TESTING OF SOIL PROPERTIES – BASIC TOOL FOR RATIONAL NUTRIENT MANAGEMENT IN AGRICULTURE

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Abstract

Some of the selected basic parameters of soil fertility are observed in the Czech Republic in long term system of agrochemical soil testing. The results of determination of soil reaction and contents of available essential nutrients (P, K, Mg, Ca) are used for determination of most suitable application rates of nutrients for the best nutrient management – i.e. rates for high yields and quality of production and simultaneously rates friendly to environment. Under financial support of National Agency for Agricultural Research (project No QJ1530171) and simultaneously in the interest of system of harmonized plant nutrition and fertilisation the testing system is improved and developed by:

- *determination next elements – sulphur and micronutrients (Cu, Zn, Mn, Fe, B) through uniform analytical method Mehlich 3 (and laboratory equipment ICP-OES) with minimum other expenses for users (land owners, agricultural farms and laboratories);*
- *adaptation of more accurate correction for determination of phosphorus in carbonate soils;*
- *better utilization of fertilizers in given regions and reduction of risks of phosphorus leaching into underground waters and danger of surface waters and the related environment;*
- *new determination of assessment criteria of soil supply with nutrients for subsequent more accurate specification of fertilization doses;*

All results of this testing system are stored in Land Parcel Information System (LPIS) - system based on the actual use of land in a geographic information database.

Ministry of Agriculture of the Czech Republic uses LPIS as an administrative tool in control system and LPIS also functions as a service for the farmers themselves.

Key words: *soil testing, plant nutrition, Mehlich 3, LPIS*

1. INTRODUCTION

The plants need specific conditions of nutrition for their growth and evolution. The crop yield depends, to a high extent, on nutrient supply – mainly from the soil (Mengel, K., Kirkby, E. A., 2001).

Soil testing for the content of available nutrients determination is a common base of sustainable fertilizer recommendations and good nutrient management. Some of the basic parameters of soil fertility are observed in the Czech Republic since 1961 in regular three- to six-year periods of agrochemical soil testing system (Klement et al., 2012). This testing system is provided by the Act No. 156/1998 Coll. about fertilizers in wording of later regulations, and system covers especially the determination of soil reaction and content of available nutrients - P, K, Mg, Ca. In competent cases (e.g. application of sewage sludge to the soil, soil testing in organic farming, damage of soil by flood, etc.) physical and microbiological parameters are detected (Čermák, 2000; Čermák and Mezuliáník, 2000; Čermák and Klír and Budňáková, 2002; Čermák et al., 2004; Čermák and Budňáková, 2004).

All sampling areas are fixed by coordinates in the Czech national co-ordinate system S-JTSK and recorded to a special layer of Land Parcel Identification System (LPIS). LPIS is geographic database as part of the Integrated Administrative and Control System (IACS) in the Czech Republic. It can be used for agrochemical soil testing, too. This system makes it possible to provide sampling and mainly

results valuation and data comparison from the same areas during the history of agrochemical soil testing. For the precise localization and better orientation in the terrain GPS equipment is used.

All results of agrochemical soil testing are recorded to LPIS and there are available for government body and – "on line and free of charge" for farmers. Data in LPIS is a base for program unit "Rational fertilisation". This application was made for automatic proposal fertilisers rates according to phosphorus and potassium content in the soil and nutritional requirements of crops for the yield formation. Need of liming materials is calculated according to pH value. Nitrogen fertilisation is not included, because nitrogen is not determined in frame of agrochemical soil testing.

Based on these input data the most economic proposals of fertilisation is made for relevant crop and status of soil. All data in LPIS database can be sorted "uplink or in descending order". Data export for printing list (e.g. for farmers) is possible in PDF format. Each farmer has his access on-line from home. All information, including fertilization recommendation are available on-line or in printing form (text and maps).

Agricultural practice needs to improve this soil testing system by determination next parameters/elements – like content of sulphur and micronutrients (Cu, Zn, Mn, Fe, B) detected through suitable analytical method and without next necessary costs for sampling and analyses.

A few of analytical methods for availability of nutrients were tested in the past (Zbíral et al., 1999; Trávník et al., 1999) – table 1.

