Wheat Grain Nutrient Concentrations: Wide-scale Average Values May Not Be Adequate for Field Nutrient Budgets

By Tom Jensen and Rob Norton

Large variability is observed in grain nutrient concentrations, which results in a degree of uncertainty in developing detailed nutrient budgets on a sub-region or individual field basis. This paper examines the interaction between individual grain nutrient values and the geographic scale in which they are collected and discusses the appropriate use of grain nutrient concentrations in developing nutrient budgets.

A nutrient budget for a wheat crop is similar in concept to a bank account. A balanced bank account is maintained by having deposits equal withdrawals. For a wheat crop nutrient budget, removals in the harvested grain of the crop need to equal nutrient inputs made available to the crop. Some mineral nutrients need to be supplemented in amounts close to removals, while other nutrients can be supplied by a combination of what is mineralized annually from the soil supplemented by fertilizer inputs, and yet other nutrients can be supplied sustainably from the soil for many years.

A working group within IPNI developed a decision support system (DSS) for farmers to decide what rate of supplemental fertilizer nutrients to apply to a wheat crop (see article on Nutrient Expert Wheat in this issue). This type of DSS is needed in areas where soil testing services are not commonly available. Since yields are often recorded, or at least quite accurately estimated, an understanding of the nutrient concentrations of grain is important in developing budgets for plant nutrients. One challenge is deciding what grain nutrient concentrations should be used to calculate the amount in nutrient removed. For a specific nutrient the amount removed in the grain is a product of nutrient concentration and crop yield.

IPNI has conducted three projects to assess the variability of grain nutrient concentrations in some of the important wheat-growing areas of the world. In 2009, a selection of wheat samples from India, China, Russia, USA, and Canada were tested for nutrient concentration. At the same time, the grain nutrient contents were assessed from two varieties of wheat from 70 sites in the southeast region of Australia. These sites were part of the Australian National Variety Testing (NVT) program conducted during the years 2008 and 2009. The third project was a sub-regional study in 2010 conducted in western Canada where grain samples from ten wheat varieties at six trial sites were analyzed for their nutrient content.

Common abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; S = sulfur; Ca = calcium; Mg = magnesium; B = boron; Cl^- = chloride; Cu = copper; Mn = manganese; Zn = zinc.

There have been several studies undertaken on grain nutrient densities in Australia (Schultz and French, 1978) and much of that information has been collated and published in "Plant Analysis – An Interpretation Manual" (Reuter et al., 1997). Those values are now used as benchmarks in developing regional nutrient budgets. However, the variability observed in regional, cultivar, and annual changes in grain nutrient concentrations results in a degree of uncertainty to develop detailed nutrient budgets on a sub-region or individual field basis. In this article, the spread of the values measured is reported as the coefficient of variation or CV. This is a measure of the "normal" range of values; in fact it is the range that covers the middle 67% of measurements made. **Table 1** compares the means and CVs for selected macro and micronutrient grain concentrations from the three IPNI studies with the mean and proposed critical values in Reuter et al. (1997).

The data from the three studies show that the variability around a mean value, as shown by the CV, decreases for most nutrient concentrations as you move from an international data set, down to a region, and then down to a sub-region level. For example the CV values for S went from 22 to 13, then to 11. Some of the nutrient grain concentrations were more variable compared to others, for example B with respective CVs of 69 to 58 and then 38 with data originating from the global through sub-regional level. This can be explained using knowledge of the soils in southeast Australia, ranging from acidic soils to soils containing free carbonate. Their formation has meant that topsoil and subsoil B levels are highly variable. Nitrogen

Table 1. Wheat grain nutrient concentration means and coefficient of variations (CV) for multiple country, regions within a country, and sub-region studies, and Australian benchmark values.

