NEWS & VIEWS

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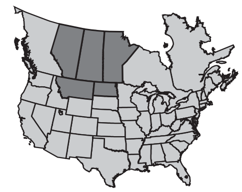

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Base Saturation and Basic Cation Saturation Ratios—How Do They Fit in Northern Great Plains Soil Analysis?

THERE ARE ever-increasing options for soil testing available to producers these days, with regional laboratories being joined by labs from other parts of North America. While almost all of these soil testing labs follow some recommended analytical procedures…and subscribe to the North American Proficiency testing program (sample analysis accuracy)…the philosophy of fertilizer recommendation used by different labs can vary significantly.

Fertilizer recommendation philosophy refers to the process and the assumptions behind the use of soil analysis information, in most cases a set of field response data, and estimates of soil nutrient mineralization (release) to make fertilizer recommendations. Most regional labs in the northern Great Plains have a set of field crop response data on which to base their fertilizer recommendations. Others will use alternative methods of estimating crop requirements for nutrients to make a fertilizer recommendation, such as nutrient removal. Another of these alternative methods is the base saturation or basic cation saturation ratio (BCSR) method.

Base Saturation

The term base saturation is used to characterize how completely occupied are the adsorbing (surface held) sites of soil mineral and organic particles with basic cations. The basic cations commonly found in the soil are calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na). The acidic cations are aluminum (Al) and hydrogen (H). So, base saturation describes how completely the soil particle surface is filled with the basic cations (Ca, Mg, K, and Na). When all the soil particle exchange sites are occupied with bases, we have 100% saturation. This happens when the soil pH is well above 7 (alkaline). However, at lower pH values, some H and Al find their way onto the surface of the soil mineral and organic particles and that drops the base saturation to less than 100. So, base saturation is:

$$\%BS = \frac{Ca+Mg+Na+K}{Ca+Mg+Na+K+H+Al} \times 100$$

Base saturation has been used to make decisions on whether a soil should be limed or not, along with a number of other tools. It is not a soil testing index and does not necessarily imply nutrient fertility of a soil.

Basic Cation Saturation Ratio (BSCR)

This BCSR term is used to describe the "ideal proportions" of the major exchangeable cation nutrients, those being Ca, Mg, K, and H. It was proposed in the 1940s and 1950s by Bear and associates (1945 and 1948) and is being used by a number of soil testing labs to provide fertilizer recommendations. The philosophy is not concerned with recommendations for nitrogen (N), phosphorus (P), sulfur (S), or micronutrients.

The fertilizer recommendations made using BCSR do not consider the sufficiency approach, which is built on the concept that certain levels of plant nutrients in the soil can be defined as optimum, below which a crop response is likely. Most public and private soil testing laboratories responsible for fertilizer recommendations use this sufficiency approach method. The BCSR considers only the ratio of the cations in the soil without consideration to their uptake by plants, with a low ratio forcing a fertilizer recommendation.

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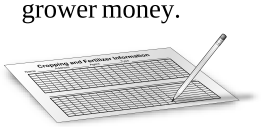
Table 1. Crop response to K fertilizer on soils showing a low cation ratio, but high levels of soil test K in Saskatchewan in 2001 and 2002. (A. Johnston, unpublished)

	2001	- - - - - - - - - -	- - - - - -	2002 - - - -	- - - - - -	- - - - - - - - - -
	Durum	Barley	Durum	Durum	Durum	Durum
Location ➧	Lacadena	Rouleau	Rouleau	Rouleau	McTaggart	McTaggart
Grain Yield, bu/A						
Check	37.1	27.0	28.8	50.9	46.9	49.8
KCl[1]	35.5	26.2	28.6	52.1	47.2	49.6
Pr>f	0.545	0.582	0.880	0.476	0.632	0.581
CV (%)	6	8	6	4	4	1
Soil Properties						
Soil test K[2]	>510	>510	>510	>510	>510	>510
% Ca	73	76	75	75	70	70
% Mg	23	21	20	20	27	27
% K	2.1	1.7	3.1	3.1	2.1	2.4
% Na	2.1	1.1	1.2	1.2	1.2	1.1

[1]Potash applied at 20 lb K_2O/A.
[2]Soil test K (0 to 6 in.) using Enviro-Test Labs modified Kelowna analysis (lb K/A).

