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Inorganic chemical analysis of plant tissue: possibilities and limitations

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Abstract

The variability of analytical results for determination of 23 inorganic components in different plant materials was evaluated, using data over the last five years of an extensive (on the average 120 participants) bimonthly collaborative interlaboratory study. In particular, the relation between content level and coefficient of variation (c.v.) was examined. Usually, a constant c.v. value was found at high content levels, with a sharp increase in c.v. at low levels.

The precision found for N, P, K, Ca, Cl, Mg, Zn and nitrate was high enough (c.v. < 20 %) to yield reasonably comparable content values. Comparison of analytical results for B, Cu, Fe, Cd, Mn and Na, may be difficult, since about 20 % c.v. was reached already at the levels usually present in plant material. The analytical results for Al, Co, Cr, Mo, Ni, Pb, S, Se and sulphate varied considerably, irrespective of the content level, which means that comparable results are very hard to produce with these components.

Introduction

The chemical analysis of plant tissue has become important in the management of intensive crop production. The purpose of this kind of analysis is to measure the total content of elements or species in the plant tissue. The concentration values are then used to indicate nutrient sufficiency or deficiency or the toxicity situation of the crop.

Many laboratories are involved in plant tissue analysis. However, since no 'standard' method is used, the question of how well laboratories agree on the results of plant tissue analyses is often asked. In order to answer this question, a collaborative type study has to be conducted to evaluate interlaboratory variability associated with plant tissue analysis.

Such a collaborative study, intended as a means for comparison of chemical ana-

lytical results, has been conducted by our university since 1956, and at the time being about 190 laboratories from 54 countries all over the world are participating. In the following, the data from the period 1981-1985 are used to show the interlaboratory variability in the determination of various elements. All data were obtained by the particular methodology and instrumentation routinely used by each laboratory.

Procedure

For each parameter the average value and the standard deviation were calculated for all available data. Values differing by more than two times the standard deviation from this average were discarded. A second average and standard deviation were computed. This procedure was repeated and a third average and standard deviation were calculated. With this last set of data the coefficient of variation was calculated:

$$\text{c.v.} = \frac{\text{standard deviation}}{\text{average}} \times 100\ \%$$

These coefficients of variation were then plotted as a function of corresponding average content of the parameters determined in the different plant tissues (Fig. 1). Because of the used calculation procedure and the fact that not all laboratories had determined all of the parameters, these average values and corresponding coefficients of variation are not always based upon equal numbers of analytical values. The number of values, however, was considered large enough to take the present parameters into consideration without introducing an additional variability.

Results and discussion

The general pattern in the results is, as expected, a constant coefficient of variation over a more or less broad range of concentrations, strongly increasing in the lower concentration range depending of the parameter under consideration (Fig. 1).

The 'constant' variability range can be considered as inherent to interlaboratory variation in cases where no analytical-technical difficulties are present. This 'constant' interlaboratory variability amounts to about 10 % for the following parameters:

CV = 5-10 % for Cl, K, Mg, N_{total}, P
CV = 10 % for Ca, Cu, Mn, nitrates, Zn
CV = 10-15 % for B, Fe, Na

For the other parameters studied no such clear-cut trend was observed, which indicates that the analytical difficulties are such that interlaboratory comparison is not feasible. This is the case for Al, Co, Cr, Mo, Ni, Pb, Se and sulphate. For all these parameters, with the exception of Al and sulphate, holds that the content in plant material is very low. This necessarily means that chemical analyses are not easy to perform.

