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Growing Conditions Influence Nitrogen Recommendations

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Contents

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Introduction

WHEAT *(TRITICUM AESTIVUM* L.) IS THE primary cereal grown in Idaho. Nitrogen (N) is the nutrient that most often limits wheat yields and, when applied based on crop requirements, should result in substantial economic return to growers. Environmental and socioeconomic issues have revealed the pressing need for us to better understand the role and fate of N in crop production systems. Despite significant developments in wheat breeding and genetics and recent advances in precision nutrient management, fertilizer nitrogen use efficiency (NUE, a function of unit of yield achieved per unit of N input) remains low in most cereal systems. In fact, only 35% of all N applied worldwide as fertilizer is taken up by the crops (Omara et al. 2019). Based on University of Idaho research, it has been estimated that only about 50% of the N applied to wheat is utilized by the crop (Walsh and Belmont 2015). "Blanket" fertilization without considering residual soil N levels and overapplication of N represent the major factors that result in low NUE values. Applying the right rate of fertilizer is key to achieving high yields while reducing its deleterious environmental impact.

Field Trials

To assess the effect of N rates on the yield and quality of spring wheat, field trials funded by the Idaho Wheat Commission were conducted at five locations (Aberdeen, Ashton, Parma, Rupert, and Soda Springs) in southern Idaho in 2015–17 (Figure 1). Soft white spring wheat (cv. Alturas) was planted at Parma and hard red spring wheat (cv. Cabernet) at all other sites. These varieties were chosen because they are widely grown varieties for the area where the experimental locations were located. The growing conditions progressed from substantially higher precipitation and cooler air temperatures in 2015 to lower precipitation and warmer air temperatures in 2016 and 2017. Residual soil N varied from 50 to 215 lb N/a for fourteen site-years, with a mean value of 100 lb N/a, typical for southern Idaho cropping systems. Granular urea (46-0-0) was surface broadcasted immediately after planting at five rates (0, 75, 120, 225, and 300 lbs N per acre). Each treatment was replicated four times in a randomized complete block design, resulting in a total of 20 plots (5 by 20 ft in size) at each location. All sites were irrigated every 7–10 days using sprinkler irrigation systems, except at Soda Springs, a dryland site. At maturity, yield was determined by harvesting wheat with a small plot research combine. Grain N concentration was measured using near infrared reflectance spectroscopy. Protein content was calculated by multiplying grain N content by 5.7 (Fowler et al. 1990), expressed as a percentage. Wheat grain N uptake was calculated by multiplying yield by grain N concentration. N use efficiency was determined with the difference method (Varvel and Peterson 1990): N uptake in wheat grain of the N-unfertilized treatment (check plot) was deducted from N uptake of the fertilized plots and divided by the rate of N fertilizer. The effects of N rate on spring wheat grain yield, protein content, grain N uptake, and NUE were assessed. Data were analyzed using SAS statistical software 9.4 (Littell et al. 1996). Effect of N rate on wheat yield and protein are reported in Tables 1–3. Effect of N rate on N uptake and NUE are reported in Tables 4–6.

Figure 1. Map of experimental locations across southern Idaho, 2015-17.

Visual differences in wheat biomass (Figure 2) did not always reflect differences in grain yield. N fertilization enhanced yield at just two of fourteen site-years. Across all site-years, grain protein content in general increased with the N rate. N application improved grain quality (increased protein) even when yield was not increased. Hard red spring wheat (planted at Parma) has a high-protein target value of 12.0%–15.0%, while soft white spring wheat (planted at all other locations) has a low-protein expectation level of 8.5%–10.5%. In this study, grain protein values at Parma ranged from 8.7% to 12.3% (an average of 10.0%); at all other locations they ranged from 8.9% to 17.2% (13.0% average). While Parma's hard red spring wheat grain protein values were lower than target levels, soft white spring wheat protein values were higher (mainly at very high N rates). N uptake was affected by N fertilization at four of fourteen site-years. Typically, a strong relationship between N fertilization levels and grain N uptake indicates that the N requirement per bu of grain yield increases at the higher yield levels. Grain protein concentration is typically enhanced with increasing

Figure 2. Biomass differences between the 0-N check (left) and 300 lb N/a treatment (right) Soda Springs, ID, 2016.

