Effect of Fertilizer Nitrogen Rate on Yield of Six Spring Wheats

Armand Bauer

A study was initiated in 1968 to determine the effect of fertilizer nitrogen rate on responses of spring wheat varieties grown under irrigation at the Carrington Irrigation Station. Unfortunately, the trial was destroyed by hail on July 23. The study was expanded in 1969, both with respect to numbers of wheat varieties included in the trial and by the expansion to a dryland series, and was conducted at the Carrington Irrigation Station.[1]

[1]The cooperation and assistance of personnel at the Carrington Station is acknowledged and appreciated.

Dr. Bauer is professor, Department of Soils.

Numerous fertilizer nitrogen rate trials have been conducted in North Dakota over the past 20 years with wheat (1, 2, 4, 5). These have indicated the approximate fertilizer nitrogen (N) rates needed to eliminate available nitrogen as a yield-limiting factor. These trials were conducted on dryland, albeit under very favorable moisture conditions in some cases, and did not include variety as a variable. These show that yield responses to rates higher than 60 pounds of nitrogen (N) occurred on very few occasions.

With the advent of shorter-strawed varieties, higher fertilizer rates are being advocated, especially of nitrogen, on the premise that higher yields will be realized from the new varieties because of improved genetic potential for higher yield and because these varieties are considered less prone to lodging and hence can "withstand" higher rates. An objective of the study was to test these premises by eliminating known yield-limiting factors that can be controlled by management.

Because of interest in new wheat varieties and the general lack of information about their response to so-called "high fertility levels," some of the pertinent data obtained in 1969 are reported. Additional data on other aspects of the study have been accumulated and some other analyses are not completed.

Methods

Five rates of nitrogen (N) 0, 50, 100, 150, and 200 pounds per acre from ammonium nitrate (34-0-0)[2] were applied to six varieties, Waldron, Ciano, Red River 68,[3] World Seeds 1812,[3] Bonanza (Dekalb 4114-A),[4] and Inia. The study was conducted on dryland and under irrigation on Heimdal silt loam cropped to flax in 1968.

Phosphorus and potash were broadcast in the spring at a rate supplying about 109 pounds P_2O_5 and 60 pounds K_2O per acre and plowed down. An additional 43 pounds P_2O_5 and 22 pounds K_2O per acre were applied by drill attachment at planting on May 5. Nitrogen was broadcast after seeding. Plots on which 50 and 100 pounds nitrogen (N) were applied received the amount on May 5; plots on which 150 and 200 pounds nitrogen (N) were applied received 100 pounds on May 5 and the remainder on June 10.

Seeding rate was the same for all varieties in terms of number of viable seeds per acre. Seeds were spaced an average of 1 to 1½ inches within the row; rows were seven inches apart. Each plot was 6½ feet wide and 22 to 25 feet long. Each treatment was repeated four times. Plots were seeded with a common drill.

Soil samples to 24 inches were taken from six holes at the experimental site for a soil nitrate test. The nitrate-nitrogen level averaged 45 pounds per acre, expressed as the element.

Access tubes were installed in six dryland and six irrigated plots. Soil moisture information was obtained with a neutron probe 6 times during the season to soil depths of 60 inches. The average available soil moisture content at the 6 to 48-inch depth at seeding was about 5.9 inches on irrigated plots and 3.5 inches on dryland. Irrigation water was applied three times by sprinkler; a total of six inches. Dates of irrigation were June 7 (2½ inches), July 15 (2 inches), and July 29 (1½ inches). Both the dryland and irrigated plots received about 10.9 inches rainfall during the growing season.

Herbicides and fungicides were applied to all plots.

Stand counts were made on June 10 and 11. Plants were counted in the center three rows, each three feet long.

Plant height measurements were made on July 28, three measurements per plot.

Yield was determined from four square yard samples per plot harvested by hand.

Total nitrogen content of the grain, the basis for determining protein, was determined by the Kjeldahl method by the Department of Cereal Chemistry and Technology.

Ergot count was made after grain was cleaned on the grain harvested for yield determination.

The data were analyzed statistically as a split-plot. Data from irrigated plots were analyzed separately from dryland. Duncan's range test was used to test differences among means. The 5 per cent confidence level was used as the standard of significance (the odds are at least 19 out of 20 that differences are due to the variable tested rather than chance).

Results

Data of plant population are shown in Table 1 and are in terms of number of plants per 9 feet of row.

