EVALUATION OF THE NUTRITIONAL STATUS OF OILSEED RAPE PLANTS BY LEAF ANALYSIS

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INTRODUCTION

In accordance with LIEBIG's law of the minimum, maximal utilization of any applied nutrient is only possible, if no other nutrient deficiency occurs. Thus economically successful and ecologically tolerable agriculture requires plant nutrition which makes provision for a sufficient supply of the full range of elements essential for the growth of higher plants. Aiming for the highest possible utilization of fertilizers, it is not longer only a question of optimizing the economics of plant production, but with view to the increased sensitivity regarding environmental problems also necessary to minimize element losses from agricultural to natural ecosystems.

Table 1 stresses this important dependency by an example from oilseed rape cropping in Northern-Germany.

Tab. 1: Yield of oilseed rape and net utilization of fertilizer nitrogen by seeds depending upon the nutritional status of the crop (all three fields were cropped in 1981 with JET-NEUF and were similar in other growth parameters (e.g soil, clima, diseases)).

deficient elements	seed yield t/ha	protein content %	nitrogen fertilization kg/ha	nitrogen utilization %
S,K,Mg,Zn,Cu,B	1.4	19	230	19
K,Mg,B	2.2	21	230	32
none	4.8	22	230	75

Plant analysis is a powerful tool for the evaluation of the nutritional status of agricultural crops (Bergman, 1988, Chapman, 1966). The basis of its reliability, however, depends very much upon the quality of the analytical data and their interpretation. This contribution deals with a plant analysis system for oilseed rape evaluated from a data base containing more than 3000 observations for oilseed rape collected between 1980 and 1990 in the intensive cropping area of the German federal state Schleswig-Holstein.

METHODS OF PLANT ANALYSIS FOR THE EVALUATION OF THE NUTRITIONAL STATUS OF OILSEED RAPE

A reliable plant analysis system needs distinct conventions concerning developmental stage and part of the plant as well as suitable chemical parameters (Thomas, 1984). For oilseed rape the evaluation of these criteria is demonstrated here by the example of the nutrient sulphur.

Suitable chemical parameters. It is often stressed that mobile fractions of a nutrient are more suitable as chemical parameters than total element concentration. One of the most reported example in this field is the advantage of sulphate-S instead of total sulphur (S) concentrations (Freney et al., 1982; Maynard et al. 1983). Concentrations of mobile nutrient fractions in plant tissue are, however, more dependent upon the nutritional status of other elements (eg. sulphate-S depending upon the nitrogen status of the plant; Janzen and Bettany, 1984). In addition to this principal problem in oilseed rape the sulphate-S content in vegetative parts is strongly influenced by the release of sulphate from glucosinolates during their enzymatical decomposition (Schnug, 1990a). Thus factors concerning the handling of samples in the field may strongly influence the sulphate-S concentration in rapeseed leaves (fig. 1; see also Schnug, 1988 a and b).

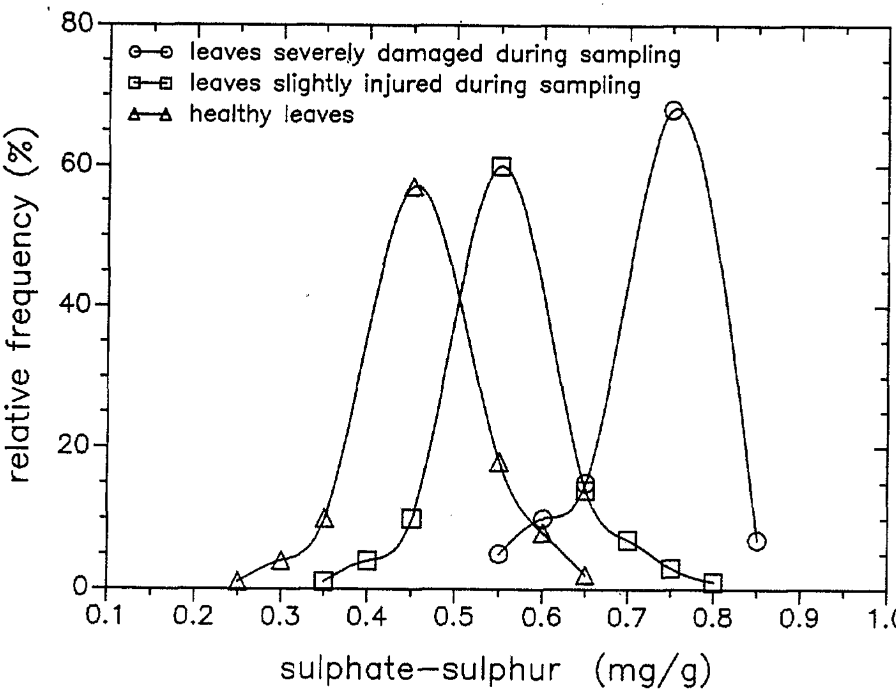

Figure 1. Relative frequency of sulphate-S concentrations in younger rapeseed leaves related to physical damages during sampling (Schnug, 1988b).