In the case of Al and sulphate, the concentrations are reasonably high. The high

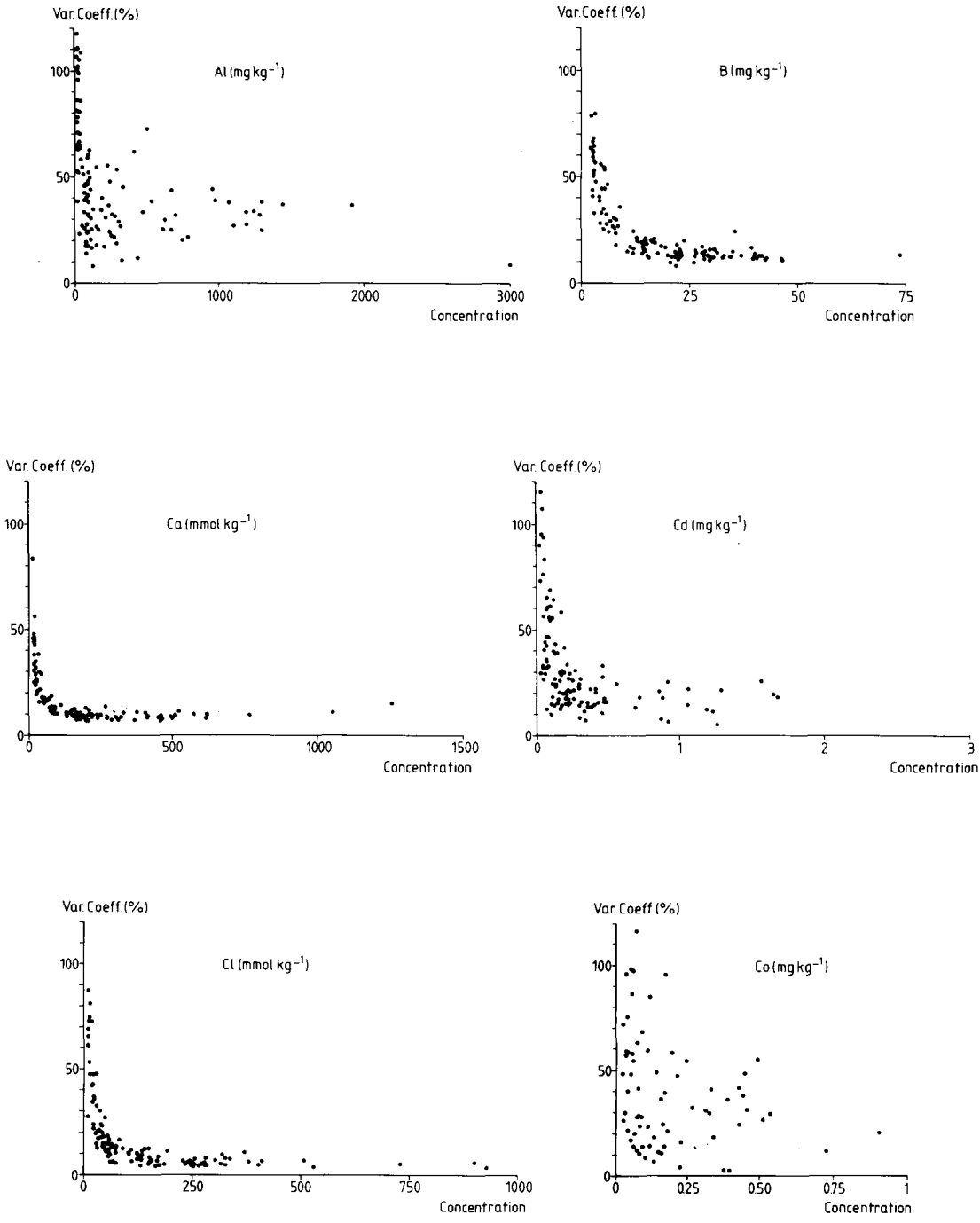
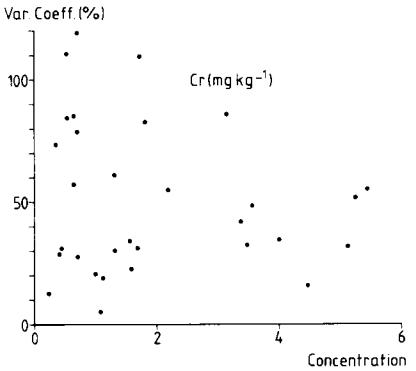
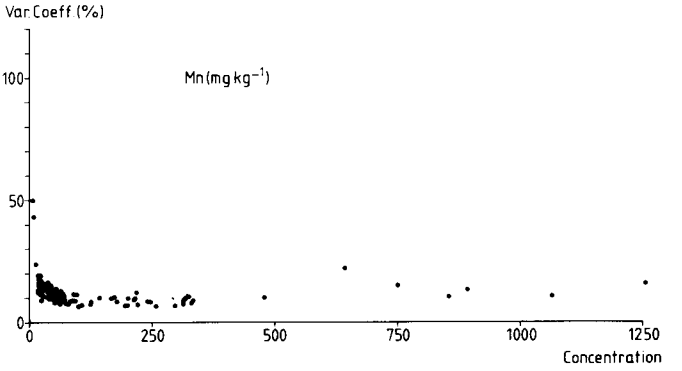
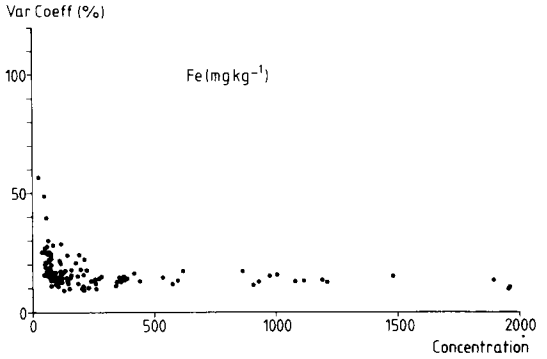
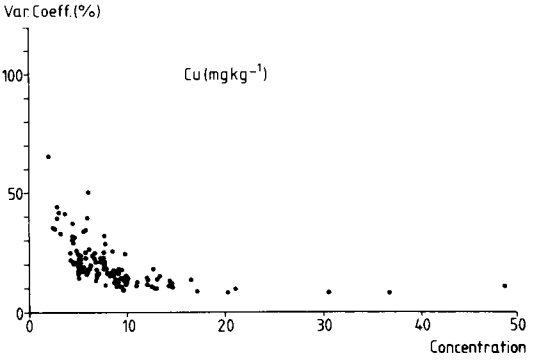


