NS	NS	—	—
Nitrogen x Variety		NS	NS	NS	NS	**	NS	NS	—	—

[1] Late season nitrogen: 30 = 30 lbs N/acre at pollen shed, 30+30 = 30 lbs N/acre at pollen shed and 30 lbs N/acre at the first irrigation after pollen shed, and 30+30+30 = 30 lbs N/acre at pollen shed, 30 lbs N/acre at the first irrigation after pollen shed, and 30 lbs N/acre at the 2nd irrigation after pollen shed.

[2] Grain yield calculated on a 10% moisture basis.

[3] Grain protein calculated on a 12% moisture basis.

[4] LSD (5%) = least significant difference at the 5% probability level.

[5] NS and ** = not significant at the 5% probability level, and significant at the 1% probability level.

Table 6. Yield and nitrogen uptake as affected by late season nitrogen application for the variety Turbo.

Late season nitrogen[1]	Total Yield[2]	Grain Yield	Straw Yield	Harvest Index	Straw Nitrogen	Total N Uptake	Grain N Uptake	Straw N Uptake	Nitrogen Harvest Index
lbs/acre	lbs/acre	lbs/acre	lbs/acre	%	%	lbs/acre	lbs/acre	lbs/acre	%
30	19978	7890	10909	39.6	0.30	201	167	34	83.1
30+30	19758	7785	11765	39.5	0.33	212	174	38	82.1
30+30+30	18611	7439	11251	39.9	0.44	225	179	46	79.3
LSD (5%)[3]	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1] Late season nitrogen: 30 = 30 lbs N/acre at pollen shed, 30+30 = 30 lbs N/acre at pollen shed and 30 lbs N/acre at the first irrigation after pollen shed, and 30+30+30 = 30 lbs N/acre at pollen shed, 30 lbs N/acre at the first irrigation after pollen shed, and 30 lbs N/acre at the 2nd irrigation after pollen shed.

[2] Total, grain, and straw yields calculated on a 10% moisture basis.

[3] LSD (5%) = least significant difference at the 5% probability level.

[4] NS = not significant at the 5% probability level.