Due to the so called "dilution effect" (Bergmann, 1988) total element concentrations in plants may vary depending upon the development stage. For oilseed rape this problem can be solved by use of distinct parts of the plant. Younger, fully differenciated leaves of the upper third of rapeseed plants have been proved as suitable parts, because the nutritional status of the plant is well reflected in their element concentrations (fig.2).

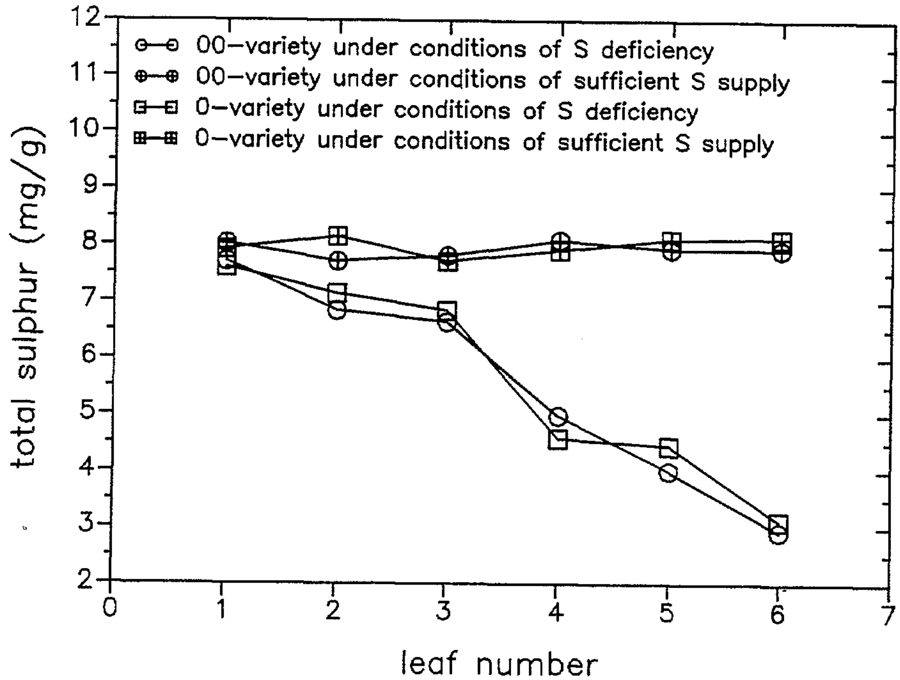

Figure 2. Total S concentrations in the last developed and fully differentiated leaf of oilseed rape plants grown with optimum and deficient S supply (Schnug, 1988b).

CALIBRATION OF PLANT ANALYSIS DATA

Due to the nonlinear relationship between nutrient concentrations in plant tissues and crop yield, critical values alone or ranges of critical values are not a reliable basis for the interpretation of plant analysis data. More expressive are "boundary lines" (WEBB, 1972) which are defined as the line along the left periphery of scattered nutrient concentrations and yield data and therefore describe the "pure nutritional status" of the crop (MOELLER-NIELSEN, 1973; WALWORTH, et al., 1986). An example of the application of boundary lines to plant analysis data is given in figure 3. The data given in figure 3 are derived from a data base consisting of more than 3000 results collected in field experiments and field surveys. The highest seed yield observed in the field was 5.5 t/ha. In the same way the boundary lines for all plant nutrients were established. An overview of the algorithms for each boundary line is given in table 2. To simplify the use of the boundary lines the range of each line is divided into sections with a steep (A) and a flat (B) slope. The highest valid value for the nutrient concentration in section B defines the critical value, which implicates that no further yield increase can be expected above this value by increasing plant nutrient concentrations.

