05/25 - Factory estimates of K in beet tissue water for monitoring the potassium status of soils

Summary

1. The project used beet and soil sampled by British Sugar staff from individual fields prior to the 2005-06 processing campaign to validate the use of factory tarehouse estimates of potassium concentrations in beet tissue-water to characterise the K status of the soil.

2. Comparisons showed that the factory estimates of K in beet tissue water agreed well with concentrations established by direct laboratory measurement.

3. Experimental data from previous BBRO-funded projects on Rothamsted's long-tem K plots were use to establish the tissue-water criteria for distinguishing the broad categories of Soil K Index. These were:

   (a) a concentration of 45 mM of K/kg in beet tissue water indicated K Index 0-1 soils with less than 120 mg of exchangeable K/kg of soil;
   (b) a concentration of 46 – 65 mM K/kg of tissue water indicated soils at K Index 2 with 121-240 mg/kg of exchangeable K; and
   (c) a concentration above 66 mM K/kg of tissue water indicated a Soil K Index of 3 with more than 241 mg of exchangeable K/kg of soil.

   These three categories meet the broad requirements of MAFF Bulletin RB209 and the BBRO Grower's Guide.

4. Except for a minority of cases, the Soil K Index rankings of over 260 fields from the Allscott, Bury, Newark, Wissington and York factory areas based on K concentrations in beet tissue water agreed well with those based a soil analysis.

5. **05/25 - Factory estimates of K in beet tissue water for monitoring the K status of soils**

Introduction

Current general recommendations for potassium fertilizer use derive from experiments done 30-40 years ago which established the premise that sugar beet require a minimum of concentration of 120 -180 mg of exchangeable K per kg of topsoil (equivalent to an ADAS Soil K Index of 2-) to achieve maximum yields of sugar. The recently completed 6-year series of BBRO-funded experiments by British Sugar plc and Rothamsted Research on plots at Rothamsted with a wide range of long-established differences in exchangeable soil K has confirmed that these concentrations of exchangeable soil K are still adequate for the much higher yielding crops that are now being grown (Fig. 1*a*) [1,2].

The MAFF Bulletin on Fertilizer Use (RB 209) and the BBRO Sugar-Beet Growers' Guide [3,4] recommend that growers should aim to maintain their soils at K Index 2 for sugar beet. To achieve this, farmers should replace the K that is removed in the harvested beet and, where necessary, apply extra potash to improve the long-term reserves of soil K. The booklets provide some broad recommendations for doing this. They recommend that 100 kg of K_2O/ha is applied on soils that are below K Index 2, 75 kg K_2O/ha on soils that at Index 2, and none to soils that are at K Index 3 and above. The primary aim of these applications is to replace the K removed from the soil in the harvested beet. To increase their reserves of exchangeable soil K, it is recommended that soils of K Index 0 and 1 receive an extra 25-50 kg of K_2O/ha, provided the soils have a sufficient content of clay to retain it.

More field-specific information on the potassium status of the soil and on the amounts of K removed in the delivered beet are needed to refine these broad recommendations for individual farmers, especially those growing higher than average yielding crops. The recent BBRO Project 00/25[1] demonstrated how factory tarehouse measurements could be used to provide grower-specific information on the amounts of K removed in the delivered beet. Such information is now available to growers on the internet at *British Sugar Online*.

Further analysis of how sugar-beet crops physiologically use potassium and sodium in this, and the associated BBRO Project 04/14[2], suggested that factory tarehouse measurements could also provide broad indications of the K status of the soils on which the delivered beet had been grown. The relevant relationships are shown in Fig. 1. The two BBRO Projects showed that

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[1] BBRO 00/25: *Establishing the potassium requirements of modern high-yielding sugar beet crops for yield and quality*

[2] BBRO 04/14: *Effects of sodium and triazole fungicides on yield and quality on soils of different K index*.

[3] *MAFF Bulletin RB209: Fertiliser Recommendations for Agricultural and Horticultural Crops. 7th Edition,* HMSO:London (2000).

