Using Protein to Evaluate N Fertility in Hard Red Spring Wheat

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Introduction

Grain protein is an essential factor determining end-use quality of wheat. Grain producers wanting to capture the economic benefits of protein prize premiums are optimizing nitrogen (N) fertilization of their grain crops. It has been suggested that grain protein concentration (GPC) can be used as an indicator of N sufficiency for optimum grain yield. Although this evaluation would be "after the fact", it would permit grain producers to judge the adequacy of their fertilization program. The objective of this study was to determine if GPC could be used as an index of N sufficiency for hard red spring wheat grown in the semiarid areas of Saskatchewan.

Materials and Methods

Fertilizer response trials were conducted by SPARC in southwestern Saskatchewan from 1967 to 1999 on up to 15 sites. The dataset consisted of 2689 observations taken over 126 year-soil combinations, or environments, for wheat grown on fallow, and 1828 observations taken over 96 environments for wheat grown on stubble.

Identification of protein critical limits was carried out by the R^2 method proposed by Cate and Nelson (1971). This procedure consists of organizing the data into an ordered array of X (GPC) and Y values (grain yield), with the X,Y pairs maintained in this order throughout the analysis. Starting at a GPC value that places at least two X,Y pairs into a low protein class, the observations are separated into a low and high protein class, and the separation point is advanced for each X value, until there are at least 2 X,Y pairs in the high protein class. At each separation point a R^2 value is calculated as $1\text{-}(CSS_l = CSS_h)/CSS_t$, where CSS indicates corrected sums of squares, and the subscripts l, h, and t refer to the low protein class, high protein class, and total dataset, respectively. The critical protein level is taken at the point where the calculated R^2 reaches a maximum.

Results and Discussion

Yield-protein relationships reveal the nature of yield limiting factors. Negative relationships normally occur when N is in adequate supply, but other growth factors, often water availability, limit grain yield (Terman 1979, Clarke et al. 1990). When N supply limits crop growth, both yield and protein increases as more N becomes available, thus leading to a positive yield-protein relationship (Selles and Zentner 2001).

For wheat grown on stubble, the yield-protein relationship was negative (Fig. 1), with GPC decreasing by 1.5% protein for every 1000 kg/ha increase in grain yield. Under fallow cropping, for yields below 2858 kg/ha the relationship was negative (Fig. 1), and with the same slope as that found for wheat grown on stubble, suggesting that under fallow cropping, low yields were mainly the result of water stress. For yields above the 2858 kg/ha threshold, the relationship became positive, with GPC increasing by 1.1% protein for every 1000 kg/ha yield increase (Fig. 1). Clearly, these higher yields were controlled by N supply limitations.

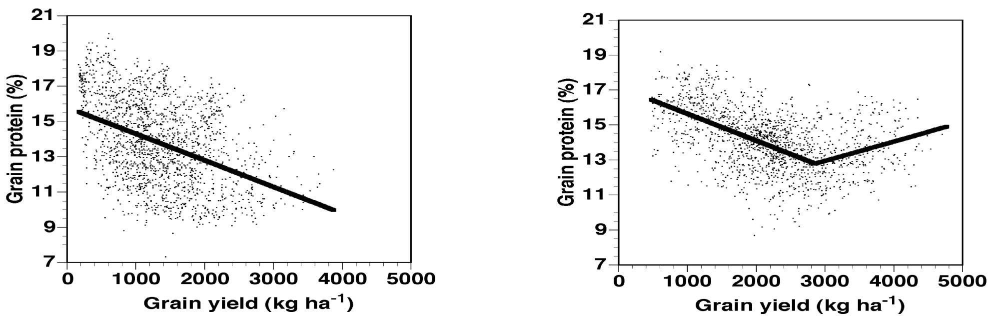

Figure 1. Yield protein relationships for stubble (left) and fallow (right).

For the portion of wheat grown on fallow with a positive yield-protein relationship, the Cate-Nelson R^2 identified a threshold protein GPC of 12.8±0.7% (Fig. 2a). According to the data presented, this critical protein concentration separated the sample into a portion with low yield and protein arising from insufficient N supply, and another portion with sufficient N characterized by high grain yield and protein (Selles and Zentner 2001). The critical point identified in this study is within the range of values identified in other studies (Goos et al. 1982; Virtanen and Peltonen 1996; Flaten and Racz 1997).

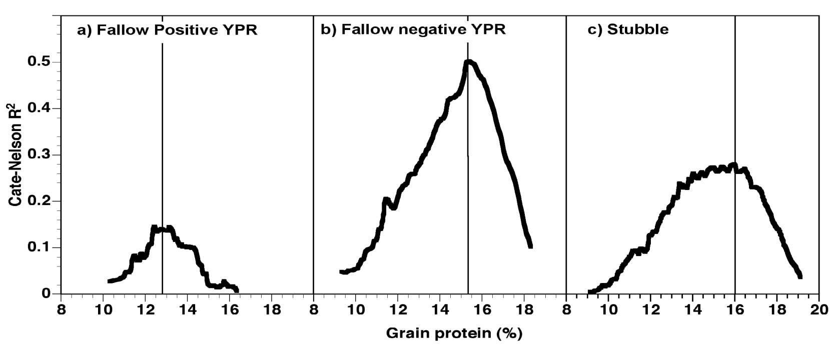

Figure 2. Results of the Cate-Nelson R2 analysis, showing critical protein values (vertical lines).

For wheat grown on fallow with yields below 2858 kg/ha (negative yield-protein relationship) and wheat grown on stubble, the Cate-Nelson procedure identified threshold GPC of 15.7±0.2% protein and 16.0±0.7% protein, respectively (Fig 2b, 2c). However, the data presented in Table 2 revealed that these high protein threshold values separate the populations into a group moderately affected by water stress and a group severely affected by water stress.

Table 1. Least squares means of grain yield, protein concentration, and water and nitrogen supply for fallow and stubble grown wheat, separated into domains by grain protein as classing variable.

Variable	Units	Fallow positive YPR[z] High protein	Fallow positive YPR[z] Low protein	Fallow negative YPR High protein	Fallow negative YPR Low protein	Stubble High protein	Stubble Low protein
Critical protein concentration	mg g^{-1}	128		154		160	
Grain yield	kg ha^{-1}	3505e	3274d	1499b	2008c	907a	1467b
GPC	mg g^{-1}	142	119	166	134	172	130
N yield	kg ha^{-1}	87f	68e	43c	47d	27a	33b
Water deficit[x]	mm	-303a	-301a	-506c	-423b	-572d	-423b
AVN[v]	kg ha^{-1}	122d	92c	86c	73b	86c	64a
NUE[u]	kg kg^{-1}	34e	40f	19b	31d	12a	28c
n		227	112	708	1642	396	1432

a-f Values within a row followed by the same letter are not significantly different ($P > 0.05$) based on the Tukey-Kramer test.
[Z] Fallow data separated into groups according to the yield-protein relationship.
[x] (Spring soil water + 1 May to 31 July rainfall) minus potential evaporation.
[V] Soil NO3-N (0-60 cm) plus fertilizer N.
[u] Grain produced per unit available N.

Conclusions

In the semiarid areas of southwestern Saskatchewan, Hard Red Spring Wheat crops with protein concentrations below 12.8% are likely to have suffered yield losses due to insufficient N supply. However, because in this area where water stress often limits grain yield and increases protein content, GPC above the 12.8% threshold value does not necessarily indicate N sufficiency. In the case of high protein crops, GPC must be evaluated jointly with information of grain yield of the harvest in question, and long-term grain yields obtained in the farm.

References

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