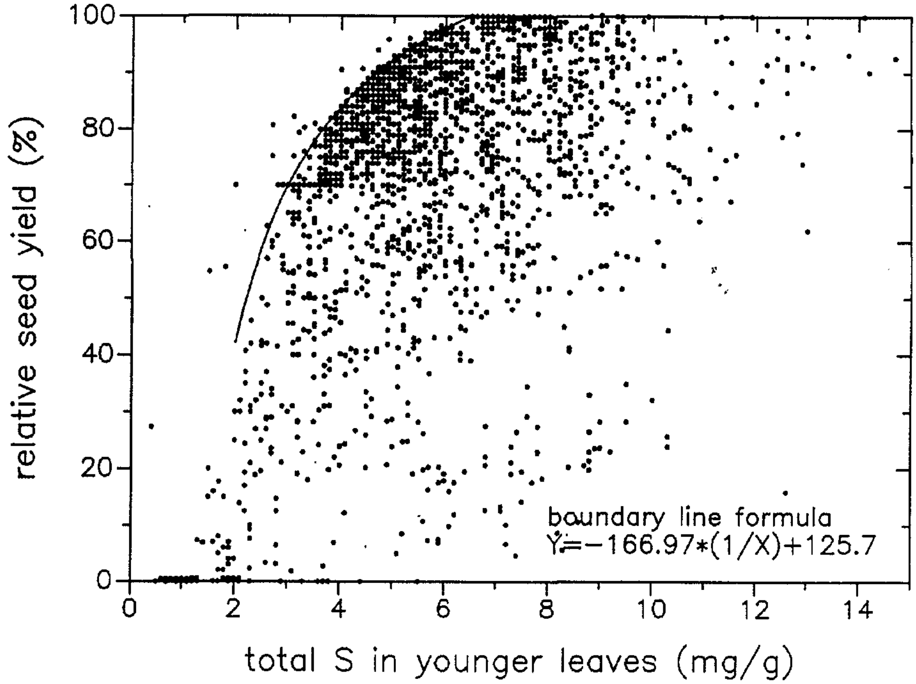

Figure 3. Relation between the total sulphur content in younger, fully differentiated leaves of the upper third of oilseed rape plants and the relative seed yield (SCHNUG, 1988b)

Tab. 2: Algorithms and valid ranges of boundary lines for unifactorial relations between nutrient concentrations in younger fully differentiated leaves of the upper third of shooting plants and relative seed yield of field grown oilseed rape (Y = relative yield (%); X = nutrient concentration in mg/g for macronutrients and mg/kg for micronutrients).

nutrient	---- section A ----		------- section B -------	
	formula	valid X	formula	valid X
N	6.07*X-121.43	20-34	2.5*X+0.01	34-40
P	43*X-64.5	1.5-3.5	2.0*X+16	3.5-4.2
S*	-166.97*1/X+125.7	1.32-6.5	-166.97*1/X+125.7	1.32-6.5
K	18.89*X-283.33	15-19.5	-1685.2*1/X-1.55*X+202.07	19.5-35
Ca	65*X-650	10-11	-1012.3*1/X-1.04*X+169.56	11-22.5
Mg	211.11*X-168.89	0.9-1.25	20*X+70	1.25-1.5
Fe	1.49*X-29.8	20-77	-14262.5*1/X-1.22*X+364.07	77-100
Mn	18.5*X-185	10-14	-1080*1/X-0.97*X+164.86	14-30
Zn	7.17*X-107.5	15-27	-4762.1*1/X-3.1*X+346.5	27-33
Cu	52.78*X-105.56	2.0-3.8	7.14*X+67.86	3.8-4.5
Cl	2.8*X-70	25-50	0.6*X+40	50-100
B	13.75*X-123.75	9.0-13	-1804.9*1/X-1.81*X+217	13-25
Mo	800*X-40	0.05-0.1	-10.842*1/X-74.45*X+156.24	0.1-0.3

* algorithms applicable to 0- as well as to 00-varieties! (Schnug, 1991a)

The highest value for valid X in section B of table 1 reflects the traditional critical value (lowest concentration for maximum yield).

CONCLUSIONS

To have a more multifactorial approach to the whole nutritional status of an oilseed rape crop a computer program called "PIPPA" (Professional Interpretation Program for Plant Analysis" was designed (Schnug, 1990b). In a first step, the PIPPA system calculates the yield level which can be expected for the supply of a certain nutrient and if all other nutrients and growth factors are sufficiently supplied. In a second step the program performs an order of rank of the mineral nutrients according to their expected limiting influence on crop yield which enables the identification of the most limiting nutrient in the investigated crop according to LIEBIG's "minimum law" (WALLACE, 1990). Thus the maximum yield level, which might be realized in a certain field without fertilization, will be the lowest one calculated by the program. Also no definitive yield response can be obtained for a certain nutrient until the nutrients with greater limitations are eliminated by fertilization. However, it should be mentioned, that the program considers that nutrients are the only yield limiting factors in the evaluated crop.

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PIPPA now first will ask you for the name of the elements and
then for their concentrations in your OILSEED RAPE leave sample

Accepted element names  :  N,P,S,K,CA,MG  FE,MN,ZN,CU,CL,B,MO
Accepted concentrations :  --- mg/g ----  ------ mg/kg ------
To end input type 'END' for element name and '0' for conc.

