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Environment and Nitrogen Rate Play Significant Roles in Winter Wheat Response to Nitrogen Management Intensification

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Environment and Nitrogen Rate Play Significant Roles in Winter Wheat Response to Nitrogen Management Intensification

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Summary

Poor nitrogen (N) management is among the leading causes of winter wheat (*Triticum aestivum* L.) yield gaps in Kansas, and sowing date—which is impacted by crop rotation—is among the most important variables determining winter wheat's attainable yields in the U.S. central Great Plains. This research aimed to investigate the relationship between N management strategies and various cropping systems in Kansas. The treatments consisted of nine combinations of three N management practices (standard, progressive, and green N) and five crop sequences (WtWt = continuous winter wheat; SyWt = winter wheat after soybean; TrSyWt = triticale (hay) – soybean – winter wheat rotation; CpWt = winter wheat after cowpea; TpDPwt = dual-purpose winter wheat after tepary bean; MoDPwt = dual-purpose winter wheat after moth bean). Standard N-management consisted of one single broadcast N application at 80 lb/a as UAN at spring greenup. Progressive N-management consisted of a split-N application at 40 and 27 lb/a each at greenup and jointing, using streamer bar nozzles and N-inhibitors added to the fertilizer. Green N management consisted of no fertilizer application except for the carryover N from the previous terminated legume crop. Crop sequences that allowed winter wheat to be sown at the optimum sowing date had the greatest yields. Green N management decreased dual-purpose winter wheat grain yield and shoot biomass. Both standard and progressive N management practices had similar results within crop sequences. Overall, our results suggested that intensive N management produced the same yields as the standard, but at lower N rates. Dual-purpose winter wheat combined with green N (i.e., relying exclusively on carryover N) was detrimental to winter wheat yield.

Introduction

Kansas is an important wheat (*Triticum aestivum* L.) producing state in the U.S. and accounts for 22% of wheat produced in the country. Most cropping systems in Kansas are winter wheat-based crop sequences. Different cropping systems can impact sowing dates for winter wheat, depending on the previous crop. For example, winter wheat grown for forage or dual-purpose (graze plus grain) is usually sown earlier in the fall (Lollato et al., 2019a). Winter wheat double-cropping with a summer crop (e.g., soybean (*Glycine max* (L.) Merrill), maize (*Zea mays* L.), and sorghum (*Sorghum bicolor* (L.) Moench) is sown later in the season and usually past the optimum sowing date (Jaenisch et al., 2021; Munaro et al., 2020). Recent studies showed that sowing date is the most important variable determining winter wheat yield in the U.S. central Great

Plains (Munaro et al., 2020; Jaenisch et al., 2021). Also, it is estimated that there is an approximate 50% winter wheat yield gap in Kansas (Lollato et al., 2017). Poor nitrogen (N) management is among the leading causes of the gap (De Oliveira Silva et al., 2020; Jaenisch et al., 2021; Lollato et al., 2019b), which can also reduce wheat protein and quality (Corassa et al., 2018). Recent evidence suggests that wheat sown later due to cropping system influence may also warrant changes in N management for improved N use efficiency (Lollato et al., 2021).

However, optimal N-management depends on yielding environments (Lollato et al., 2019c), and little is known about the performance of different N management strategies within different cropping systems. This research aimed to investigate the relationship between N management and various cropping systems in Kansas.

Procedures

Treatments Description

A rainfed field experiment with different crop rotations was established in the fall of 2019 near Ashland Bottoms, KS (fine-silty, mixed, mesic Cumulic Haplustoll). While crops planted and crop rotations depended on year of the study, this report will cover the results from the 2020-2021 growing season. The treatments consisted of nine combinations of three N management strategies (standard, progressive, and green N; Table 1) and five crop sequences (WtWt = continuous winter wheat; SyWt = winter wheat after soybean; TrSyWt = triticale (hay) – soybean – winter wheat rotation; CpWt = winter wheat after cowpea; TpDPwt = dual-purpose winter wheat after tepary bean; MoDPwt = dual-purpose winter wheat after moth bean). Standard and progressive N-management (Table 1) differed in application timing, placement, presence or absence of N inhibitors, and rate. The green N treatments did not receive inorganic N applications since the treatment is expected to include residual N from the previous legume crop. The rate of N applied in the progressive treatment was according to an in-season N recommendation, based on crop modeling that uses cropland observation through monitoring crop conditions and water balance.

