Performance criteria for evaluating site-specific nitrogen management

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Improving the efficiency with which nitrogen fertilizers are used in modern cropping systems can improve environmental quality while also providing economic benefit to agricultural producers. Maintaining high crop yields with fewer nitrogen fertilizer inputs is the essence of improved nitrogen use efficiency (NUE). Another option to improve NUE would be to obtain yield increases with the same amount of nitrogen fertilizer input. Given the high spatial and temporal variability in soil properties and crop productivity in the Palouse region, we are often interested in both—that is, in developing systems that can produce the same amount of grain with less nitrogen fertilizer as well as adopting management strategies that increase yield with the same amount of nitrogen fertilizer inputs. Site-specific nitrogen fertilizer management (otherwise known as variable rate) is considered a meaningful strategy to increase NUE.

IMPACT

The large range in nitrogen use efficiency observed in previous and current research at the Cook Agronomy Farm underscores the need to develop site-specific management strategies. Targeting site-specific management strategies to increase nitrogen use efficiency is important for reducing the costs of nitrogen fertilizer inputs and for minimizing the entry of nitrogen into unintended parts of the environment.

Managing the year-to-year and within-field variability across Palouse landscapes continues to generate interest in variable rather than uniform rates of crop production inputs such as nitrogen fertilizer. However, if agricultural producers are to adopt site-specific management decisions, they require accurate information on the variability in soil properties, coupled with knowledge of crop response to this variability. More importantly, agricultural producers will need decision support tools to evaluate whether site-specific management strategies allowed them to meet their production and NUE goals. Our aim for this research was to develop NUE-based performance classes while investigating the role of variable-rate nitrogen and seeding of soft white winter wheat for optimizing relationships between yield and NUE.

NUE is a measure of the amount of crop that is harvested divided by the amount of nitrogen supplied from soil and fertilizer sources (Table 1). The generally accepted NUE in current fertilizer guides for the region is 22 pounds of grain per pound of nitrogen supplied (Figure 1). We combined 605 data points from nitrogen fertilizer crossed with seeding-rate plot trials conducted across different landscape positions at the Cook Agronomy Farm, near Pullman, WA during the 2010, 2011 and 2012 soft white winter wheat harvest years. Over all plots and site years, the NUE ranged from 8 to 70 pounds of grain produced per pound of nitrogen supplied, with an average of 29 pounds grain per pound

Table 1. *Mean soft white winter wheat grain yield and select nitrogen use efficiency components by performance class for the 605 data points collected from 2010 to 2012 at the Cook Agronomy Farm near Pullman, WA.*

Nitrogen use efficiency component	Performance class			
	1	2	3	4
n (number of points)	311	102	82	110
Grain yield (Gw), bushels per acre	91	71	94	69
Grain protein, %	8.8	8.2	10.5	10.7
Aboveground plant nitrogen (Nt), pounds per acre	107	75	138	105
Nitrogen supply (Ns), pounds per acre	162	207	204	244
Harvest index, Gw/total biomass	0.45	0.43	0.42	0.37
Nitrogen harvest index, Ng/Nt	0.78	0.78	0.74	0.69
NUE, Gw/Ns	37	21	28	16
Unit nitrogen requirements, Ns/Gw	1.8	3.0	2.2	3.6
Nitrogen utilization efficiency, Gw/Nt	52	56	41	37
Nitrogen uptake efficiency, Nt/Ns	0.70	0.36	0.70	0.43
Total available water, inches	16	14	15	13

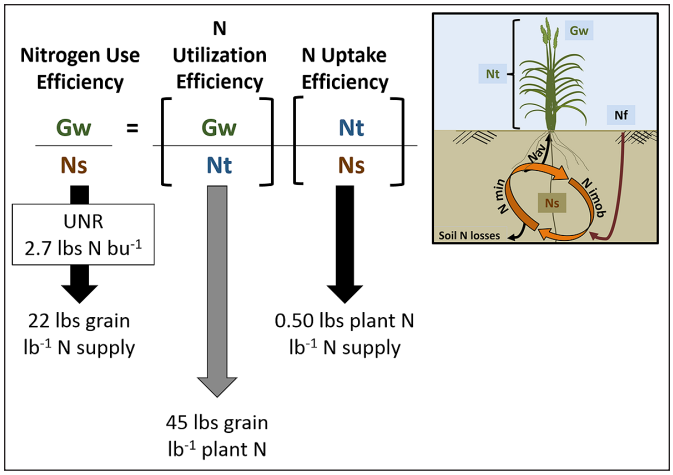

Figure 1. *Calculation of nitrogen use efficiency using soil- and plant-derived components and performance criteria established from regional soft white winter wheat fertilizer guide recommendations.*