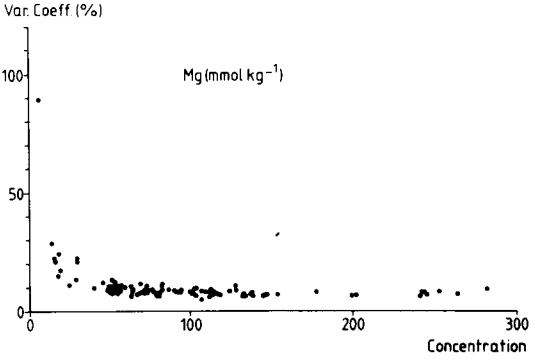
Fig. 1. Interlaboratory variability of chemical analysis of plant tissue in relation to concentration.

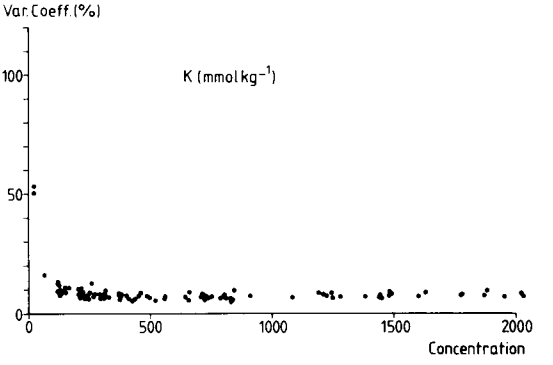












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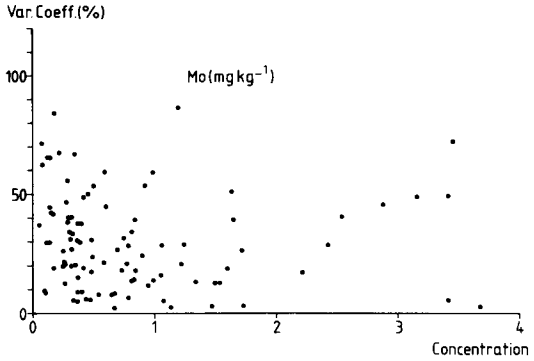