[4] *Sugar Beet: - A Grower's Guide. 6th Edition.* BBRO:Peterborough (2002)

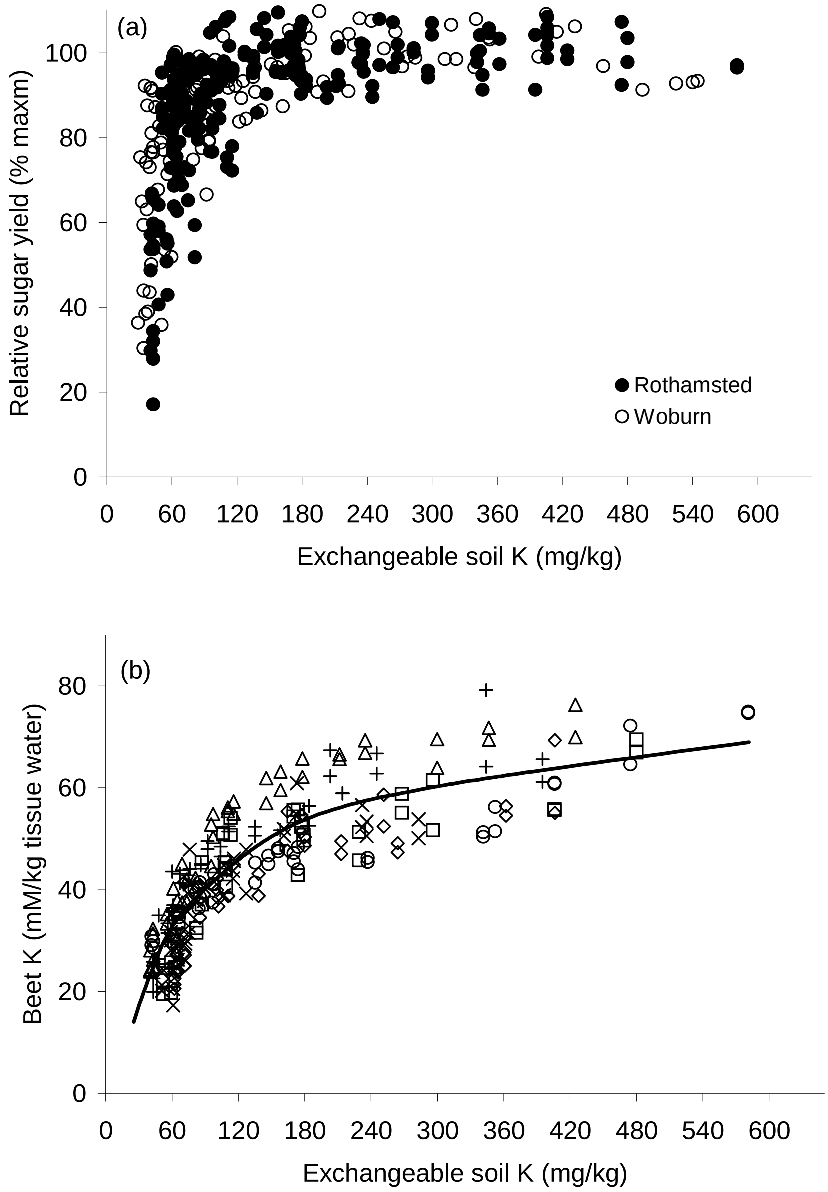

Fig. 1. *Relationships between exchangeable soil K and (a) sugar yield and (b) the concentration of K in beet tissue water established during a 6-year series of sugar-beet experiments between 2000 and 2006 on plots with long-establshed differences in soil K on a silty clay loam at Rothamsted and a sandy loam at Woburn. The symbols in (b) indicate different years and the regression equation is y = 52.7 + (-52.7 * 0.986x) +(0.028x).*

maximum sugar yields were obtained when there was at least 130 mg of exchangeable K/kg in the topsoil on both silty clay and sandy loam soils. This concentration is equivalent to Soil K index of 2- (Fig 1a), but it would be safer to use the whole K Index 2 up to 180 mg/kg to allow for variation in soil K across the field when making practical decisions on fertiliser applications. The concentrations of K in the tissue water of the harvested beet were also strongly correlated to the concentrations of K in the soil (Fig. 1*b*).

The present project has used beet and soil sampled by British Sugar staff in autumn from individual fields during the 2005 field survey to validate the use of these relationships and factory tarehouse estimates of K concentration in beet tissue-water to define the K status of UK sugar-beet soils.