Field Setup and Measurements

Winter wheat variety Zenda was sown at 90 lb/a when at optimum date (WtWt and TrSyWt, October 15); and at 120 lb/a when sown early for dual purpose (TpDPwt and MoDPwt, September 24), or late after the harvest of a summer crop (SyWt, November 7). Plots were 2000 ft^2 (40-ft wide × 50-ft long), had 7.5-in. row spacing, and were sown using a Great Plains 506 no-till drill. Diammonium phosphate (DAP; 18-46-0) starter fertilizer was applied to all plots at 50 lb/a. Grains were harvested on 6 June 2021 using a Massey Ferguson XP8 small-plot, self-propelled combine on the center of each plot (200 ft^2 area). Pests, weeds, and diseases were monitored regularly and, as they never reached critical levels, they were not considered limiting factors in this experiment.

Before harvest, whole plant biomass was collected from a representative 3.2-ft row, in which total shoot biomass weight, grain weight, harvest index, number of heads, a thousand grain weight, and grains per head were estimated. Plant N concentration (N%) was measured using dry combustion (LECO TruSpec CN combustion analyzer); shoot N uptake was estimated as the sum of the product between the sample weight and N%. Grain yield and grain protein were also measured.

Experimental Design and Statistical Analysis

The experiment was arranged as a randomized complete block design with four replications. Treatments and replications were considered fixed effects. Tukey's HSD ($\alpha = 0.05$) was used to contrast treatments and find statistically similar groups post-hoc. Regression analyses were performed using lm function available in R software with the R-Studio 9.4 interface (R Studio, PBC, Boston, MA).

Results

Weather Conditions

The 30-yr normal average precipitation (1990–2020) during winter wheat growing season in Ashland Bottoms is 26 inches. During this study, total precipitation received during winter wheat growing season was approximately 18 inches, which is below the historical average. Seasonal evapotranspiration was approximately 30 inches, therefore, precipitation likely did not supply enough water to meet the demand of the crop.

Grain Yield and Protein Concentration, and Yield Components

Winter wheat grain yield ranged from 18 to 66 lb/a across treatments (Figure 1A). Continuous winter wheat and TrSyWt rotation had the greatest yield, regardless of the N-management, while dual-purpose winter wheat under the green N treatment had the lowest yield. Grain protein concentration ranged from 7.8 to 10.5% across treatments (Figure 1B) and was similar among treatments, except for TrSyWt and progressive SyWt, which had the lowest protein content. For TrSyWt, rotation was more significant under standard N-management. Grain test weight was also similar among treatments, except for green N MoDPwt, which had greater values than WtWt, regardless of the N-management. Overall, number of heads/ft^2 and grain/ft^2 was lower for crop sequences under green N-management, and all the treatments had similar seed sizes (Table 2).

The differences in grain yield among treatments were more related to crop sequence than N-management since all N management treatments had similar yields within crop sequence. In this case, crop sequences in which winter wheat was sown at the optimum date had the greatest yield, followed by late planting, and lastly, early sowing date. We note that the treatments sown early also did not receive inorganic N and had dual-purpose winter wheat, all of which potentially contributed to reduced yields. The progressive N treatment had similar grain yield to the standard however used less inorganic N fertilizer, which can be overall beneficial to the system. The lack of difference between N-management within crop sequences was likely due to the area's weather being drier than normal. Drier environments are less susceptible to N fertilizer volatilization losses (Perin et al., 2020) which may have caused the standard N-management to behave similarly to progressive N-management in terms of the likelihood of N losses to the atmosphere.

Overall, grain yield and protein content had a significantly negative relationship (Figure 1D) likely due to the N dilution effect (De Oliveira Silva et al., 2020). The dilution effect is more apparent based on the significant negative relationships between grain and shoot N uptake and protein content (Figures 1E, F), meaning that increases in grain N uptake were driven more by increases in yield than in protein concentration.

Biomass and Nitrogen Uptake

Shoot biomass for each treatment is depicted in Figure 1C. The green N management treatment managed as dual-purpose wheat, had the lowest shoot biomass production, which was expected due to simulated grazing and no inorganic N received. Lower shoot biomass was also noted for winter wheat sown later under progressive N-management (Pr_SyWt and Pr_CpWt), which was likely caused by lower fall tillering due to later sowing date and lower N rate applied under progressive N-management than standard. Shoot biomass at maturity was a strong driver of grain yield and shoot N uptake (Figure 1G and 1H, respectively).

