Variation in Nitrogen Use Efficiency and Nitrogen Response in Winter Wheat Varieties Common to the Central Great Plains

Nate Dorsey, Nathan O. Nelson, Bryson Haverkamp, Alan K. Fritz, and Eric Adee

K-STATE Research and Extension

Introduction

Wheat accounts for more than 20% of the calories and protein consumed in the human diet and requires 216,974,683 hectares worldwide to meet demand, nearly twice that of the next largest commodity, maize. Two important issues in modern agriculture are the high costs of nitrogen fertilizers and the environmental risks associated with their application. A novel way to approach these issues is by developing crops, such as wheat, with higher nitrogen use efficiency (NUE) and response to nitrogen additions.

Figure 1. Panoramic view of the Nitrogen Use Efficiency (NUE) study in Rossville, KS. Visual differences can be seen among the 30 varieties planted in the experiment and the two different nitrogen fertilizer rates applied of 0 kg N per hectare and 100 kg N per hectare.

Objective

To determine if there are genetic differences in nitrogen response, NUE, and other related parameters (Table 1) among wheat varieties commonly grown in the Great Plains, USA.

Methods

Table 1. Definitions of NUE related terms and methods of calculation.

Measurement	Definition	Formula
Nitrogen use efficiency (NUE)	Weight of grain produced per unit of available nitrogen	NUE=grain weight/total N supply or UPE*UTE
Nitrogen uptake efficiency (NUpE)	How efficiently N is taken up by the plant from the soil	NUpE = Total N uptake/N supply in the soil
Nitrogen utilization efficiency (NUtE)	How efficiently N is absorbed from the soil and used to make grain	NUtE = grain weight/N taken up by plant or HI*BPE
Harvest index (HI)	Weight of harvested grain as a percentage of total plant weight	HI = grain weight/aboveground biomass
Biomass production efficiency (BPE)	Total plant weight compared to total plant N content at maturity	BPE = aboveground biomass/total N at maturity
Nitrogen harvest index (NHI)	Nitrogen content in the grain compared to total plant N content at maturity	NHI = N in grain/ total N at maturity
Nitrogen uptake after anthesis (NUpAA)	Difference in total N from anthesis to maturity	NUpAA = total N at maturity-total N at anthesis
Nitrogen remobilization efficiency (NRE)	How efficiently nitrogen at anthesis was remobilized to the grain	NRE= (N in grain-NUpAA)/total N at anthesis
Fertilizer use efficiency (FUE)	Fraction of nitrogen applied as fertilizer that was absorbed by the plant	FUE=(N uptake with fertilizer-N uptake without fertilizer)/N applied as fertilizer

NUE:

- Field study at Rossville, KS experiment station during the 2011 and 2012 seasons
- 30 varieties with two nitrogen rates applied, 0 and 90 kg N hectare^{-1} (2011) and 0 and 100 kg N hectare^{-1} (2012)

Nrate:

- Field study at Silverlake and Ashland Bottoms, KS during 2013 season
- Four wheat varieties with nitrogen rates of 0, 34, 90, and 146 kg N hectare^{-1}

Results

In this study NUE and several related parameters such as grain yield, nitrogen utilization efficiency (NUtE), nitrogen remobilization efficiency (NRE), and several others were significantly affected by variety at a $p<0.05$ level (Table 2 and Figure 2). This provides significant evidence of genetic differences between wheat varieties in their ability to use nitrogen.

Table 2. NUE experiment levels of significance (*P*-values) for interactions of nitrogen rate, variety, and year on NUE and related measurements

	Yield	Ng	Ns	NUE	NUpE	NUtE	HI	BPE	NUpAA	NRE	FUE
N rate	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.107	0.114	-
Variety	0.027	<0.001	0.01	0.028	0.33	<0.001	<0.001	<0.001	0.421	0.018	0.404
N rate x variety	0.904	0.276	0.056	0.544	0.606	0.341	0.275	0.258	0.04	0.296	-
Year x variety	0.51	0.244	0.317	0.67	0.337	0.43	0.004	0.131	0.515	0.566	0.587
Year x variety x nrate	0.477	0.735	0.083	0.567	0.59	0.459	0.192	0.365	0.451	0.697	-

Abbreviations: Ng, nitrogen content of the grain; Ns, nitrogen content of stover; NUE, nitrogen use efficiency; NUpE, nitrogen uptake efficiency; NUtE, nitrogen utilization efficiency; HI, harvest index; BPE, biomass production efficiency; NUpAA, nitrogen uptake after anthesis; NRE, nitrogen remobilization efficiency; FUE, fertilizer use efficiency.