Table 1. Comparison of analytical method (Zbíral et al., 1999)

Method	**P**	**K**	**Mg**	**Ca**	**S**
Mehlich 3	+	+	+	+	+
Mehlich 2	+	+	+	+	
0.01M $CaCl_2$	+	+	+		
CAL	+	+			
Egner	+				
Olsen	+				
Water					+
Schachtschabel K		+			
Schachtschabel Mg			+		

Mehlich 3 extractant seems to be a suitable method for large-scale soil testing where high sample throughput is a crucial point. It is clear that in some special cases individual extracting procedures and a customized evaluation can give better fertilizer recommendation, but for a large-scale soil survey of highly varied soils Mehlich 3 was found to be a very good choice.

The Mehlich 3 extractant can be used for a multiple-element extraction from soils with a relatively wide pH range (with some limitations for carbonate soils) and it has a potential for a simultaneous determination of plant available nutrients and micronutrients (Zbíral, 2016).

New project No QJ 1530171supported by Czech National Agency for Agriculture Research (under Ministry of Agriculture of the Czech Republic) is focused on extension of applicability and actualization of categories for determination of the content of available macroelements (mainly phosphorus and sulphur) and microelements in a soil for ensuring of the sustainability of fertility and productive capability of agricultural soils.

The aims of the project:

1) the **adaptation of more accurate correction** for **phosphorus** determination in carbonate soils which will enable better utilization of fertilizers in given regions and will decrease risks of phosphorus leaching into underground waters and danger of surface waters and the related environment;
2) the **extension of applicability** of the methodology Mehlich 3 used in the frame of system of agrochemicaly tested agricultural soils in CZ of **suphur and microelements** (Cu, Zn, Mn, Fe, B);
3) to **precise and to extent determination of nutrient concentrations with minimum other expenses** (using analytical method ICP-OES) for users (land owners, agricultural farms and laboratories) and to enable significant and necessary increase of information richness of the system of agrochemicaly tested agricultural soils in CZ;
4) **new determination of assessment criteria of soil supply with nutrients** for subsequent more accurate specification of fertilization doses and direct utilization of results in the agriculture primary production as well as also for strategic planning.

2. MATERIAL AND METHODS

In the Czech Republic, more than 500 thousands hectares of agricultural land are tested and about 70 – 80 thousands of soil samples analysed for basic soil parameters every year. The average sampling area on arable land and grassland is 7 – 10 ha. One representative soil sample consists of 30 partial small samples.

Soil acidity is determined in $CaCl_2$ solution (method of exchange of alkaline ions by solution of neutral salts). For determination of available nutrients in the soil method Mehlich 3 (0.015 M NH_4F + 0.2 M CH_3COOH + 0.25 M NH_4NO_3 + 0.013 M HNO_3) (Mehlich, 1984) is used and contents of available nutrients in soil (for different plantations) are valuated according to five categories: **low, suitable, good, high and very high** (Table 2).

Table 2. Fertilizers recommendation according to categories of nutrient content in soil

Category / Content of nutrients	Valuation & Fertilizers recommendation
Low	need of expressive fertilization of relevant nutrient; *coefficient for soil reserve improving 1.5 or 2.0*
Suitable	need of slight fertilization of relevant nutrient; *coefficient for soil reserve improving 1.25*
Good	favourable content – for its maintenance is necessary balance fertilization of relevant nutrient; *coefficient 1.0 – balance fertilization*
High	fertilizing omission of relevant nutrient until achieving of category "good"; *coefficient 0.5*
Very high	fertilizing of relevant nutrient is needless to inadmissible, next raising of relevant nutrient content is unsuitable for environmental protection; without fertilizing

According to this categorisation and amount of nutrients uptake from the soil by harvested crops (Methodology by Crop Research Institute, Klír et al., 2003 – table 3) it is possible to determine application rates for optimization of soil nutrient reserves.

Table 3. Normatives of nutrients uptake from the soil by harvested crops (most common crops)