Estimation of K concentrations in beet tissue water

It would be impractical to directly measure the tissue-water concentrations of K in beet in commercial practice, but they can be estimated indirectly from factory tarehouse data. The procedures are shown diagrammatically in Fig. 2 and the calculations summarised in Table 1. Briefly, the main tarehouse measurements that are used are the fresh-weight percentage of sugar and the concentration of K per 100g sugar.

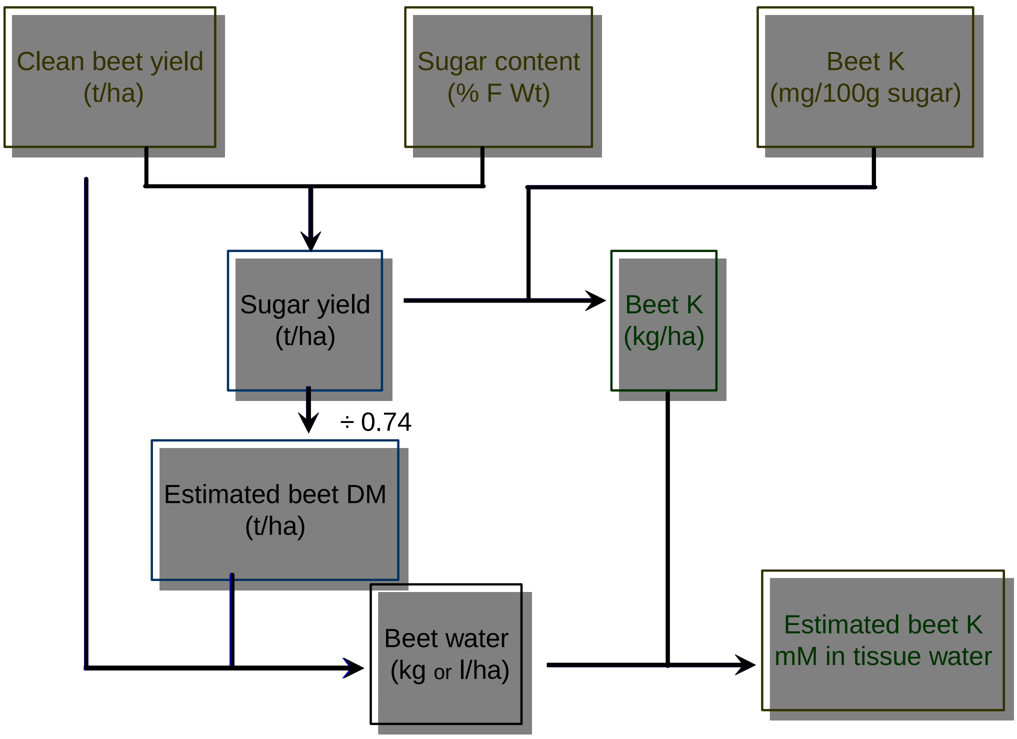

Fig. 2. *The estimation of tissue water content and tissue-water concentrations of K in beet from factory tarehouse data*

The first step estimates the dry matter content per 100g beet from the fresh-weight concentration of sugar by assuming that 0.74g of sugar equates to 1 g of dry matter. Previous physiological studies have shown this ratio to be acceptably constant in mature beet across seasons and a range of growing conditions. The tissue water content of the beet is then calculated as the difference between fresh and dry weights of the beet. Secondly, the amount of K in the beet is calculated from fresh-weight sugar concentration and the tarehouse K content (mg/100g sugar). Finally, the concentration of K in beet tissue water is obtained by dividing the beet K content by the beet tissue-water content and the molecular weight of K. Concentrations derived in this way are referred to as estimated concentrations and are expressed as millimoles (mM) of K per kg of tissue water. They are adjusted to a standard beet water content of 3.5 g water/g dry matter to allow for small variations in beet hydration between sites and seasons.