		Macronutrient†						Micronutrient†				
Study	Statistic	N	P	K	S	Ca	Mg	B	Cl-	Cu	Mn	Zn
International - 2009	Mean	2.5	3,600	4,000	1,700	890	730	2.9	330	5.7	43	31
	CV, %	16	33	20	22	61	55	69	47	61	37	42
Regional – 2008 to 2009 Southeast Australia	Mean	2.6	3,300	4,600	1,700	420	1,300	2.2	-	4.8	44	23
	CV, %	18	20	14	13	21	10	58	-	24	32	32
Sub-regional - 2010 Western Canada	Mean	2.5	3,600	3,600	1,600	340	1,500	1.6	560	4.9	52	33
	CV, %	16	14	15	11	26	16	38	14	18	27	19
Reuter et al. 1997	Mean	-	2,900	4,000	1,600	430	1,400	-	-	-	-	-
Proposed Critical Values		-	2,700	-	1,200	-	-	<2.0	1.0 to 2.5	-	20	5 to 15

†N reported as %, all other nutrients as mg/kg.

Table 2. Field site P removal in IPNI studies (2010) compared to removals estimated using a regional nutrient removal guide value (kg P/ha).

Site Name	Actual site P removal, kg P/ha	Calculated P removal using 1998 guide, kg P/ha	Over estimation using regional 1998 value, kg P/ha
Watrous, SK	19.1	19.6	0.5
Regina, SK	11.1	11.5	0.3
Moose Jaw, SK	15.7	17.8	2.1
Vulcan, AB	13.1	16.3	3.3
Delia, AB	10.7	13.8	3.1
Three Hills, AB	16.3	24.1	7.8

on the other hand appears to be closely regulated physiologically within wheat plants, as N mean values for wheat at all three levels of study were quite close, and the corresponding CV values were low compared to most of the other nutrients analyzed.

Of the three macronutrients commonly applied as fertilizers, (N, P, and K), it appears that P concentrations in wheat grains are more variable at the multi-country and regional-scale, and use of large area general values may not be appropriate for developing nutrient budgets on an individual field basis. For example an average P removal value for wheat in a regional nutrient removal guide used in western Canada (CFI, 1998) shows that a 40 bu/A crop removes about 23.5 lb P_2O_5/A (11.5 kg P in a 2,720 kg/ha crop). Using these numbers, the wheat grain P concentration would be 4,300 mg P per kg of grain. The grain P concentrations of the six sites used in the 2010 IPNI western Canada study ranged from 2,900 to 4,100 mg P per kg of grain. **Table 2** shows the actual P removal for each site compared to the amount that would be calculated if the nutrient removal guide value was used. For two of the six field sites the regional grain P concentration value gave a close estimate of actual P removal, but if used for the rest of the sites there would be an overestimation and result in P fertilizer recommendations that could be greater than needed.

In many world locations N content values are often known for wheat crops as this is measured as protein content at local grain delivery facilities, and use of grain N concentrations using these values may be accurate for calculating N nutrient budgets. Of the remaining macro and micronutrients, grain nutrient concentrations are not available unless grain samples are analyzed. Of the remaining macronutrients, Ca is more variable than Mg, which seems to be more stable, similar to N and K.

It is also important to consider the type of wheat grown in an area if improved nutrients budgets are to be developed. In the sub-regional 2012 western Canada project three different types of wheat were assessed: hard red spring or bread-type wheat; durum or pasta wheat; and Canadian Prairie Spring Red wheat or higher yielding/lower protein wheat used for animal feed or bio-fuel production. For many of the nutrients measured, grain concentrations and total nutrient removed in harvested grain were significantly different across wheat types. For example, the durum types had higher K concentrations and harvested K removals compared to the bread wheat types. The average grain K concentrations were 4,100 mg/kg for durum types compared to 3,300 mg/kg for bread wheat types, and similarly, average K removal was 16 lb/A (18 kg/ha) and 11 lb K/A (12 kg K/ha) for the respective wheat types. This variation highlights a benefit from separating these measurements according to wheat type if more accurate nutrient budgets are desired.

All of the micronutrients are quite variable and nutrient budgets for these should probably be developed at a local sub-region or field basis. Generally low amounts of micronutrient fertilizers are used compared to N, P, and K worldwide. It is advised that use of micronutrients be based on a combination of soil and plant testing or at least visual diagnosis at a field level, rather than developing nutrient budgets based on yields and general grain nutrient concentrations. BC

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