Crop	Main product	Nutrient uptake in kg . t^{-1} product					
		N	P_2O_5 (P)		K_2O (K)	MgO (Mg)	
Winter wheat	grain	25,0	12,0	(5,2)	24,0 (19,9)	4,0	(2,4)
Rye & Triticale	grain	24,0	14,0	(6,2)	26,0 (21,6)	4,0	(2,4)
Winter barley	grain	26,0	13,0	(5,7)	29,0 (24,1)	3,0	(1,8)
Spring wheat	grain	26,0	12,0	(5,2)	24,0 (19,9)	4,0	(2,4)
Spring barley	grain	24,0	12,0	(5,2)	24,0 (19,9)	3,0	(1,8)
Maize	grain	27,0	12,0	(5,2)	28,0 (23,2)	8,0	(4,8)
Oats	grain	26,0	14,0	(6,2)	29,0 (24,1)	4,0	(2,4)
Peas	grain	-	17,0	(7,5)	45,0 (37,4)	6,0	(3,6)
Winter rape	grain	50,0	25,0	(11,0)	60,0 (49,8)	8,0	(4,8)
Poppy	grain	40,0	20,0	(8,8)	50,0 (41,5)	-	
Red clover	hay	-	6,0	(2,6)	15,0 (12,5)	6,0	(3,6)
Alfa-alfa	hay	-	7,0	(3,1)	18,0 (14,9)	3,0	(1,8)
Crop mixture (clover+grass)	hay	-	6,0	(2,6)	15,0 (12,5)	-	
Crop mixture (alfa-alfa+grass)	hay	-	7,0	(3,1)	17,0 (14,1)	-	
Prairie hay	hay	17,0	7,0	(3,1)	15,0 (12,5)	4,0	(2,4)
Silage maize	green matter	3,0	1,0	(0,4)	3,0 (2,5)	0,5	(0,3)
Sugar-beet	tuber	4,4	1,6	(0,7)	5,7 (4,7)	1,4	(0,8)
Potato	tuber	5,0	2,0	(0,9)	8,0 (6,6)	1,5	(0,9)

For correction of phosphorus determination in carbonate soils (i.e. better evaluative criteria) and simultaneously the extension of applicability of the methodology Mehlich 3 for sulphur and selected microelements (Zn, B) pot experiments were established in 2015.

There were graded rates of phosphorus and sulphur applied to spring barley and the yield of grain (in grams per pot) and simultaneously availability of phosphorus and sulphur were observed (Figure 1 and 2).

Simultaneously availability of boron and zinc (in $mg.kg^{-1}$ by method Mehlich 3) under graded application rates of phosphorus and sulphur (P 0.5 and S 0.5 = half rate; P 1 and S 1 = full rate; P 2 and S 2 = double application rate) were observed (Figure 3 and 4).

Figure 1. Correlation between yields of spring barley and P concentrations in soils determined by Mehlich 3

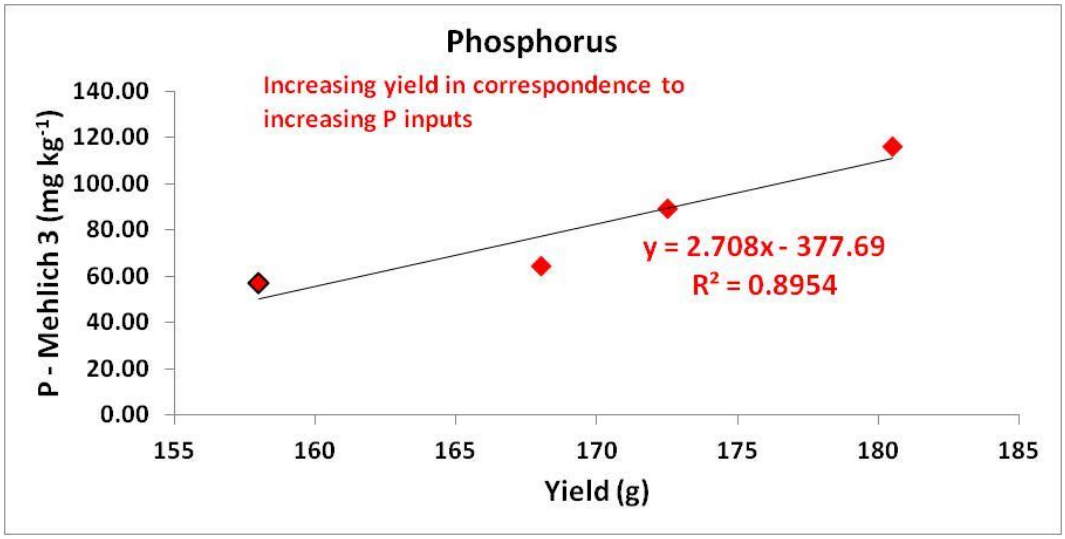


Figure 2. Correlation between yields of spring barley and S concentrations in soils determined by Mehlich 3