Preliminary Conclusions

Overall, crop sequences that allowed winter wheat to be sown near the optimum date resulted in greater grain yields than other crop sequences with early or late sowing dates. Dual-purpose winter wheat relying on green N seems to be infeasible as the N supply may not meet the N demand. Nitrogen management intensification resulted in similar yields to the standard N management though using less N fertilizer per acre.

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Table 1. Nitrogen management (i.e., application timing, N inhibitor additive, and placement method) in winter wheat at Feekes 4 and Feekes 7 stages of plant development at Ashland Bottoms, KS, during 2020–2021 growing season

	Feekes 4		Feekes 7		
N Management	**Nitrogen**[1]	**Additive**[2]	**Nitrogen**	**Additive**	**Placement**
Standard [St]	80 lb/a	---	---	---	Broadcast
Progressive [Pr]	40 lb/a	Nitrogen inhibitors	27 lb/a	Nitrogen inhibitors	Streamer bar
Green N [Gr]	---	---	---	---	---

[1] Source: Urea ammonium nitrate (UAN 32-0-0).

[2] Nitrification inhibitor (Centuro, Koch Agronomic Services Co., Wichita, KS, 67220) at 5 gallons per ton of fertilizer (UAN); and urease + nitrification inhibitor (Agrotain Plus SC, Koch Agronomic Services Co., Wichita, KS, 67220) at 3 gallons per ton of fertilizer (UAN).

Table 2. Winter wheat grain yield components under various nitrogen (N) management and crop sequence treatments near Manhattan, KS, during 2020–2021 growing season

Nitrogen[1]	Crop sequence[2]	Test weight (lb/bu)	Heads/ft^2	Grain/ft^2	Seeds/lb
Standard	WtWt	60 ± 0.2§ ab†	87 ± 5 abc	1566 ± 93 abc	17.7K[3] ± 236 a
Progressive	WtWt	59 ± 0.2 ab	63 ± 5 abc	1336 ± 93 abc	17.7K ± 236 a
Standard	SyWt	59 ± 0.2 ab	73 ± 5 abc	1223 ± 93 abc	17.5K ± 236 a
Progressive	SyWt	60 ± 0.2 ab	61 ± 5 abc	1014 ± 93 abc	17.2K ± 236 a
Standard	TrSyWt	60 ± 0.2 ab	77 ± 5 abc	1346 ± 93 abc	17.7K ± 236 a
Progressive	TrSyWt	60 ± 0.2 ab	86 ± 5 abc	1521 ± 93 abc	16.9K ± 236 a
Progressive	CpWt	60 ± 0.2 ab	72 ± 5 abc	1935 ± 93 abc	16.7K ± 236 a
Green N	TpDPwt	60 ± 0.2 ab	55 ± 5 abc	1753 ± 93 abc	16.8K ± 236 a
Green N	MoDPwt	61 ± 0.2 ab	49 ± 5 abc	1742 ± 93 abc	16.6K ± 236 a

[1] N-management: Standard (single N-application using broadcasting applicator with the absence of N-inhibitors at 80 lb/a of N); Progressive (split N-application into two timings using streamer bars with the presence of N-inhibitors at 80 lb/a of N); and Green N (absence of N application from fertilizer).

[2] WtWt = continuous winter wheat; SyWt = winter wheat after soybean; TrSyWt = triticale (hay) – soybean – winter wheat rotation; CpWt = winter wheat after cowpea; TpDPwt = dual purpose winter wheat after tepary beans; MoDPwt = dual purpose winter wheat after moth beans.

[3] K = thousand.

§Standard error of the mean.

†Means within the same column followed by the same letter are not significantly different at α = 0.05 probability level of significance using Tukey's HSD test.