Table 1. *The estimation of K concentrations in beet tissue water from factory tarehouse data*

	Attribute	Calculation
A.	Estimate of root dry matter (g/100g beet)	= Sugar %F Wt ÷ 0.74
B.	Estimate of tissue water (g/100g beet)	= 100 - A
C.	Estimated beet K (mM/kg tissue water)	= (1000 * mg K/100g sugar * Sugar % F Wt) ÷ (B * 100 * 39)
D.	Standardized beet K (mM/kg tissue water) (standardised to 3.5 g water/g DM)	= C * ((A ÷ B) ÷ 3.5)

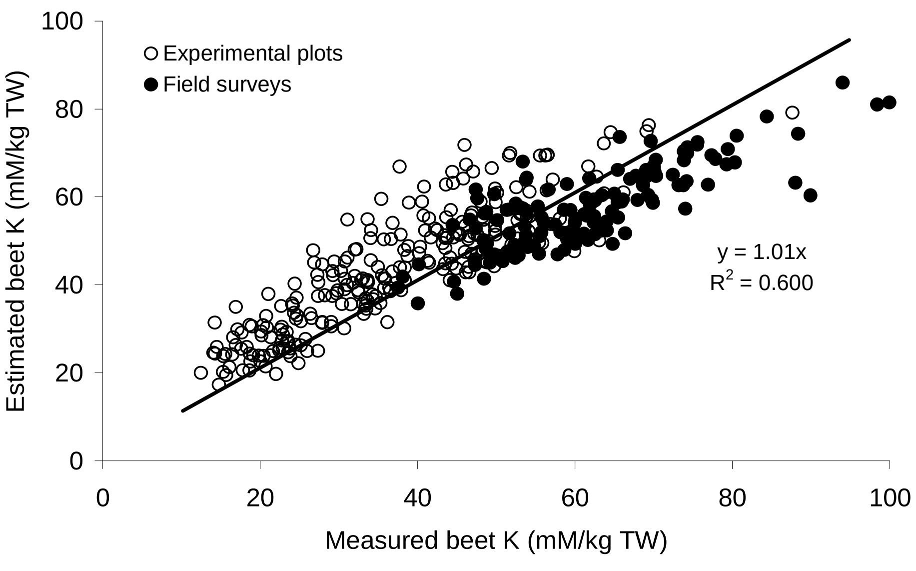

Fig. 3. *Relationship between experimentally measured concentrations of K in beet tissue water and those estimated from tarehouse data from Rothamsted's 2000-05 K experiments and commercial beet fields sampled by British Sugar staff in 1999*

Figure 3, which incorporates data both from the experiments on the long-term K plots at Rothamsted[1,2] and from commercial fields[5] confirms that indirect estimates of K in beet tissue water derived from tarehouse data agree well with concentrations established by direct laboratory measurement. Additional sensitivity analyses showed that varying the assumed percentage of sugar in beet dry matter from 72 to 78% (covering the extremes published for experimental crops) caused estimated tissue-water concentrations of K to vary by only 2-4 mM across a 25-75 mM range.

Tissue-water criteria for assessment of the K status of soils

The data presented in Fig 1*b* is re-plotted in Fig. 4 to examine how far tissue-water measurements of beet K discriminate soils of different K Index. To do this, the data were ranked by Soil K Index and the means and standard deviations of both beet and soil K calculated for each Soil Index group. The figure shows that the differences in tissue-water K are too small and their confidence limits too wide to discriminate between individual categories of Soil K Index, especially at the higher end of the scale. They do, however, allow soils to be broadly categorised into those that are deficient in K (Index 0 and 1), those that have adequate levels of exchangeable K (Index 2- and 2+), and those that have more than adequate levels of exchangeable K *(*Index 3 and above). The relationship has been used to establish the criteria for categorising soils during the validation exercise summarised in Table 2.

