NITROGEN FERTILIZATION AND OVERIRRIGATION OF SPRING AND WINTER WHEAT[1]

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When fall or spring wheat is irrigated early in the spring before the available soil moisture is depleted, the yellowing that frequently results is a symptom of reduced crop vigor. Robins and Domingo (1) observed no benefit from irrigating spring wheat before the boot stage unless severe moisture stress developed. They also found that reductions in early vegetative growth and plant height that resulted from drought greatly reduced susceptibility to lodging during and following later irrigations. Although irrigation may be necessary for emergence under extreme drought conditions, Salter and Goode (2) found that water applied before emergence reduced grain yield. They concluded that water stress during the shooting and earing stages of growth, when development of the reproductive organs is taking place, would cause the greatest yield loss.

The experiments reported here show the influence of excessive irrigation and nitrogen fertilization on grain and straw yield, and on protein content of spring- and fall-seeded wheat.

MATERIALS AND METHODS

Nugaines wheat was seeded with a grain drill in rows spaced 6 inches apart in plots 112 by 32 feet on Portneuf silt loam soil October 7, 1966, on the University of Idaho, Twin Falls Branch Agricultural Experiment Station at Kimberly. The treatments were replicated four times and arranged in a split-plot design. The plots were irrigated 1 week after planting. Lemhi wheat was seeded March 28, 1967 in alternate 11- and 13-inch spaced rows with individual planters mounted on a tool bar and the plots were corrugated for irrigation in the wide-spaced rows. Both wheat varieties were fertilized with ammonium nitrate using a calibrated 8-foot spreader on March 27 and 28, 1967. Nitrogen rates were 0, 80, and 160 lbs per acre on the Nugaines and 0, 50, and 100 lbs per acre on the Lemhi wheat.

Three moisture levels were maintained by irrigating when tensiometers placed at 18 inches read 0.65 bars (I_1); when tensiometers placed at 18 inches read 0.45 bars (I_2); and when tensiometers placed at 12 inches read 0.45 bars (I_3) (Table 1). This corresponded to 20, 23, and 25% moisture by weight, and represents use of approximately 50, 30, and 20% of the available water. Irrigation periods were approximately 12 hours each. Water was applied in corrugates 24 inches apart.

The wheat was harvested with a 6-foot self-propelled combine. Grain yields were measured, and straw yields were determined by cutting 30 square feet of each plot with a small sickle-bar mower, weighing, threshing, and subtracting the weight of grain. Protein content of the grain was determined by dye absorption, by Mr. Martin Wise at the University of Idaho Grain Laboratory at Aberdeen, Idaho.

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a multi-step process which first converts the potassium values to a double salt and isolates it prior to conversion to potassium sulfate. The process is carried out under carefully controlled conditions of temperature and brine composition.

Annual capacity of the potassium sulfate plant will be 240,000 tons (125,000 tons K_2O). GSL's product prepared in this manner shows remarkably purity - 52% K_2O equivalent (or higher) with less than 0.1% chloride. Three grades of varying screen sizes will be available: standard, fine and (by mid 1971) granular.

All products are dust free and free flowing. Typical specifications are given in the following table.

POTASSIUM SULFATE

TYPICAL PRODUCT SPECIFICATIONS

Chemical Specifications	Granular	Standard	Fine
K_2O	52.5	53.0	52.5
Cl	0.1	0.1	0.1
H_2O	0.1	0.1	0.1
Physical Specifications (Tyler Standard Sieve Sizes)			
+ 6 Mesh	2%		
+ 8 Mesh	21-25%		
+ 14 Mesh	95%		
+ 20 Mesh		2-16%	
+ 28 Mesh		22-47%	
+ 35 Mesh		62-73%	
+ 48 Mesh		90%	7%
+ 65 Mesh		95%	27-29%
+100 Mesh			47-98%
+150 Mesh			100%
Bulk Density lbs/cft.			
Loose	76	87	84
Tapped	82	97	97
Angle of Repose	39°	35°	35°

Table 1. Irrigation schedule.