This poses a problem in calcareous soils found on the northern Great Plains, where soil Ca levels are high, but K and Mg levels are more than sufficient as well. This is shown in some field trial results from Saskatchewan (**Table 1**). Addition of K fertilizer on these soils provided no response to K, even though the cation ratio was very low. In these instances, a sufficiency analysis showed that there was an abundance of available K.

All of these experiments were carried out on-farm using yield monitors. Each trial had four replicates and two treatments: treated with KCl and untreated. All sites were heavy clay soils, providing a high soil test K, but very low K saturation. In all cases the percent K would have prompted a K application using BCSR philosophy, but no recommendation using a sufficiency method. In this example, using the sufficiency recommendation saved the grower money.



There are a number of studies in the literature that refer to the use of BCSR methods. Danhke and Olson (1990) noted: "It is surprising that the cation concept has received the credibility accorded to it in consideration of the early and recent literature accounts on the issue" that show no relationship between plant yields and BCSR. More recently, Karamanos and co-workers (2003) showed that there was no relationship between yield increases and the K saturation of western Canadian soils. Signigicant barley (cv. Harrington) grain yield responses were obtained with seed row application of 13 lb K_2O/A in over half of the 73 experiments they reported on. These responses were independent of K saturation and appeared to be more frequent at higher rather than lower K saturation values (**Figure 1**). Caution should be exercised when these ratios are used to derive fertilizer recommendations of crops, because as Barber (1984) pointed out the activity ratio of K and Ca at the root surface may differ by a factor of 20 from the same ratio in the soil solution only a few hours after a

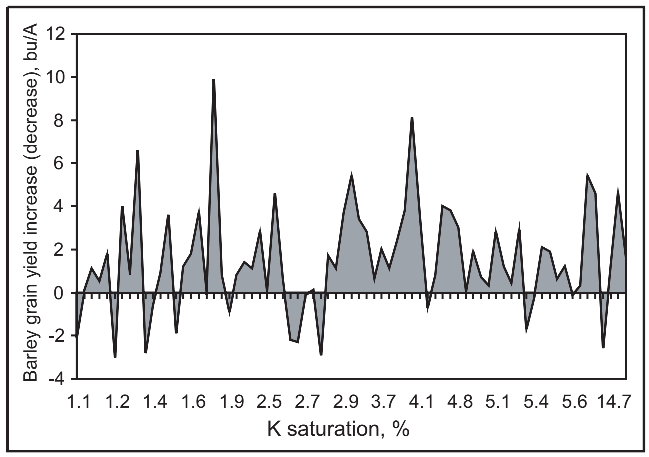


Figure 1. Barley grain yield responses with seedrow application of 13 lb K_2O/A, as affected by soil K saturation. (Karamanos, et al., 2003)

root has been absorbing these two nutrients. This means that ratios extracted in a laboratory environment may not have any resemblance to those at the natural root environment.

Most northern Great Plains soils are very well supplied with nutrients like K, and where deficiencies do occur "traditional" soil testing techniques provide satisfactory predictability. Unfortunately, where a BCSR is used the recommendation may be meaningless and lack the necessary calibration required for northern Great Plains soils and environmental conditions.

Are There K Responses on High Testing Soils?

Yes, soils testing high in K can show responses to potash additions. Potassium is considered relatively immobile in soils, except for sands, moving mostly by diffusion from the soil to roots. Diffusion is a slow, short-range process which depends on soil moisture, and to a lesser extent on soil temperature. Prairie soils are frequently cool early in the spring at planting. The colder the soil, the slower the K will diffuse, the slower plant roots grow, and the slower K will be taken up by roots. Diffusion and the rate of K uptake by plants may limit K availability, even though the soil tests high in available K. Applying low rates of starter K (15 to 20 lb K_2O/A) under these conditions helps increase the soil solution K, providing a ready supply for early season plant root access. Work by Skogley and others (1981) in Montana (**Table 2**) and Karamanos and co-workers (2003) in western Canada showed quite clearly that crops did respond a certain portion of the time on high testing soils. While the frequency of response may be low, the yields obtained often more than covered the fertilizer addition cost.