Population differed among varieties under dryland conditions. A population of 70 plants per 9 feet of row is approximately 581,000 plants per acre.

Plant height measurements were made on July 28; the crop was in the heading stage. Data are presented in Table 2.

The data in Table 2 show that Waldron was taller than the other varieties both under irrigation and on dryland, followed by Red River 68. Plant height was increased by fertilizer nitrogen; the maximum increase averaged from 1 to 2 inches.

Estimates of the incidence of lodging were made on August 7. No attempt was made to evaluate the degree of lodging. The data in Table 3 indicate the number of replications in which lodging occurred.

[2]Supplied by Cominco American, Inc.
[3]Supplied by Agsco, Inc., Grand Forks, North Dakota.
[4]Supplied by DeKalb Agriculture Research, Inc., Fargo, North Dakota.

Table 1. Number of wheat plants per 9 feet of row, counted June 10-11.

Management	Variety	Number of plants: Nitrogen (N) rate, pounds per acre 0	50	100	150	200	Average
Irrigated	Waldron	71	73	77	75	69	73
	Ciano	70	73	73	68	82	73
	Red River 68	76	79	67	71	74	73
	World Seeds 1812	73	72	66	83	75	74
	Bonanza	74	81	85	66	80	77
	Inia	70	74	69	68	67	69
	Average	72	75	73	72	74	
Dryland	Waldron	82	76	74	70	73	75 d[1/]
	Ciano	70	73	72	65	64	69 b
	Red River 68	65	75	72	68	73	70 b
	World Seeds 1812	72	72	80	67	73	73 c
	Bonanza	67	75	67	61	65	69 b
	Inia	61	70	67	70	68	67 a
	Average	70	73	72	67	69	

[1/] Based on statistical analysis, numbers in the column followed by the same letter do not differ at the 5% confidence level.

Table 2. Height of wheat grown on dryland and irrigated Heimdal silt loam as influenced by fertilizer nitrogen rate.

Management	Variety	Plant height (inches): Nitrogen (N) rate, pounds per acre 0	50	100	150	200	Average
Irrigated	Waldron	34	36	37	36	36	36 c [1/]
	Ciano	27	29	29	30	28	29 a
	Red River 68	29	31	31	31	30	31 b
	World Seeds 1812	28	29	30	29	29	29 a
	Bonanza	28	29	31	30	30	29 a
	Inia	28	29	29	30	28	29 a
	Average	29 a[1/]	31 b	31 b	31 b	30 ab	
Dryland	Waldron	32	34	35	34	34	34 e
	Ciano	25	27	27	29	27	27 a
	Red River 68	29	29	31	31	31	30 d
	World Seeds 1812	28	29	29	28	30	29 c
	Bonanza	27	28	28	29	29	28 b
	Inia	26	26	28	29	27	27 a
	Average	28 a	29 ab	30 b	30 b	30 b	

[1]Numbers followed by the same letter in the "average" column or row do not differ from each other at the 5% confidence level.

Table 3. Number of replicates in which lodging of wheat occurred as influenced by fertilizer nitrogen rate.

Management	Variety	Lodging incidence Nitrogen (N) rate, pounds per acre 0	50	100	150	200
Irrigated	Waldron	0	0	0	1	2
	Ciano	0	0	0	1	0
	Red River 68	0	0	2	3	4
	World Seeds 1812	0	0	0	0	2
	Bonanza	0	3	1	4	4
	Inia	0	0	0	0	0
Dryland	Waldron	0	0	0	0	0
	Ciano	0	0	0	0	0
	Red River 68	0	0	0	0	0
	World Seeds 1812	0	0	0	0	0
	Bonanza	0	0	0	0	0
	Inia	0	0	0	0	0

Lodging was not observed on dryland on any variety irrespective of fertilizer nitrogen rate. Under irrigation, lodging occurred in Bonanza at the 50-pound nitrogen rate and higher, and on Red River 68 at the 100-pound rate and higher; the incidence of lodging in Ciano and Inia was slight to none.

Grain yield data are presented in Table 4.

Grain yields were increased by 50 pounds of fertilizer nitrogen on all varieties; the average yield increase was almost 22 bushels under irrigation and 13 on dryland. Except for the variety Ciano, grain yields were not increased by higher rates of fertilizer nitrogen (based on statistical analysis). Application of fertilizer nitrogen in greater amounts than needed for maximum response did not effect a yield decrease.

