NITROGEN RESPONSE TO 2-ROW BARLEY IN NORTH DAKOTA

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ABSTRACT

As the demand of two-row malting barley (*Hordeum vulgare* L.) increases, having sound N recommendations is increasingly necessary. Not only does N play a role in grain yield, but it may also significantly impact grain malting characteristics including protein, plump, and test weight. To determine the impacts N rate and N availability have on two-row malting barley, two experimental sites were established in both Spring 2020 and 2021. The experiments wer organized as a randomized complete block design with a split-plot arrangement; each site consisted of 100 experimental units in 2020 and 50 experimental units in 2021. Treatments consisted of five fertilizer rates (0, 40, 80, 120, and 160 lbs N ac^{-1}) and two barley cultivars (ND Genesis and AAC Synergy), with cultivar as the main plot and N treatment as subplots. Additionally, soil nitrate-N samples were taken prior to planting and N credits from the previous crop were considered to determine the total known available soil N (TKAN) in each N treatment. It was determined that there was a strong relationship between N rate and grain yield. There was also a strong positive correlation between N rate and grain protein. When the relationship between grain yield and TKAN was modeled using a best-fit regression, it was determined maximum yield can be reached at 186 lbs TKAN ac^{-1}. Additionally, grain protein content at 186 lbs TKAN ac^{-1} was 12.8%, which meets malting quality requirements. No significant interactions between N rate and kernel plump or test weight were noted at the N rates applied in these experiments.

INTRODUCTION

One of the keys to producing an economical crop is to apply mineral nutrients at a rate which maximizes profitability. Farmers need improved, locally-based recommendations which address each specific crop. In the case of two-row spring malting barley (*Hordeum vulgare* L.), a more accurate determination of N rate is essential not only to limit costs due to excessive rate and to enable application of rates that support the most profitable yield, but also to meeting the strict grain quality requirements of the maltsters, who are the primary buyers of this commodity (Franzen and Goos, 2019). McKenzie et al. (2005) asserted N fertilization is the most important factor in malting barley production. Having sound N application rates for two-row malting barley, aside from mitigating potential environmental impacts, will help to maximize yield, quality, and economic returns for growers.

Historically, the state of North Dakota has been a large producer of barley, ranking third in the USA for total barley production in 2020 (Jantzi et al., 2020), which has been traditionally of six-row type cultivars. However, in recent years, malting companies have suddenly begun to buy only two-row barley types over six-row types– thus production has followed these decisions. Of the 38 malting barley cultivars recommended by the American Malting Barley Association, 31 of them are now two-row types (Heisel, 2020). One of the reasons behind this change in preference from six-row to two-row barley for malting is their generally lower grain protein content (McKenzie et al., 2005; Franzen and Goos, 2019). Barley with lower protein content allows for more rapid water uptake during malting, which allows the grain to progress through the process more quickly (Hertsgaard et al., 2008), decreasing malting cost. Additionally, high levels of protein in the malt produces problems during beer fermentation processes, particularly cloudiness in the final product.

For grain to meet quality requirements set by maltsters, the percentage of plump kernels in the grain in addition to protein content not more than the industry standard, have to be met (Lauer and Partridge, 1990; O'Donovan et al., 2015). Furthermore, there is a correlation between the aforementioned quality factors and N fertilization (McKenzie et al., 2005). Although specific quality requirements vary amongst maltsters, the American Malting Barley Association sets the ideal criteria for two-row barley as follows: protein content ≤13.0% and >90% plump kernels retained on a 6/64 inch sieve (American Malting Barley Association Inc., 2019). Two of the most common reasons for malting barley rejection are high protein content and a low percentage of plump kernels (Institute of Barley and Malt Sciences, 2007). The consequence of grain rejection by malters is very severe; often feed-barley is priced about half of malting grade, and rejection most often results in a wasted journey to and from the malting receiving station back to the farm.

Studies indicate a positive relationship between N rate and grain protein (Lauer and Partridge, 1990; McKenzie et al., 2005; O'Donovan et al., 2015). Additionally, a minor inverse relationship between protein content and plump has also been reported (Clancy et al., 1991; Baethgen et al., 1995; McKenzie et al., 2005). In some cases, the supplemental N rate needed to attain maximum grain yield is greater than the N rate at which grain quality is within the optimum range. Baethgen et al. (1995) stated a balance must be found between obtaining maximum yield for malting barley and meeting quality requirements. This balance between yield and quality should also consider N use efficiency. As a result, grain could be produced at a level which will maximize economic returns for the farmer and meet malting quality requirements. To accurately reflect the actual N needs of two-row malting barley, it is necessary calculate the recommendation directly from the crop through state field N-rate trials. The purpose of this study is to determine, specifically for two-row barley, the rate of available N which will maximize yield and optimize grain quality characteristics for malting at an economically optimum level.