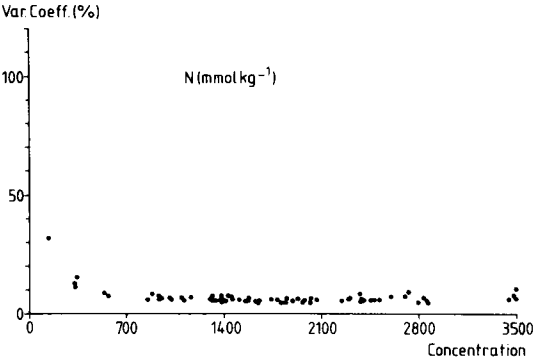

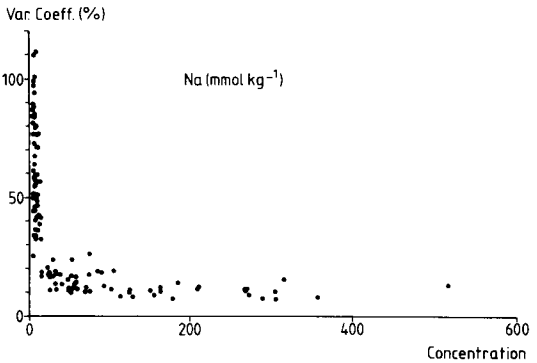

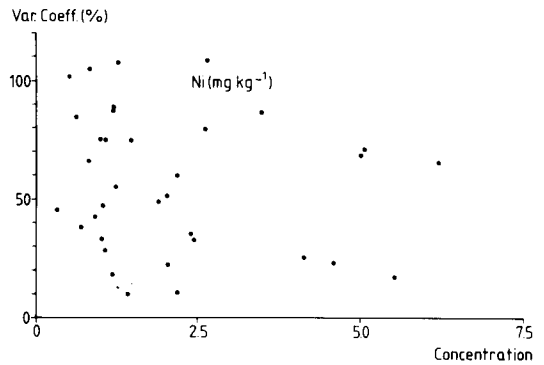

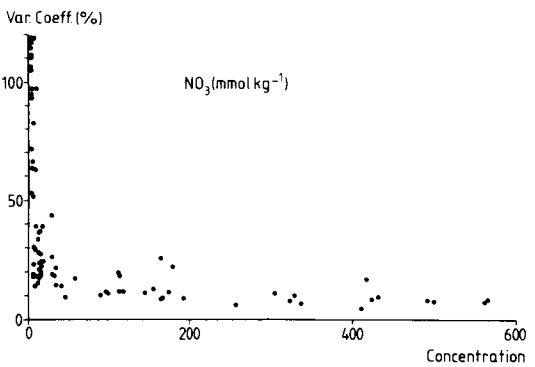

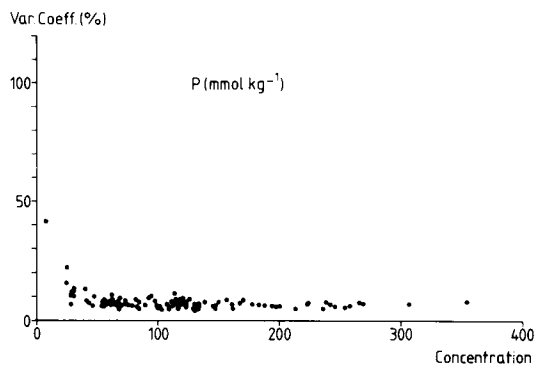

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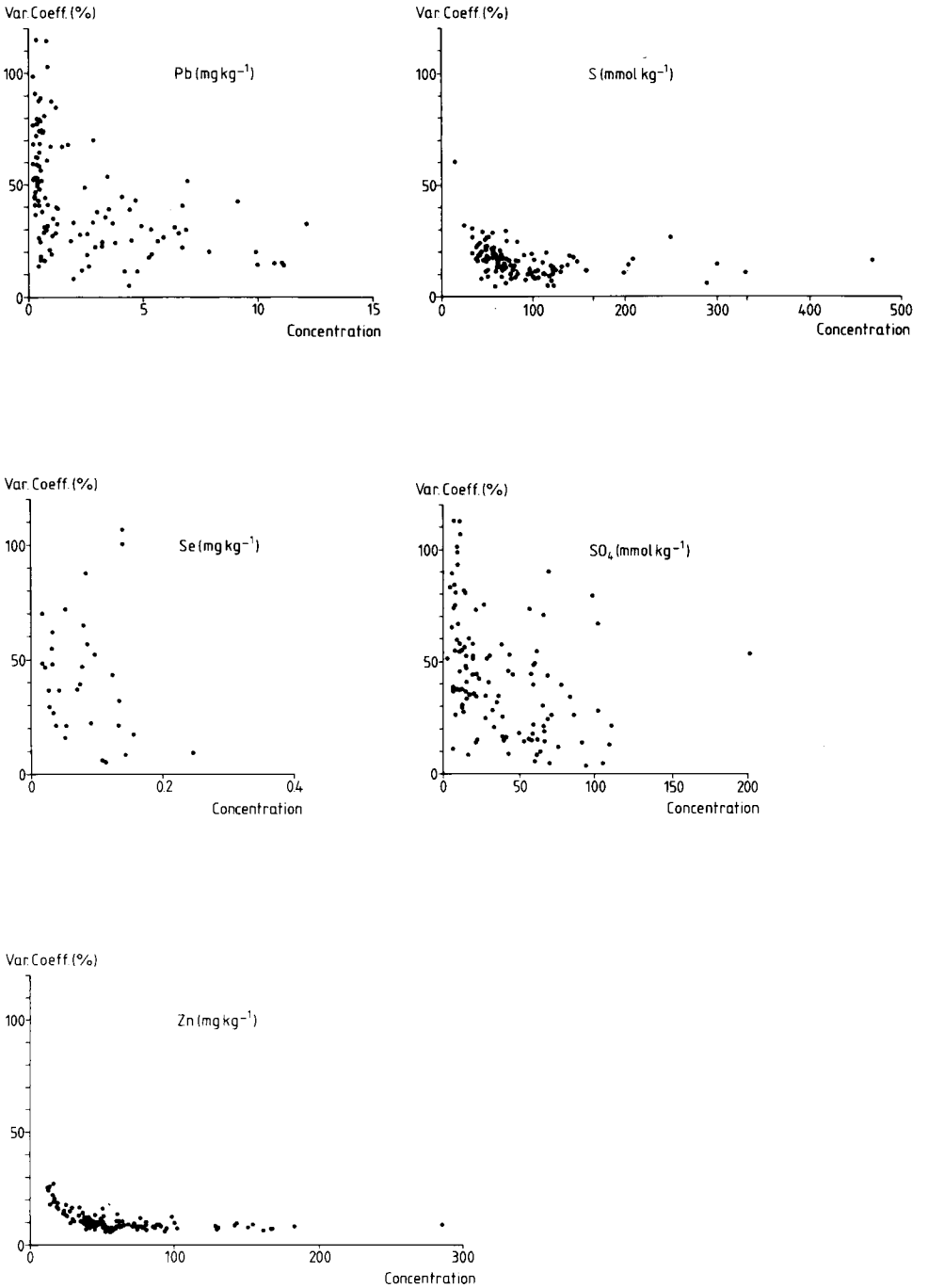