	No. Of Irrigations	Date	Approximate water into soil (inches)
		1967	
		Lemhi	
I_1	3	6/5, 6/27, 7/6	18
I_2	5	5/1, 5/22, 6/12, 6/15, 7/7	30
I_3	6	4/27, 5/19, 5/29, 6/12, 6/26, 7/5	36
		Nugaines	
I_1	1	5/22	6
I_2	4	4/14, 5/8, 5/29, 6/9	24
I_3	8	4/10, 5/8, 5/17, 5/23, 5/29, 6/12, 6/26, 7/6	48
		1968	
	No. of Irrigations	Date	Approximate water into soil (inches)
		Lemhi	
I_1	3	6/12, 7/2, 7/18	18
I_2	3	5/23, 6/26, 7/18	18
I_3	4	5/3, 5/22, 6/13, 7/18	24
		Nugaines	
I_1	3	6/4, 6/29, 7/9	18
I_2	5	5/11, 6/7, 6/21, 7/2, 7/9	30
I_3	9	5/2, 5/11, 5/22, 5/31, 6/6, 6/19, 6/29, 7/5, 7/9	54

Treatments for 1968 were the same as 1967 except all the plots were planted with spaced-row planters similar to the Lemhi wheat in 1967. Nugaines was planted November 1, 1967 and Lemhi wheat on March 22, 1968 for harvest in August 1968. Nitrogen was applied March 22, 1968 at 0, 110, and 220 for Nugaines and at 0, 57, and 114 lbs per acre on Lemhi wheat. Temperature and rainfall data for the two growing seasons are given in Table 2. Soil samples were taken periodically during the growing seasons and analyzed for nitrate.

RESULTS AND DISCUSSION

Only the first increment of nitrogen fertilizer significantly increased the grain yields of Lemhi and Nugaines wheat in 1967 (Table 3). The greatest mean grain yields with both the Nugaines and Lemhi wheat varieties were obtained with the least amount of water. In both cases interactions between nitrogen fertilization and irrigation were significant. The I_2 and I_3 treatments decreased yields below the I_1 treatment without added nitrogen and smaller decreases or slight increases in yield resulted for the wetter treatments when nitrogen was added.

For Lemhi wheat, straw yields were significantly increased only by the first increment of nitrogen fertilizer. Mean straw yields were highest with the I_1 treatment, but nitrogen fertilization compensated to some extent for overirrigation on the I_2 and I_3 treatments (Table 4). Straw yields of Nugaines wheat were not significantly influenced by nitrogen or irrigation in 1967.

Table 2. Air temperatures and precipitation during the 1967 and 1968 growing seasons at Kimberly, Idaho. (From ESSA Records).

1967	Precipitation	Largest Single Storm		Air Temperature, F.		
	Inches	Inches	Date	Max.	Min.	Mean
March	1.20	0.39	29	51.5	28.1	39.8
April	1.90	.81	28	51.8	30.7	41.3
May	.58	.31	10	67.1	41.0	54.1
June	2.38	.48	14	72.2	48.2	60.2
July	.29	.16	17	88.8	55.8	72.3
August	.01	.01	27	89.5	54.2	71.8
September	.28	.14	28	79.6	47.2	63.4
October	.94	.48	28	62.6	32.4	47.5
1968						
March	1.00	0.37	17	54.4	29.5	42.0
April	.44	.32	5	55.8	30.7	43.3
May	.93	.31	14	67.4	40.8	54.1
June	.93	.48	9	76.1	49.4	62.8
July	trace			87.9	53.3	70.7
August	3.23	1.27	21	75.8	49.3	62.2

Table 3. 1967 Lemhi and Nugaines grain yields.

N	Grain Yield			
	Irrigations[1]			
Treatment	I_1	I_2	I_3	Mean
lbs/acre	bu/acre			
	Lemhi			
0	66.0	44.9	49.6	53.5 a[2]
50	64.2	54.8	58.5	59.2 b
100	62.0	60.4	64.3	62.2 b
Mean	64.1 b	53.4 a	57.5 a	
	Nugaines			
0	99.1	83.2	82.2	88.2 a
80	100.4	95.3	95.8	97.2 b
160	94.0	101.1	94.2	96.5 b
Mean	97.8 b	93.2 ab	90.7 a	

[1]Irrigations see Table 1.

[2]Duncan multiple range comparisons were applied at the 0.05 significance level.

The highest nitrogen application increased grain protein content in both wheat varieties (Table 5). The two wetter treatments decreased protein content below that found with the I_1 irrigation treatment. No significant interactions were observed between nitrogen and irrigation.