Table 2. *Criteria used to assess Soil K Indices from K concentrations in beet tissue-water*

Exchangeable soil K mg/kg	Soil K Index group	Beet K range mM/kg TW	Soil K status	Recommended K fertiliser practice
< 120	0 - 1	<45	Deficient	Replacement K + extra to build up reserves
121 - 240	2	45-65	Adequate	Replacement K only
> 241	3+	> 65	More than adequate	None required

[5] BBRO 00/26: *Predicting changes in the sugar content of delivered beet during the processing campaign.*

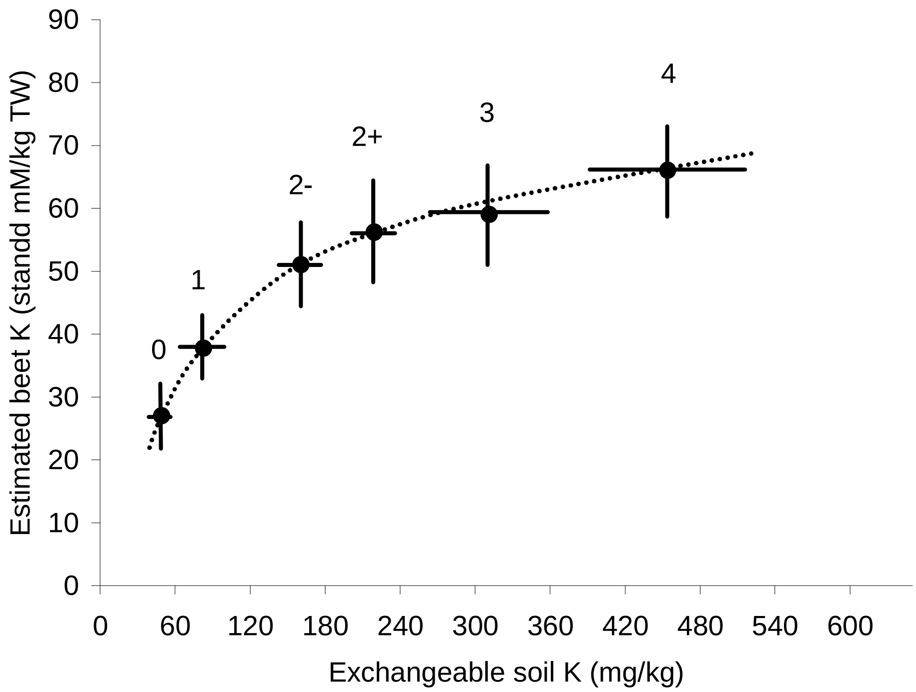

Fig. 4. *The ability of concentrations of K in beet tissue-water to discriminate between soils of different K index . The horizontal and vertical bars indicate the respective confidence limits for soil K and K in beet tissue-water, and the values above each point the approximate Soil K Index.*

The validation exercise

In the run-up to the 2005 processing campaign, British Sugar staff sampled beet from about 500 statistically-selected fields to survey growing practices and obtain a forward estimate of the yield and quality of the national crop. Beet were taken fortnightly from the beginning of August and analysed in the Wissington factory tarehouse laboratory. The present study used tarehouse data for the 7th and 8th weeks of sampling (*i.e.* the weeks closest to factory opening). The data were used to estimate concentrations of K in beet tissue water as outlined in Table 1. The topsoil of each field in the Allscott, Bury, Newark, Wissington and York factory regions was sampled, and a subset sent to the NRM laboratory for measurement of the concentration of exchangeable K. The subset of approximately 300 soils was selected on the basis of beet tissue-water concentrations of K in the field, the numbers being weighted to include all of the very low and very high concentrations which were fewer in number.

The estimated concentration of K in the beet ranged from about 30 to 120 mM/kg tissue water and that of exchangeable K in the soil from less than 40 to well over 800 mg/kg. The values for individual fields were reasonably well correlated and agreed well with the relationship established by the Rothamsted experiments (Fig. 5). The K status of the soil in each field was categorised using the beet tissue-water K criteria in Table 2. The tissue-water and soil analysis classifications are compared in Table 3.