Fig. 1 (continued).

variation encountered may therefore be ascribed to less adequate analytical procedures. For example, it is known (Daniel et al., 1984; Ledent et al., 1984) that in case dry ashing is used without subsequent expulsion of silica, often too low Al values are found. This may be one of the causes of the high variability with this element.

The situation for total S and Cd is not a clear-cut one either. In the case of sulphur, losses during the digestion or incomplete digestion (compounds such as methionine are very difficult to digest; Novozamsky & van Eck, 1977) may be one reason for the somewhat higher interlaboratory variability.

Although Cd shows a more or less constant pattern at higher content levels, in the plant tissue analysed the concentrations were apparently at the lower level.

Conclusions

The data presented here can be used for the assessment of the possibilities and limitations of plant analysis data for the evaluation of the nutrient status of plants. For that purpose, a maximum acceptable c.v. value must be chosen. Then, the lowest content value can be estimated from the graphs for the different parameters. Table 1 gives these values for a chosen c.v. level of 20 %, together with values for 'normal' content ranges as reported by different authors. No analytical problems are to be expected with the determination of K, N and P, since the normal levels are much higher than the values that correspond with 20 % c.v. (Fig. 1). From Table 1 it is apparent that the situation for Ca, Cl, Mg and Zn is also favourable. Comparison of results is difficult for B, Cu, Fe and Mn, since values that correspond with 20 % c.v. fall in the range of normal values. The remaining parameters, i.e. Al, Co, Cr, Mo, Ni, Pb, S, Se and sulphate, pose severe problems with respect to the comparability of analytical results from different laboratories.

Generally speaking, the present results reveal that for a great number of parameters further analytical chemical investigations and optimisation of the methods used are urgently needed.

Table 1. Lowest measurable level of some nutrient elements for a chosen interlaboratory variability level of 20 % c.v., compared to literature values for 'normal' nutrient contents.

		Lowest measurable content	'Normal content range'		
			Benton Jones (1972)	Finck (1968)	Mengel & Kirkby (1982)
Ca	(mmol kg^{-1})	30		250-500	125-175
Cl	(mmol kg^{-1})	40			60-600
Mg	(mmol kg^{-1})	15		80-160	±200
Na	(mmol kg^{-1})	30			
NO_3	(mmol kg^{-1})	15			
B	(mg kg^{-1})	10	20-100	5-30	3-100
Cu	(mg kg^{-1})	7.5	5-20	5-10	2-20
Fe	(mg kg^{-1})	200	50-200		±100
Mn	(mg kg^{-1})	25	20-500	40-80	20
Zn	(mg kg^{-1})	15	25-150	20-30	20-120

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