Table 1. Effect of N rate on wheat yield and protein content, 2015.

N rate, lb/a	Aberdeen		Ashton		Rupert		Soda Springs	
	Yield, bu/a	Protein, %	Yield, bu/a	Protein, %	Yield, bu/a	Protein, %	Yield, bu/a	Protein, %
0	52 ab	9.3 b	72 b	10.6 c	107 ab	11.1	50 a	10.5 a
75	56 a	10.4 a	79 ab	11.2 bc	101 ab	13.1	57 a	11.2 a
150	49 ab	10.3 b	76 ab	13.4 ab	110 a	9.9	57 a	13.0 a
225	39 bc	12.3 a	82 ab	15.5 a	102 ab	11.6	54 a	14.0 a
300	28 c	13.1 a	89 a	13.4 ab	90 b	10.8	60 a	14.2 a

Values within each column followed by the same letter are not statistically different (95% confidence level).

Table 2. Effect of N rate on wheat yield and protein content, 2016.

N rate, lb/a	Aberdeen		Ashton		Parma		Rupert		Soda Springs	
	Yield, bu/a	Protein, %	Yield, bu/a	Protein, %	Yield, bu/a	Protein, %	Yield, bu/a	Protein, %	Yield, bu/a	Protein, %
0	87a	12.4 c	65 a	12.2 d	75 a	8.7 c	106 b	8.9 b	29 a	13.5 a
75	93 a	13.2 bc	57 ab	13.3 c	82 a	9.1 c	129 a	9.8 b	31 a	13.1 a
150	95 a	15.5 ab	60 ab	14.4 b	93 a	11.1 b	126 a	10.1 b	29 a	13.7 a
225	85 a	15.7 a	55 ab	15.1 b	92 a	11.5 b	134 a	11.5 a	31 a	14.9 a
300	89 a	16.4 a	46 b	15.3 a	77 a	12.3 a	133 a	12.4 a	35 a	14.7 a

Values within each column followed by the same letter are not statistically different (95% confidence level).

Table 3. Effect of N rate on wheat yield and protein content, 2017.

N rate, lb/a	Aberdeen		Ashton		Parma		Rupert		Soda Springs	
	Yield, bu/a	Protein, %	Yield, bu/a	Protein, %	Yield, bu/a	Protein, %	Yield, bu/a	Protein, %	Yield, bu/a	Protein, %
0	43 a	12.5 b	80 a	16.5 a	69 b	9.1 c	95 b	11.8 c	30 a	11.8 a
75	45 a	12.4 b	76 a	16.4 a	71 b	9.6 bc	101 ab	12.1 bc	30 a	10.0 ab
150	54 a	13.2 b	84 a	16.5 a	79 ab	10.5 ab	111 a	12.5 abc	31 a	11.4 ab
225	44 a	13.5 ab	74 a	17.0 a	82 a	11.3 a	100 ab	12.8 ab	38 a	11.4 ab
300	39 a	14.8 a	79 a	17.2 a	77 ab	11.0 a	89 b	13.3 a	38 a	11.0 b

Values within each column followed by the same letter are not statistically different (95% confidence level).

Table 4. Effect of N rate on wheat N uptake and NUE, 2015.

N rate, lb/a	Aberdeen		Ashton		Rupert		Soda Springs	
	N uptake, lb/a	NUE, %	N uptake, lb/a	NUE, %	N uptake, lb/a	NUE, %	N uptake, lb/a	NUE, %
0	51 ab	–	80 b	–	125 a	–	54 a	–
75	62 a	15.1 a	92 b	15.6 a	124 a	-1.4 a	67 a	17.3 a
150	53 ab	1.3 a	107 ab	17.6 a	113 a	-7.8 a	79 a	16.9 a
225	50 ab	-0.3 a	134 a	23.7 a	124 a	-0.2 a	78 a	10.7 a
300	39 b	-3.8 a	127 a	15.5 a	102 a	-7.6 a	89 a	11.6 a

Values within each column followed by the same letter are not statistically different (95% confidence level).
"–" = NUE values not calculated for 0 N rate.

Table 5. Effect of N rate on wheat N uptake and NUE, 2016.