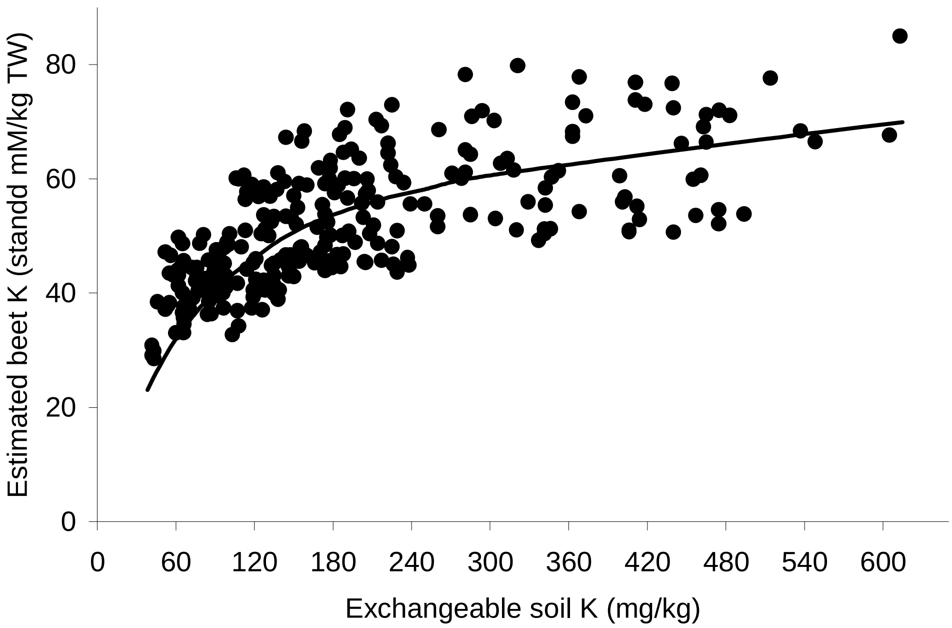

Fig. 5. *Relationship between K concentrations in the tissue-water of beet sampled from British Sugar Survey fields in the autumn of 2005 and the concentration of exchangeable K in the soil. The fitted curve is the experimentally-determined relationship from Fig.1b.*

Table 3. *Classification of the K status of the surveyed fields by soil measurement and by the concentrations of K in beet tissue water (TW)*

Classified by measured soil K			Classified by beet tissue water K		
Exchangeable soil K mg/kg	Soil K Index group	No. fields	mM/kg TW < 45 0-1	45 - 65 2	= 65 3+
< 120	0 - 1	83	61	22	
121 - 240	2	117	17	90	10
> 241	3+	67		23	44
	Total	267			

Laboratory soil analyses indicate that nearly three-quarters of the 83 fields tested that had K Indices of 0 or 1 would have been categorised as such on the basis of the concentration of K in the tissue water of their beet. The tissue-water criteria categorised the remaining fields at K Index 2 with the majority at the lower end of the range.

Similarly, three-quarters of the 117 fields whose measured exchangeable soil K classified showed they were at Soil K Index 2 have also been categorised as such by the concentration of K in the tissue-water of their beet 15% of the remaining fields were categorised by tissue-water measurements as at the upper end of Soil K Index 1 and 9% at the lower end of the Index 3. Finally, two-thirds of the 67 fields classified as K Index 3 and above by soil analysis were categorised similarly by the tissue water measurement. The tissue-water procedure classified the remainder of these soils at the upper end of Soil Index 2.

Soil analysis only measures the K content of the topsoil. When comparing the soil analysis and beet tissue-water approaches, it should be borne in mind, that there are substantial and variable quantities of exchangeable K within the subsoil that can be accessed by the growing crop and which will be reflected in the overall concentrations of K within the harvested beet. It could be argued that, in this respect, the concentrations of K in beet tissue-water are a better indicator of the overall amounts of K accessible to the crop within the entire soil profile.

The three broad levels of exchangeable soil K that can be categorised by beet tissue water measurements (deficient, adequate or more than adequate) are all that is needed to determine whether both a replacement and build-up application of K specified by MAFF Bulletin RB209 and the BBRO Growers Guide need be applied, or whether only replacement K (or none) is needed. Earlier work has shown that contract-specific and accurate estimates of the amounts of K removed in the delivered beet can also be derived from factory tarehouse data[5,6]. The two pieces of information should substantially improve on the broad generalizations currently being provided in the MAFF and BBRO guides by helping growers tailor their K fertilizer inputs more closely to their own enterprises.

The relevant pages of the *British Sugar On-Line* web site will be updated to include information on the concentration of K in beet tissue-water and a general estimate of the K status of the soils on which the beet were grown.

[6]. PJ Jarvis *et al*. Recent research on potassium and sodium recommendations for sugar beet. *British Sugar Beet Review* **71** (4), 4-9 (2003).