The early growing season in 1967 was excellent for wheat. Wheat stands were excellent, with tillering producing many stems from each wheat plant. A cool moderate season with adequate moisture from irrigation and rainfall developed plants that should have had an outstanding yield potential. A rather

Table 4. 1967 Lemhi and Nugaines straw yields.

N Treatment	Straw Yields: Irrigations[1] I_1	I_2	I_3	Mean
lbs/acre	lbs/acre			
		Lemhi		
0	9,100	3,700	5,600	6,100 a[2]
50	9,600	5,900	6,200	7,200 b
100	8,000	6,400	7,600	7,300 b
Mean	8,900 b	5,300 a	6,500 a	
		Nugaines		
0	11,300	11,400	12,000	11,600 a
80	12,300	11,500	11,600	11,800 a
160	13,000	15,100	12,100	13,400 a
Mean	12,200 a	12,700 a	11,900 a	

Table 5. Protein content of Nugaines and Lemhi wheat in 1967.

N Treatment	Wheat Protein: Irrigations[1] I_1	I_2	I_3	Mean
lbs/acre	percent			
		Lemhi		
0	12.7	9.9	10.8	10.8 a[2]
50	13.1	9.6	9.4	10.7 a
100	13.5	10.9	11.1	11.8 b
Mean	13.1 b	10.1 a	10.0 a	
		Nugaines		
0	9.8	8.8	8.6	9.1 a
80	10.2	9.3	10.3	10.0 a
160	12.6	10.4	10.6	11.2 b
Mean	10.9 b	9.5 a	9.8 a	

[1]Irrigations as shown in Table 1.

[2]Duncan multiple range comparisons were applied at the 0.05 significance level.

abrupt temperature change from daily maxima in the low 70's to average daily maxima near 90 F for the third and fourth weeks of June and the month of July may have produced atmospheric drought that reduced the wheat yield (2). The 1967 wheat yields in the area were generally below normal, presumably because of adverse climatic developments.

Early irrigation of the Lemhi wheat in both the I_2 and I_3 (5/1 and 4/27) treatments appreciably decreased yield when no nitrogen was applied. This first irrigation caused some yellowing and apparently stunted the plants, decreasing their yield. When nitrogen fertilizer was applied, the yellowing did not develop with early irrigation. Nitrate nitrogen measurements in the 0 to 6" soil depth on May 2, 1967 showed 13 to 16 ppm N in the N_1 treatments and 53 to 74 ppm N in the N_3 treatments. On May 25, 7 to 22 ppm N and 32 to 45 ppm N were detected in the same treatments. A trend toward lower nitrate N in the I_3 than the I_1 treatments with no N fertilizer suggests that the yellowing is associated with nitrogen deficiency resulting from leaching nitrate from the immediate root zone of the young Lemhi wheat plants. Nitrification may also have been slowed by lower soil temperatures that resulted from irrigation. Maximum soil temperatures were decreased 4 to 10 degrees and minimum soil temperatures were decreased 2 to 4 degrees F for 7 days following irrigation on May 3, 1968.

Soft white wheat that is used for milling pastry flour should have a protein content below about 9.5 to 10.0% for best baking characteristics. Soil fertility on the Lemhi wheat plots was high enough to produce wheat with higher than optimum protein content. Excessive irrigation decreased the protein content in all the I_2 and I_3 treatments but some of them remained higher than optimum. Nugaines wheat also had protein higher than optimum in some treatments. Although excessive irrigation decreased the protein content, a more efficient and desirable method of obtaining lower protein would be to use less nitrogen.

The response to nitrogen in 1968 was good; each increment of nitrogen increased yields of Lemhi wheat, and the first increment increased Nugaines wheat yields (Table 6). Excessive irrigation decreased wheat yields of both varieties. The first irrigation (May 3) of Lemhi wheat caused yellowing and stunting from which the wheat never recovered. When no nitrogen was added, the I_3 treatment decreased Lemhi wheat yields 52% and Nugaines wheat yields about 25%. Nitrogen fertilization almost eliminated yellowing and improved yields of both wheat varieties, compensating for overirrigation. Statistical interactions between irrigation and nitrogen were significant for Lemhi but not for Nugaines wheat. This indicates that the more extensive growth of Nugaines wheat early in the season may have decreased its sensitivity to over-irrigation.

Table 6. 1968 Lemhi and Nugaines grain yields.