Step	NUE Criteria	Performance Class
1	Gw/Nt is equal to or greater than 45	
	If yes, go to Step 2	
	If no, go to Step 3	
2	Nt/Ns is equal to or greater than 0.5	
	If yes ……..	Class 1
	If no ……..	Class 2
3	Nt/Ns is equal to or greater than 0.5	
	If yes ……..	Class 3
	If no ……..	Class 4

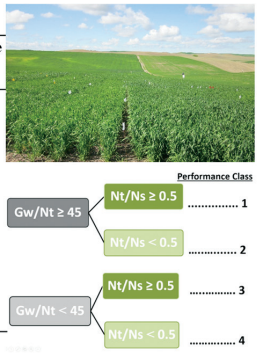

Figure 2. *Dichotomous key to classification of soft white winter wheat performance based on the nitrogen use efficiency components of nitrogen utilization efficiency (Gw/Nt) and nitrogen uptake efficiency (Nt/Ns).*

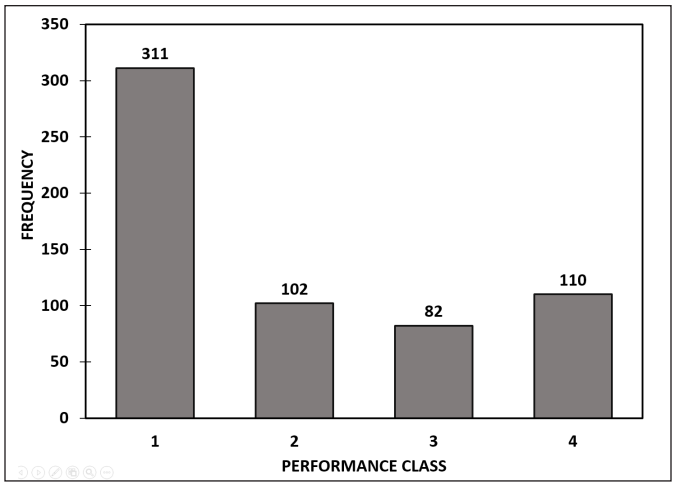

Figure 3. *Frequency of performance classes for the 605 data points collected during 2010, 2011, and 2012 soft white winter wheat nitrogen rate × seed rate plot trials at the Cook Agronomy Farm near Pullman, WA.*

of nitrogen supply. This corresponds to a unit nitrogen requirement (UNR) range of 0.6 to 7.6 pounds of nitrogen supply per pound of grain yield (average of 2.4 pounds of nitrogen supply per pound of grain).

To evaluate and diagnose conditions contributing to NUE below fertilizer guide specifications, we partitioned NUE into several soil- and crop-based components or indices (see Table 1). NUE (Gw/Ns) was partitioned into nitrogen utilization efficiency (Gw/Nt) and nitrogen uptake efficiency (Nt/Ns) (Figure 1). We developed a dichotomous key to separate wheat performance into four classes based on nitrogen utilization efficiency (Gw/Nt) and nitrogen uptake efficiency (Nt/Ns), following the criteria of the regional soft white winter wheat fertilizer guides (Figure 1). Regional fertilizer guides estimate a UNR of 2.7 pounds of nitrogen per bushel of soft white winter wheat, and this value assumes a nitrogen uptake efficiency of at least 50%. Using these criteria, we calculated a nitrogen utilization efficiency value of greater than or equal to 45 pounds nitrogen per pound of grain as a performance goal. It should be noted that the NUE defined here is the inverse of the UNR.

Performance classes 1 and 2 are where wheat achieved a nitrogen utilization efficiency of 45 or greater (Figure 2). Performance classes 3 and 4 are conditions in which the nitrogen utilization efficiency goal of 45 was not achieved. Within the nitrogen utilization efficiency criteria, performance classes were further separated based on a nitrogen uptake efficiency criterion of 50%. Performance classes 1 and 3 are where nitrogen uptake efficiency is greater than or equal to 50%, and classes 2 and 4 are where nitrogen uptake efficiency is below 50%. Performance class 1 represents a situation in which soft white winter wheat crop and management strategies are well suited to the environmental conditions. In performance class 1, grain yields are high, with nitrogen utilization efficiency and nitrogen uptake efficiency goals achieved (Table 1). Performance class 1 was achieved in 311 out of 605 data observations, or approximately 50% of the time (Figure 3). Performance classes 2, 3, and 4 represent field or management situations in which site-specific management strategies might enhance NUE. We are continuing to use soil- and crop-based NUE components to diagnose environmental or management strategies contributing to low NUE. For example, low nitrogen utilization or uptake efficiency may be related to nitrogen loss (low nitrogen retention efficiency), over- or under-fertilization, a below-optimal plant population (nitrogen sink capacity), or moisture-stress-induced nitrogen deficiency (available water supplies). We will use this approach to develop decision support tools for evaluating how site-specific management strategies contribute to achieving yield, protein, NUE, and economic performance goals.

Tabitha Brown sharing her research at a Cook Farm field day. Photo by Brad Stokes.