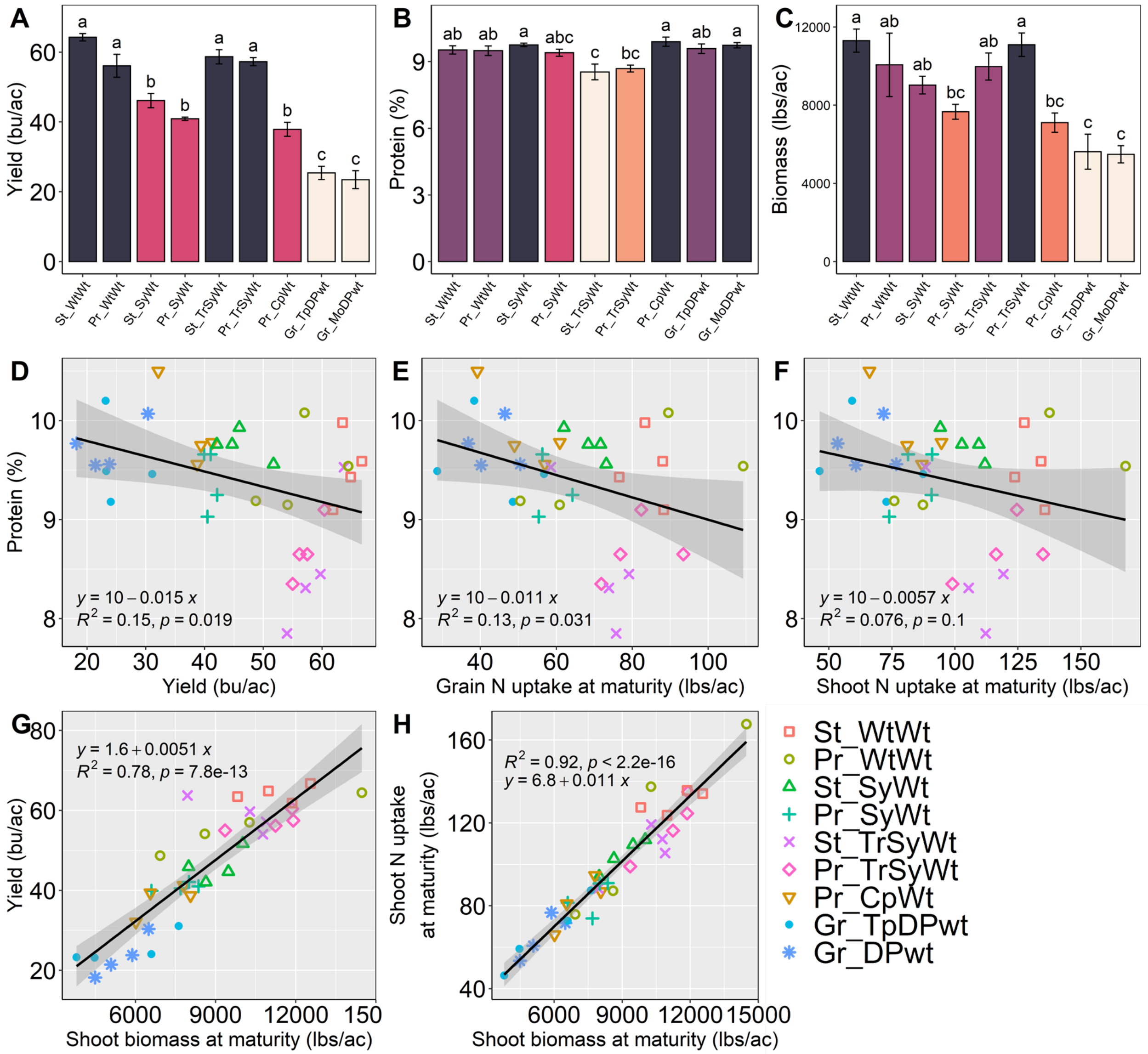

Figure 1. Grain yield (A), grain protein content (B), and shoot biomass (C); relationship of grain protein content with grain yield (D), with grain nitrogen [N] uptake at maturity (E), and shoot N uptake at maturity (F); and relationship of shoot biomass at maturity with grain yield (G), and with shoot N uptake at maturity (H) for winter wheat under nine treatments' combination of N-management and crop sequence near Manhattan, KS, during 2020–2021 growing season. N management treatments were Standard [St] (single N-application using broadcasting applicator with the absence of N inhibitors at 80 lb/a of N); Progressive [Pr] (split N application into two timings using streamer bars with the presence of N-inhibitors at 80 lb/a of N); and Green N [Gr] (absence of N application from fertilizer). Crop sequences included WtWt = continuous winter wheat; SyWt = winter wheat after soybean; TrSyWt = triticale (hay) – soybean – winter wheat rotation; CpWt = winter wheat after cowpea; TpDPwt = dual-purpose winter wheat after tepary beans; MoDPwt = dual-purpose winter wheat after moth beans.