METHODS AND MATERIALS

Site Descriptions

These experiments were conducted over two growing seasons; 2020 and 2021, with two experimental sites each year. In total, four site-years of data were generated at locations in Grand Forks and Barnes Counties in North Dakota. The experiments were located 3 miles southeast of Valley City (VC) and near Logan Center (LC), which is about 10 miles WNW of Northwood. The soil at the VC 2020 site was dominated by Swenoda soils; the 2021 site consisted of Barnes loams (Soil Survey Staff, 2020). The Valley City site has been managed under no-till production for 40^{+} years with the previous crop of the 2020 season being sunflower and previous crop for the 2021 season was corn. At the LC site, the soils in 2020 and 2021 were Barnes loams (Soil Survey Staff, 2020). The LC site was only recently transitioned to a no-till system (< 5 years ago). The previous crop on this site was dry bean (pinto bean) in 2020 and 2021.

Experimental Design

The independent variables in the experiments consisted of five N treatments within two cultivars of two-row barley. The N treatments ranged from 0 to 160 lbs N ac^{-1} (0, 40, 80, 120, 160 lbs N ac^{-1}), which span the range above and below current North Dakota N recommendations for two-row barley. The two cultivars used were ND Genesis and AAC Synergy; two-row malting barley cultivars that are recommended by the American Malting Barley Association (Heisel, 2020). Each experimental unit was 8 ft wide by 40 ft long and were organized in a randomized complete block design with a split-plot arrangement. Barley cultivar was the whole-plot treatment and N rate the sub-plot treatment. The experiment was replicated 10 times in 2020 (n=100) and 5 times in 2021 (n=50)

Total known plant available N (TKAN) was calculated as outlined by Franzen (2018) which is the sum of preplant soil nitrate (N_S), previous crop N credits (N_{PC}), no-tillage N credits (N_{TC}), and amount of fertilizer N applied (N_{Fert}). The preplant soil nitrate tests were taken to a depth of 2 feet across a transect of each site within 2 weeks of seeding.

Crop Management

Barley was sown at a 7.5-inch row-spacing with John Deere 1890 air drills at both locations at the rate of 1.5 to 3 bu ac^{-1}, depending on the site. In-season crop management was conducted by the cooperating farmers, to manage pest and disease pressure, as outlined by the North Dakota Extension Integrated Pest Management Program.

At the time of planting, N fertilizer was broadcast applied to the specific treatments. To limit the amount of N lost to volatilization, SUPERU™ (Koch Industries, Wichita, KS) was used as the fertilizer N source. SUPERU is a urea-based fertilizer treated with *dicyandiamide* (DCD) and *N-(n-butyl) thiophosphoric triamide* (NBTP), a nitrification and urease inhibitor, respectively. Additionally, 100 lbs ac^{-1} of pelletized gypsum (calcium sulfate, 20% S) was broadcast applied at the time of N application (Calcium Products, Gilmore City, IA).

Data Collection and Analysis

Grain weight was measured, and moisture and test weight were measured using a Dickey-John model GAC500 XT grain analyzer (Dickey-John, Auburn, Illinois). Grain weights were adjusted to the standard moisture content of 13.5% for yield calculation. Quality measurements were conducted by the NDSU Barley Quality Laboratory, supervised by Paul Schwarz. Quality relating to kernel size was determined by sieving. Percent plump kernels were considered the weight of kernels which do not pass through a 6/64 inch sieve. Grain protein content was determined using near infrared spectroscopy (NIR).

Data analysis was performed using SAS and JMP (SAS Institute, Cary, NC). Analysis of variance (ANOVA) was carried out as randomized complete block design with a split plot arrangement using PROC MIXED. Regression analysis was performed using JMP. Data in this study was considered statistically significant at $p \leq 0.05$.

RESULTS AND DISCUSSION

Grain Yield and Quality

Weather conditions in 2020 varied greatly from 2021, most notably in terms of precipitation. At the LC location, April-July precipitation was 0.84 inches above normal in 2020, in 2021 precipitation was 5.66 inches below normal (NDAWN, 2020). A similar situation was noted at the VC sites as well, precipitation data collected approximately 9 miles from the site show 1.17 inches above normal 2020 and 6.65 inches below normal April-July precipitation (NDAWN, 2020). The drought conditions experienced in 2021 lead to lower average yields compared to the 2020 trials. Additionally, higher grain protein content was noted in the 2021 trials, expectedly a result of the drought conditions, an interaction noted in previous studies (Erbs et al., 2015; Gordon et al., 2020; Liang et al., 2021). Although yield and protein varied between years and locations treatment means were considered homogeneous based on the rule of 10-fold, allowing for combined analysis.