When averaged over all fertilizer nitrogen rates, yields among varieties differed under irrigation but not dryland. Under irrigation, the maximum average yield difference among varieties was about seven bushels.

Table 4. Grain yield of wheat grown on dryland and irrigated Heimdal silt loam as influenced by fertilizer nitrogen rate.

Management	Variety	Grain yield, bushels per acre Nitrogen (N) rate, pounds per acre 0	50	100	150	200	Average
Irrigated	Waldron	30.9 a[1/]	56.3 cdefgh	51.5 bcdef	51.8 bcdef	54.2 cdefg	48.9 ab[2/]
	Ciano	27.4 a	53.3 bcdefg	59.3 efgh	65.2 h	60.5 tgh	53.1 cd
	Red River 68	33.4 a	50.8 bcde	48.4 bc	51.8 bcdef	51.2 bcdef	47.1 a
	World Seeds 1812	33.4 a	51.8 bcdef	57.5 cdefgh	57.2 cdefgh	49.4 bcd	49.9 abc
	Bonanza	31.4 a	57.0 cdefgh	58.7 defgh	56.0 cdefgh	54.5 bcdefgh	51.5 bc
	Inia	45.8 b	61.3 gh	57.7 cdefgh	56.8 cdefgh	62.4 gh	56.8 d
	Average	33.8 a[2/]	55.1 b	55.6 b	56.5 b	55.4 b	
Dryland	Waldron	35.2	44.1	52.1	52.8	49.5	46.7
	Ciano	32.4	52.3	50.0	53.5	45.6	46.8
	Red River 68	32.9	48.4	54.0	50.2	47.2	46.5
	World Seeds 1812	36.9	47.3	47.3	47.1	42.9	44.3
	Bonanza	38.1	50.7	56.3	55.7	53.5	50.8
	Inia	35.0	45.5	51.3	49.6	44.3	45.1
	Average	35.1 a[2/]	48.1 bc	51.9 c	51.5 c	47.2 b	

1/ Numbers in the table followed by the same letter do not differ at the 5% confidence level. (Exclude the "average" column or row).

2/ Numbers in the "average" column or in the row followed by the same letter do not differ at the 5% confidence level.

Test weight data are shown in Table 5.

Test weight of grain was not altered by the fertilizer nitrogen (N) rate, 50 pounds per acre, that produced yield increase except in the variety Bonanza when grown on dryland. In the case of Bonanza on dryland, test weight decreased. Nitrogen fertilizer applied in larger amounts than needed for yield increases nearly always produced decreases in test weight; the notable exception is Ciano grown under irrigation. The greatest decreases occurred in the variety Bonanza, both under irrigation and dryland, over the fertilizer application range of 0 to 200 pounds of fertilizer nitrogen.

When averaged over all fertilizer nitrogen rates, Ciano and Inia had the highest test weights, and Waldron and Bonanza under irrigation and Bonanza on dryland had the lowest.

Data of the per cent protein of the grain are shown in Table 6. The total nitrogen content determined by the Kjeldahl method and multiplied by 5.7 was taken to represent protein.

Grain protein was increased by the fertilizer nitrogen rate that produced yield increase, 50 pounds per acre, when the wheat was grown on dryland and in three varieties grown under irrigation; these three were Waldron, Ciano, and Bonanza. Application of fertilizer nitrogen (N) at the 200-pound rate produced further increases in protein content in dryland-grown grain, and in three varieties grown under irrigation; these three were World Seeds 1812, Bonanza and Inia. The variety Waldron had the highest or equal to the highest protein content at any fertilizer nitrogen rate applied. The variety Bonanza had a low or lower protein content than any other variety where no fertilizer nitrogen was applied, but it also increased to the greatest extent in protein in terms of absolute amounts, where the fertilizer nitrogen rate was increased to 200 pounds per acre.

When averaged over all fertilizer nitrogen rates under irrigation, protein content of Waldron was highest, and that of Inia and World Seeds 1812 lowest. On dryland, World Seeds 1812 and Red

Table 5. Test weight of wheat grown on dryland and irrigated Heimdal silt loam as influenced by fertilizer nitrogen rate.