>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>> to continue  press <RETURN>
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the following graphic shows the rank of the minimum factors in your rape crop

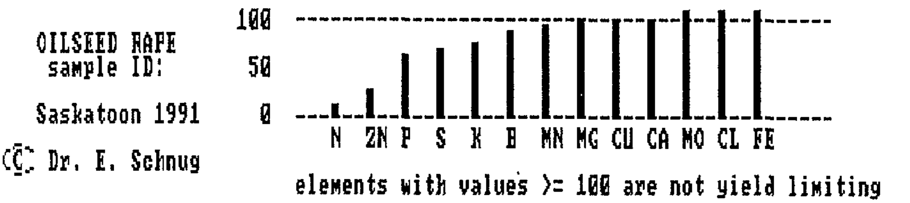

Figure 4. Output of the PIPPA system for analytical data of an oilseed rape leaf sample

Plant analysis as tool in practical plant nutrition is not very common. However, this seems likely to change in future as the problems in European oilseed rape cropping caused by S deficiency increases and soil analysis for S fails totally (Schnug, 1991b). Research actvities on sulphur have greatly increased and just recently the critical value of 0.65% S and the shape of the boundary line given in table 1 are confirmed by Pedersen and Oestergaard (1991). Thus for S the PIPPA system provides special features for the estimation of optimum fertilization in order to meet the different demands for the maximum seed yield and sufficient low glucosinolate contents in the seeds to secure the payment of quality dependant subsidies.

Experimental versions of the PIPPA program system (also for cereals) are available from ILLIT (Institute for Agricultural and Ecological Innovations and Technologies), Hansastrasse 18, D-2300 Kiel 1, FRG.

REFERENCES

BERGMANN, W. 1988. Ernährungsstörungen bei Kulturpflanzen. (Gustav Fischer Verlag, Stuttgart (2. Aufl.)).

FRENEY, J.R., RANDALL, P.J. and SPENCER, K. 1982. Diagnosis of sulphur deficiency in plants. Proc. Int. Sulphur Conference London, 1, 439 - 444.

JANZEN, H. H. and BETTANY, J. R. 1984. Sulfur nutrition of rapeseed: I. Influence of fertilizer nitrogen and sulfur rates. Soil Sci. Soc. Am. J. 48, 100 - 107.

MAYNARD, D.G., STEWART, J.W.B. and BETTANY, J.R., 1984. Use of plant analysis to predict sulfur deficiency in rapeseed (Brassica napus and B. campestris). Can. J. Soil Sci. 63, 387 -396.

MOELLER-NIELSEN, J. 1973. Kornplanters ernaeringstilstand vurderet og reguleret udfra planternes kemiske sammensaetning. Diss. Kgl. Veterinaer- og Landbohoiskole, Kopenhagen.

PEDERSEN, C. A. og Oestergaard, H. S. 1991. Goedskning og kalkning. In: Skriver, K. (ed.) Oversigt over Landsforsoegene 1990. Aarhus Stiftsbogtrykkerie, pp. 70-112.

SCHNUG, E. 1988a. Bestimmung des Gesamtglucosinolatgehaltes in vegetativen Pflanzenteilen durch quantitative Analyse enzymatisch freisetzbaren Sulfates. Fresenius Z. Anal. Chem. 330, 50 - 55.

SCHNUG, E. 1988b. Quantitative und qualitative Aspekte der Diagnose und Therapie der Schwefelversorgung von Raps (Brassica napus L.) unter besonderer Berücksichtigung glucosinolatarmer Sorten. Habilitationsschrift Agrarwiss. Fakultät der Christian-Albrechts-Universität zu Kiel

SCHNUG, E. 1990a. Glucosinolates - fundamental, environmental and agricultural aspects. Sulfur Nutrition and Sulfur Assimilation in Higher Plants (ed. H. Rennenberg et al.), pp 97-106, SPB Academic Publishing bv, The Hague, The Netherlands, 1990

SCHNUG, E. 1990b. PIPPA - a professional interpretation program for plant analysis data of oilseed rape and cereals. Proc. Inaugural Congress of the European Society of Agronomy Paris 1 P 35.

SCHNUG, E. 1991a. Sulphur metabolism in oilseed rape plants with special regard to double low varieties. Proc. 8th Int. Rapeseed Congress Saskatoon 1991 (in press)

SCHNUG, E. 1991b. Sulphur nutritional status of European crops and consequences for agriculture. Sulphur in Agriculture 15 (in press)

THOMAS, P. 1984. Canola Growers Manual. Canola Council of Canada Winnipeg.

WALLACE, A. 1990. Crop improvement through multidisciplinary approaches to different types of stresses-law of the maximum. J. Plant Nutr. 13, 313-325

WALWORTH, J.L., LETZSCH, W.S. and SUMNER, M.E. 1986. Use of boundary lines in establishing diagnostic norms. Soil Sci. Soc. Amer. J. 50, 123-128.

WEBB, R.A. 1972. Use of the boundary line in the analysis of biological data. J. Horticult. Sci. 47, 309-319.

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