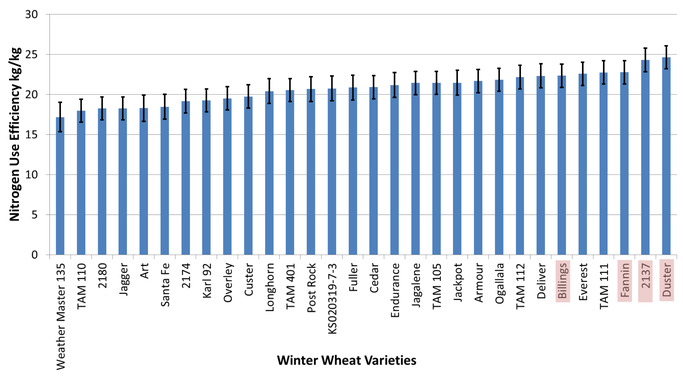

Figure 2. Differences in nitrogen use efficiency of 30 common wheat varieties grown in the Great Plains region

Interestingly, nitrogen uptake efficiency (NUpE) was not significantly different between varieties (Table 2). This suggests that while wheat varieties may have similar abilities to uptake N from the soil, their differences lie in their ability to remobilize nitrogen and photosynthates from their tissues to grain during reproductive growth (Figures 3 and 4).

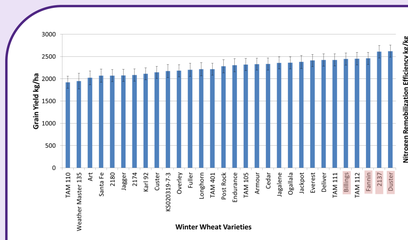

Figure 3. Average grain yield of wheat varieties for 2011 and 2012 seasons

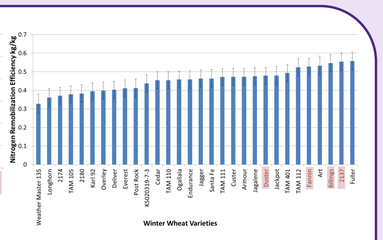

Figure 4. Differences in nitrogen remobilization efficiency among 30 wheat varieties

Table 3. N-rate experiment at Ashland Bottoms and Silverlake, KS levels of significance (*P*-values) for interactions of nitrogen rate and variety on several parameters

	Yield	Ng	Ns	NUE	NUpE	NUtE	HI	BPE	NUpAA	NRE	FUE
Ashland Bottoms											
N rate	<0.001	<0.001	<0.001	<0.001	<0.001	0.102	0.419	<0.001	0.192	0.955	0.775
Variety	0.036	0.472	0.097	0.32	0.916	0.155	0.473	0.306	0.39	0.597	0.729
N rate x variety	0.041	0.762	0.347	0.633	0.94	0.97	0.619	0.998	0.993	0.631	0.816
Silverlake, KS											
N rate	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.651	<0.001	0.729	0.242	0.400
Variety	<0.001	0.789	0.831	<0.001	0.217	0.675	0.039	0.182	0.604	0.407	0.489
N rate x variety	0.433	0.212	0.956	0.915	0.819	0.726	0.489	0.419	0.264	0.472	0.797

Abbreviations: Ng, nitrogen content of the grain; Ns, nitrogen content of stover; NUE, nitrogen use efficiency; NUpE, nitrogen uptake efficiency; NUtE, nitrogen utilization efficiency; HI, harvest index; BPE, biomass production efficiency; NUpAA, nitrogen uptake after anthesis; NRE, nitrogen remobilization efficiency; FUE, fertilizer use efficiency.

The fields and conditions for the N-rate experiment were different at both locations, which created contrasting results. The only significant variety interaction at Ashland Bottoms was yield, while there were several parameters, including NUE, significant at Silverlake (Table 3). There was also a significant N rate by variety interaction for yield at Ashland, suggesting significant differences in N response among the varieties. When NUE was compared to N-response at both sites, there were similar trends (Figures 5-8), suggesting that varieties with higher NUE may respond well even to low additions of N.

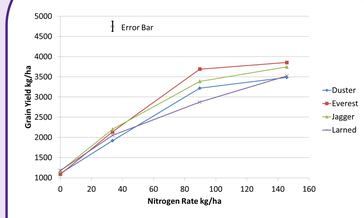

Figure 5. N-response at Ashland Bottoms, KS

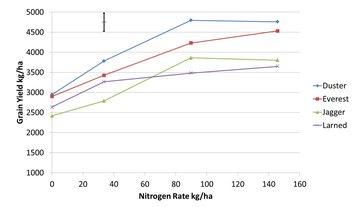

Figure 6. N-response at Silverlake, KS

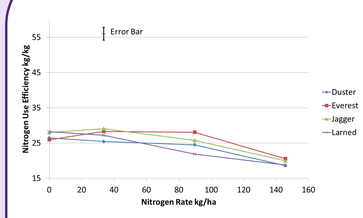

Figure 7. NUE for Ashland Bottoms, KS N-rate experiment

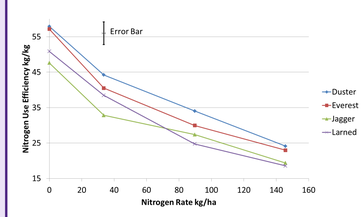

Figure 8. NUE for Silverlake, KS N-rate experiment

Conclusions

These studies provide significant evidence for genetic differences among wheat varieties in nitrogen response, NUE, and other related parameters. NUE is a growing topic of interest and concern, and breeders could potentially use this information to develop wheat varieties with high nitrogen response and nitrogen use efficiency, saving farmers money and minimizing negative environmental effects.