		Test weight, pounds per bushel					
		Nitrogen (N) rate, pounds per acre					
Management	Variety	0	50	100	150	200	Average
Irrigated	Waldron	59.7 efg[1/]	59.8 efg	57.9 bc	58.2 bcd	57.4 b	58.6 a[2/]
	Ciano	62.2 jk	62.6 k	61.9 hijk	60.7 gh	61.4 hijk	61.8 c
	Red River 68	62.1 ijk	61.6 hijk	59.1 cdef	59.3 def	57.6 b	60.0 b
	World Seeds 1812	61.8 hijk	60.9 ghi	59.9 fg	59.0 cdef	58.6 bcde	60.0 b
	Bonanza	61.6 hijk	60.8 gh	58.9 cdef	55.5 a	54.8 a	58.3 a
	Inia	62.3 jk	62.2 jk	61.9 hijk	60.9 ghi	61.3 hij	61.7 c
	Average	61.6 c[2/]	61.3 c	60.0 b	59.0 a	58.6 a	
Dryland	Waldron	61.3 efghi	60.7 cdefg	60.5 cdef	60.4 cde	59.9 bcd	60.5 b[2/]
	Ciano	63.5 l	63.0 jkl	62.5 hijkl	61.7 efghij	60.5 cdef	62.2 d
	Red River 68	62.6 ijkl	61.9 fghij	62.0 ghijk	59.6 bc	59.1 b	61.0 bc
	World Seeds 1812	62.3 hijkl	62.5 hijkl	61.1 defgh	59.7 bcd	59.8 bcd	61.1 c
	Bonanza	62.4 hijkl	59.6 bc	58.6 b	57.3 a	56.7 a	58.9 a
	Inia	63.5 l	63.4 kl	62.8 jkl	62.3 hijkl	61.8 efghij	62.7 d
	Average	62.6 c[2/]	61.9 bc	61.3 b	60.2 a	59.7 a	

1/ Numbers in the table followed by the same letter do not differ at the 5% confidence level. (Exclude the "average" column or row).

2/ Numbers in the "average" column or row followed by the same letter do not differ at the 5% confidence level.

Table 6. Protein content of wheat grown on dryland and irrigated Heimdal silt loam as influenced by fertilizer nitrogen rate.

Management	Variety	Protein content in per cent[1]/ Nitrogen rate, pounds per acre 0	50	100	150	200	Average
Irrigated	Waldron	14.0 fghijk[2]/	15.2 lmn	14.4 ijklm	15.4 mn	15.7 n	14.9 d[3]/
	Ciano	13.4 defghi	14.8 jklmn	13.8 efghijk	14.7 klmn	15.0 klmn	14.3 c
	Red River 68	12.2 abcd	13.3 defghi	14.1 ghijkl	15.2 lmn	14.2 hijklm	13.8 b
	World Seeds 1812	11.9 abc	12.6 abcde	12.8 abcdef	13.4 defghi	14.1 ghijkl	13.0 a
	Bonanza	11.6 a	12.9 bcdefg	13.3 defghi	14.8 jklmn	15.2 lmn	13.5 b
	Inia	11.8 ab	12.3 abcd	13.1 cdefgh	13.4 defghi	13.6 efghij	12.8 a
	Average	12.5 a[3]/	13.5 b	13.6 b	14.5 c	14.6 c	
Dryland	Waldron	15.4	15.9	15.4	15.8	16.2	15.7 e[3]/
	Ciano	13.2	14.5	15.0	15.7	16.1	14.9 d
	Red River 68	11.9	12.9	12.4	14.1	14.1	13.1 ab
	World Seeds 1812	11.9	12.7	13.2	13.7	13.8	13.0 a
	Bonanza	11.7	13.8	13.6	14.6	15.1	13.7 c
	Inia	12.6	12.9	13.7	14.2	14.2	13.5 bc
	Average	12.8 a[3]/	13.8 b	13.9 b	14.7 c	14.9 c	

1/ Kjeldahl nitrogen x 5.7

2/ Numbers in the table followed by the same letter do not differ at the 5% confidence level. (Exclude the "average" column or row).

3/ Numbers in the "average" column or row followed by the same letter do not differ at the 5% confidence level.

River 68 were as low or tending lower than the other varieties.

Data of the number of ergot bodies per pound of grain was shown in Table 7. The count was made after the grain was cleaned.

Ergot body numbers were higher in Waldron and Ciano than in the other varieties. Under irrigation, ergot body numbers were higher or tended to be higher in Ciano where fertilizer nitrogen was applied, although in actual count the maximum difference was about three bodies per pound among fertilizer treatments. In Waldron, the highest count was obtained from plots supplied with 150 pounds fertilizer nitrogen (N). On dryland, the ergot body count in Waldron decreased where fertilizer nitrogen was applied.