N rate, lb/a	Aberdeen		Ashton		Parma		Rupert		Soda Springs	
	N uptake, lb/a	NUE, %	N uptake, lb/a	NUE, %	N uptake, lb/a	NUE, %	N uptake, lb/a	NUE, %	N uptake, lb/a	NUE, %
0	114 a	–	84 a	–	68 b	–	100 c	–	51 a	–
75	129 a	19.9 a	80 a	-4.6 a	78 b	13.1 b	133 b	44.1 a	62 a	2.0 a
150	155 a	27.2 a	91 a	4.9 a	108 a	26.6 a	134 b	22.3 b	53 a	0.0 a
225	140 a	11.4 a	87 a	1.7 a	111 a	19.1 ab	162 a	27.6 b	50 a	2.9 a
300	153 a	13.0 a	75 a	-3.0 a	100 a	10.7 b	174 a	24.5 b	39 a	4.1 a

Values within each column followed by the same letter are not statistically different (95% confidence level).
"–" = NUE values not calculated for 0 N rate.

Table 6. Effect of N rate on wheat N uptake and NUE, 2017.

N rate, lb/a	Aberdeen		Ashton		Parma		Rupert		Soda Springs	
	N uptake, lb/a	NUE, %	N uptake, lb/a	NUE, %	N uptake, lb/a	NUE, %	N uptake, lb/a	NUE, %	N uptake, lb/a	NUE, %
0	58 a	–	138 a	–	67 c	–	117 b	–	38 a	–
75	59 a	1.4 a	132 a	-8.2 a	71 bc	6.4 a	129 ab	15.3 ab	32 a	-7.9 b
150	75 a	11.4 a	145 a	4.3 a	88 ab	14.0 a	146 a	19.1 a	37 a	-0.3 ab
225	63 a	2.5 a	132 a	-2.7 a	98 a	13.8 a	135 ab	8.1 ab	45 a	3.5 a
300	61 a	1.0 a	143 a	1.6 a	89 ab	7.4 a	125 ab	2.6 b	44 a	2.3 a

Values within each column followed by the same letter are not statistically different (95% confidence level).
"–" = NUE values not calculated for 0 N rate.

N fertilizer rates. However, higher N rates do not always improve wheat yields potentially due to high preplant soil residual N, emphasizing the necessity for preplant soil testing for N concentrations in the soil. NUE was affected by the N fertilizer rate at only two of fourteen site-years. Optimal NUE is achieved by controlled remobilization of canopy-N to the developing grain as the crop matures. Based on University of Idaho wheat research, crops take up less than 50% of the N applied as fertilizer. In this study, the general trend across all site-years was that very high fertilizer N rates resulted in very low NUE values due to disproportionate/minimal yield increases as compared to N fertilizer inputs, or even lower grain yields, in some cases. Thus, the N uptake and accumulation of proteins in the wheat grain were more prominent drivers for greater NUE, compared to grain yield. These findings underscore the challenging task of determining the appropriate N rates for optimizing wheat yield production and highlight the importance of adjusting N rates based on location, year, and the prevalent environmental conditions.

Traditional N-response trials are not consistently useful in prescribing appropriate N rates. Employing tools such as N-rich strips, in combination with crop sensors, may be beneficial for detecting and quantifying site- and year-specific yield potential and the responsiveness of the crop to N fertilizer. Currently, University of Idaho researchers are working on updating N fertilizer guidelines for wheat by incorporating environmental parameters like soil moisture and crop sensors.

Conclusion and Recommendations

- Application of all N fertilizer at planting is not always efficient for wheat.
- Higher N rates resulted in enhanced protein content, but low NUE.

- N fertilizer rates for wheat should account for site- and year-specific conditions.
- When prescribing N rates, yield potential and responsiveness to N should be considered.

Further Reading

This report summarizes findings published in a full-length journal publication: Walsh, O. S., J. Marshall E. Nambi, S. Shafian, D. Jayawardena, C. Jackson, R. Lamichhane, E. Owusu Ansah, and J. McClintick-Chess. 2022. Spring Wheat Yield and Quality Response to Nitrogen Rate. *Agronomy Journal* DOI: 10.1002/agj2.21101.

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