No statistical differences were noted between the two barley cultivars for any of the parameters measured in this study. It was determined the relationship between N rate and grain yield was significant [Table 1]. Grain protein content showed a significant increase with increasing N rates, a relationship previously established by Lauer and Partridge (1990), McKenzie et al. (2005), and O'Donovan et al. (2015). No significant interactions between N rate and kernel plump or test weight were noted at the N rates applied in this experiment. [Table 1].

Table 1. N rate means combined across varieties and environments.

N Rate	Grain Yield	Grain Protein	Kernel Plump	Test Weight
lb ac^{-1}	bu ac^{-1}	%	%	lb bu^{-1}
0	39.4a†	11.2a	92.2a	47.1a
40	51.7ab	11.9b	93.2a	47.3a
80	58.9b	12.5c	93.7a	47.9a
120	60.3b	12.9d	93.3a	47.8a
160	60.0b	13.3d	93.0a	47.8a

†Means with the same letter are not significantly different at the 0.05 probability level.

Total Known Available N

The sum of soil available nitrate (N_S), N credits from previous crops (N_{PC}), and tillage (N_{TC}) ranged from 52 lb ac^{-1} to 93 lb ac^{-1} across research sites and years In 2020 and 2021, the LC site received a 40 lb ac^{-1} N credit from the previous crop of dry beans but was penalized 20 lb ac^{-1} for being in the transitional no-till stage (Franzen, 2018). No previous crop credits were assessed at the VC site, but a 40 lb ac^{-1} long term no-till N credit was added each year (Franzen, 2018).

Optimum Nitrogen Rate

To allow representative combination of yield data, the yield at each site was calculated on a proportional/relative basis where the maximum yield is equal to 1. When relative grain yield is plotted against TKAN and fitted with polynomial trendline (r^2=0.66), maximum yield is realized at 186 lb TKAN ac^{-1} [Figure 2]. The relationship between grain protein content and TKAN was modeled using a linear regression (r^2=0.29) [Figure 2]; using this equation, grain protein content at 186 lb TKAN ac^{-1} is 12.8%.

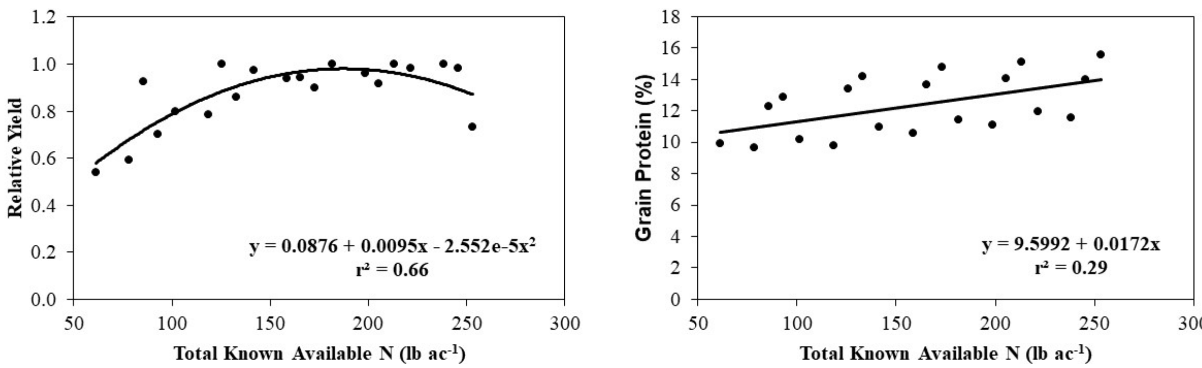

Figure 1. Left: Relative yield data averaged across reps and varieties compared to TKAN, fitted with a quadratic trendline. Right: Grain protein averaged across replications and varieties compared to TKAN fitted with a linear trendline.

CONCLUSION

After two years of field experiments resulting in four site-years of data, we determined that grain yield and protein content in two-row malting barley is driven by the amount of N available to the plant. No relationship was noted between N rate and kernel plump or test weight. Regression analysis of grain yield and TKAN determined maximum grain yield was be attained at 186 lbs N ac^{-1}. Additionally, when fertilized at the rate of maximum yield, grain protein content averaged 12.8%, which is below the 13.0% standard maximum protein content for malting (American Malting Barley Association Inc., 2019).

To calculate the TKAN for use with this recommendation, pre-plant soil nitrate-N to a depth of 2 feet must be determined. Additionally, N credits from the immediately previous crop and tillage system must be taken into consideration. More specific information on N credits are outlined in (Franzen, 2018).

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