Discussion

The fertilizer nitrogen rate producing the highest yields in these trials was essentially the same as the rate producing the highest yields in trials conducted in previous years on dryland, under favorable soil moisture and growing season rainfall conditions. This is not to infer that higher rates are not needed to eliminate fertility as the yield-limiting factor on many soils of the state. The outcome supports the information developed in previous years that the available nitrogen present in the soil at or prior to seeding must be taken into consideration to predict with precision the fertilizer nitrogen rate needed to eliminate available nitrogen as a yield-limiting factor without applying excess amounts. On the other hand, the outcome did not support the premise that the genetic potential for yield response to nitrogen was exhibited more strongly in these short-strawed varieties than in the so-called standard variety.

The effect of applying more fertilizer nitrogen than needed on test weight and protein con-

tent of grain, as exhibited in this study, is generally supported by data reported previously (3). However, the magnitude of reduction in test weight and the increase in protein varies with varieties.

The reason, from a physiological standpoint, is unknown for the reduction in number of ergot bodies in Waldron grown on dryland where fertilizer nitrogen was applied. But it provides another argument for the establishment of an adequate fertility level where ergot is a factor to be taken into account.

REFERENCES

1. **Bauer, A., and R. A. Young.** "Nitrogen on non-fallow boosts yields of small grains," **North Dakota Farm Research** 20:4, 1959.
2. **Bauer, A., R. A. Young and J. L. Ozbun.** "Effects of moisture and fertilizer on yields of spring wheat and barley," **Agronomy Journal** 57:354, 1965.
3. **Bauer, A., R. A. Young and E. H. Vasey.** "How nitrogen affects protein and test weight," **North Dakota Farm Research.** 24:18, 1966.
4. **Bauer, A., E. H. Vasey, R. A. Young and J. L. Ozbun.** "Stored soil moisture best guide to nitrogen needed," **North Dakota Farm Research.** 24:15, 1967.
5. **Bauer, A., and J. C. Zubriski.** "Nitrogen fertilizer, its effect on small grain on non-fallow land," **North Dakota Farm Research.** 20:10, 1958.

Table 7. Number of ergot bodies per pound of wheat grain, grown on dryland and irrigated Heimdal silt loam as influenced by fertilizer nitrogen rate.

Management	Variety	Number of Ergot bodies per pound of grain[1]/ Nitrogen (N) rate, pounds per acre 0	50	100	150	200	Average
Irrigated	Waldron	4.1 c[2]/	3.9 c	3.4 c	6.7 d	2.8 c	4.2 c[3]/
	Ciano	0.9 ab	2.5 bc	3.1 c	2.4 bc	3.3 c	2.5 b
	Red River 68	0.2 a	0.1 a	0.4 a	0.2 a	0.5 a	0.3 a
	World Seeds 1812	0.3 a	0.4 a	0.3 a	0.3 a	0.4 a	0.3 a
	Bonanza	0 a	0.4 a	0.8 a	0.3 a	0.6 a	0.4 a
	Inia	0.3 a	0.2 a	0.4 a	0.3 a	0.5 a	0.3 a
	Average	1.0	1.2	1.4	1.7	1.3	
Dryland	Waldron	23.1 d	5.9 c	3.8 abc	3.6 abc	3.1 abc	7.9 c[3]/
	Ciano	6.1 c	3.6 abc	2.9 abc	3.1 abc	4.9 bc	4.1 b
	Red River 68	0 a	0.1 a	0.1 a	0.3 a	0 a	0.1 a
	World Seeds 1812	0.6 a	0.3 a	0.1 a	0.4 a	0.3 a	0.3 a
	Bonanza	0.4 a	0 a	0.1 a	0.3 a	0 a	0.2 a
	Inia	1.6 ab	1.2 ab	1.1 a	1.2 ab	0.4 a	1.1 a
	Average	5.3 b[3]/	1.8 a	1.3 a	1.5 a	1.4 a	

1/ Counted after grain was cleaned. Count made on grain harvested from 4 square yards per plot.

2/ Numbers in the table followed by the same letter do not differ at the 5% confidence level. (Exclude the "average" column or row).

3/ Numbers in the "average" column or row followed by the same letter do not differ at the 5% confidence level.