N Treatment	Grain Yield: Irrigations[1] I_1	I_2	I_3	Mean
lbs/acre	bu/acre			
		Lemhi		
0	64.9	55.9	30.8	50.5 a[2]
57	67.6	66.7	58.0	64.1 b
114	70.1	75.2	69.0	71.4 c
Mean	67.5 b	65.9 b	52.6 a	
		Nugaines		
0	93.8	96.0	70.3	86.7 a
110	119.2	120.6	109.2	116.3 b
220	128.8	124.8	113.6	122.4 b
Mean	113.9 b	113.8 b	97.7 a	

[1]Irrigations as shown in Table 1.

[2]Duncan multiple range test was applied at the 0.05 significance level.

With both wheat varieties, the first increment of nitrogen increased straw yields but the increases from the second increment of nitrogen were not statistically significant (Table 7). As was observed in previous years, the straw yield of Nugaines was about twice as great as that of Lemhi. Yields for both varieties were highest with the intermediate irrigation treatment.

The protein content of both wheat varieties was fairly high, increasing with each increment of nitrogen and decreasing with the I_3 irrigation treatment (Table 8). Interactions between nitrogen and irrigation were significant at the 0.05 significance level for Nugaines but not for Lemhi wheat protein.

Table 7. 1968 Lemhi and Nugaines straw yields.

N	Straw Yields			
	Irrigations[1]			
Treatment	I_1	I_2	I_3	Mean
lbs/acre	lbs/acre			
	Lemhi			
0	3,700	4,100	2,000	3,300 a[2]
57	4,000	4,800	4,000	4,300 b
114	4,200	4,900	4,800	4,600 b
Mean	4,000 a	4,600 b	3,600 a	
	Nugaines			
0	6,200	7,100	5,100	6,100 a
110	7,700	8,500	7,900	8,000 b
220	8,100	8,900	8,800	8,600 b
Mean	7,300 a	8,200 b	7,300 a	

Table 8. 1968 Lemhi and Nugaines wheat protein content.

N	Wheat Protein			
	Irrigations[1]			
Treatment	I_1	I_2	I_3	Mean
lbs/acre	percent			
	Lemhi			
0	11.0	10.2	9.2	10.0 a[2]
57	11.4	11.5	10.0	11.0 b
114	11.8	12.0	10.6	11.5 c
Mean	11.4 b	11.2 b	10.0 a	
	Nugaines			
0	8.2	8.5	8.2	8.3 a
110	10.3	10.3	9.1	9.9 b
220	11.4	11.3	10.3	11.0 c
Mean	10.0 b	10.0 b	9.2 a	

[1] Irrigations as shown in Table 1.

[2] Duncan multiple range test was applied at the 0.05 significance level.

SUMMARY

Nugaines and Lemhi wheat were grown in 1967 and 1968 with three nitrogen fertilization rates and three irrigation treatments each year. When no nitrogen was applied to the Lemhi wheat, the check plots with optimum irrigation (I_1) yielded approximately 65 bu/acre. Irrigating too early (April 27, 1967 or May 3, 1968) caused yellowing and stunting and the wheat yielded 50 bu/acre in 1967 and 31 bu/acre in 1968. Nugaines wheat yields were decreased from 99 to 82 bu/acre in 1967 and from 94 to 70 bu/acre in 1968 on the nitrogen check plots with overirrigation. Wheat yields in 1967 were below normal because of adverse weather conditions in late June and July during flowering and heading. Nitrogen fertilization compensated, for the most part, for excessive irrigation with both wheat varieties and increased yields to those of the best check plots. Maximum yields of 66 and 101 bu/acre in 1967, and 75 and 129 bu/acre in 1968 were obtained with Lemhi and Nugaines wheat by nitrogen fertilization and proper irrigation.

Lemhi wheat straw yields averaged about 6,900 and 4,100 lbs/acre in 1967 and 1968 while Nugaines straw yields were almost twice as great with 12,250 and 7,600 lbs/acre in 1967 and 1968. These large straw yields should effectively maintain soil organic matter but may require special handling and management in relation to the crop following wheat.

Heavy nitrogen fertilization treatments increased wheat protein levels above the 9.5 to 10.0 percent desirable for best baking quality in soft white wheat used for pastry. Overirrigation decreased wheat protein. A more desirable method of decreasing wheat protein would be to use less nitrogen fertilizer.

LITERATURE CITED

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