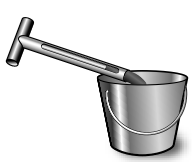
Table 2. Response of various crops to K fertilizer in Montana. (Skogley and Haby, 1981)

Crop	Response frequency, %	Avg. yield increase[1]	Avg. application rate, lb K_2O/A
Winter wheat	47	5.5 bu/A	20
Spring wheat	30	4.8 bu/A	20
Barley	44	3.9 bu/A	32
Barley (irrigated)	70	9.2 bu/A	43
Alfalfa hay	50	694 lb/A	75 to 200
Native range	17	315 lb/A	70

[1]Average yield increase on responsive sites only, non-responsive sites not included.

Crop varietal differences can also play a major role in response to K additions. For example, work with four barley varieties showed that significant ($p = 0.05$) responses to 13 lb K_2O/A occurred only 7% of the time with B1512, but 50% of the time with Harrington (**Figure 2**). While plant disease was not measured, Harrington is one of the most disease susceptible barley varieties grown in western Canada.

Soil nutrients are not uniformly distributed throughout fields, especially with variable topography. Past research by Penney and co-workers (1996) using grid soil sampling has shown that fertility levels of many fields are more variable than once thought. This high variability can lead to a soil with average K level which is considered sufficient, while large areas of the field are in the deficient range. For example, they found soil test K in a typical field to vary from 59 to 310 parts per million (ppm), with a mean of 135 ppm. Based on this average value, the field did not require any K fertilizer, yet the grid sampling revealed that 30% of the field needed K and another 33% may need extra K. When collecting a composite sample, it does not take many 300 ppm samples to inflate the average, leading to an erroneous fertilizer recommendation.



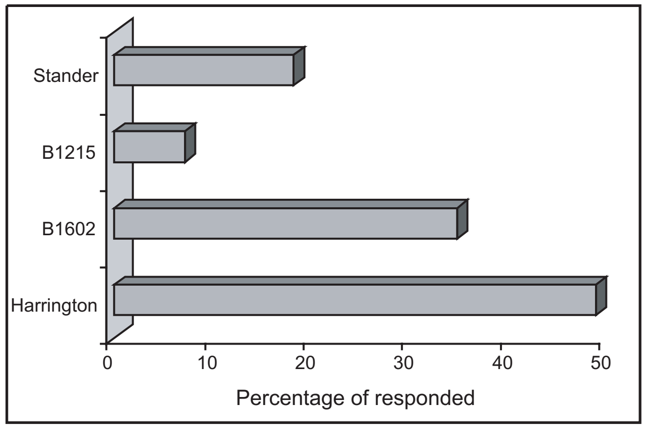


Figure 2. Yield response of four barley varieties to seedrow application of 13 lb K_2O/A. (Karamanos et al., 2003)

What about Chloride?

Another study on the northern Great Plains showed a response to K in only one portion of the landscape. Schoenau and co-workers (1999) reported a 17 bu/A wheat yield increase in the footslope area that had been fertilized with muriate of potash, while no response was recorded in the upper slope position. While the soil had almost 200 ppm of available K, the chloride (Cl) levels were low in the footslope position. Unlike K, Cl is very mobile in the soil and easily leached, especially in low-lying areas that accumulate water. Chloride is a plant nutrient that is often low in Great Plains soils and muriate of potash contains 47 to 48% Cl. Research by Grant and co-workers (1999) in the Canadian Prairies demonstrated the importance of Cl fertilization in cereal grains, especially the variability between cultivars. Chloride is highly mobile in soils, and variability across the landscape makes prediction difficult.

Making the Most of Soil Test Results

This article was written to show the problems that come from inappropriate use of an old and faulty fertilizer recommendation method. In this case, the BCSR is an example of a fertilizer recommendation philosophy which has almost no support in the scientific community. **As an agronomist or grower, you will ultimately make your own decisions on what information you want to use in making effective fertilizer recommendations. Hopefully, we have presented enough information here to prevent you from using the BCSR method on northern Great Plains soils.** ■

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