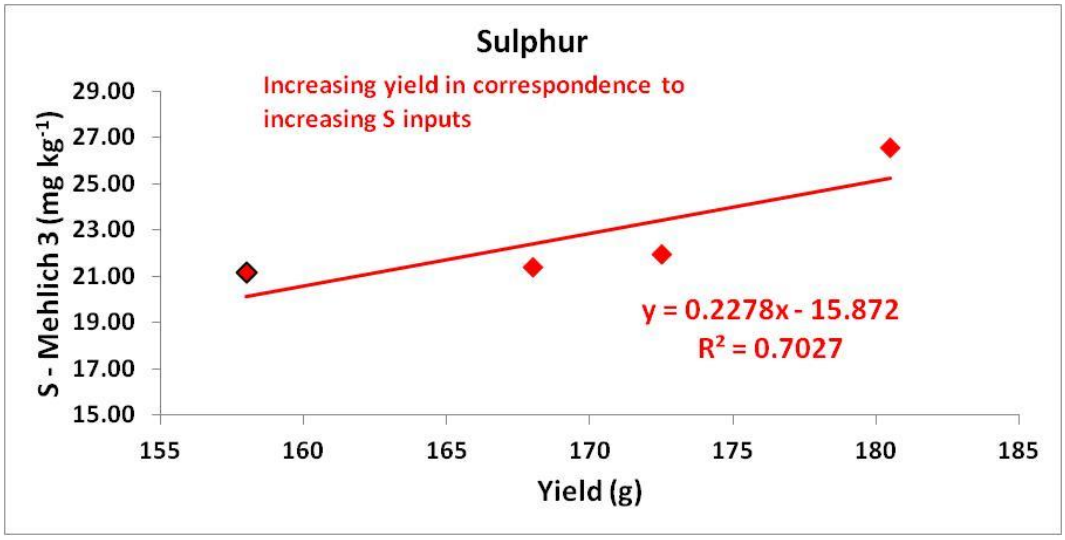


Figure 3. Determination of available boron

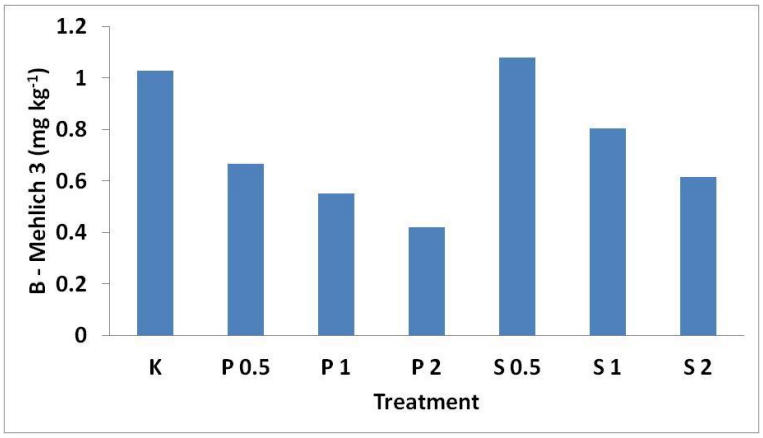
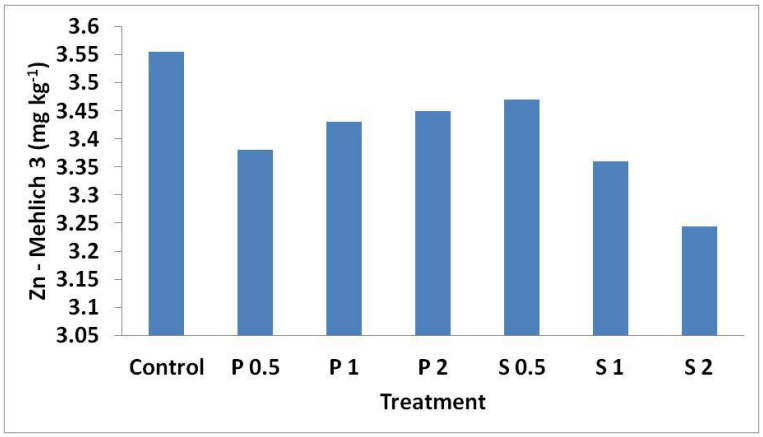


Figure 4. Determination of available zinc



CONCLUSIONS

The usability of the methodology Mehlich 3 for sulphur and selected microelements (Zn, B) detection and simultaneously improvement of phosphorus detection was confirmed because:

1) Phosphorus and sulphur concentrations in soils determined by Mehlich 3 increased in correspondence to the soil treatments with P and S inputs.
2) Relative availability of P and S increased following treatments with P and S
3) Availability of boron and zinc was affected under graded P and S inputs:
   a) increased doses of sulphur caused lower availability of boron and zinc;
   b) increased doses of phosphorus caused lower availability of boron and on the other hand higher of zinc;

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