Improved Soil Testing System in the Czech Republic (New Valuation of Micronutrients Content in Soil and Phosphorus Content in Carbonate Soils)

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ABSTRACT

The official systematic soil testing system in the Czech Republic has practically 60 years duration – since 1961 is provided for needs of state administrative body and simultaneously for farmers. The extraction procedure Mehlich 3 is the official analytical method presently used (since 1999) in this soil testing system for the determination of available macronutrients (P, K, Mg, Ca). On the ground of uniformity, suitability and relatively cheap process of this analytical procedure, Mehlich 3 extractant can be used for a multiple-element extraction from soils, including determination available micronutrients (B, Cu, Zn, Mn, Fe). On the other hand Mehlich 3 extractant has some limits for right determination of available phosphorus content in carbonate soils (i.e. soils with pH value 7.2 and higher and simultaneously with content of available calcium 3500 and more mg kg^{-1} of soil). Extraction method Mehlich 3 used for determination of available phosphorus, usually doesn´t indicate real phosphorus content in carbonate soils. There is content of available phosphorus more or less undervalued according to valid limits (criteria) for all soils. New, updated criteria of valuation of available phosphorus content in carbonate soils will be used for elimination of this incorrectness.

Keywords: micronutrients, carbonate soils, Mehlich 3, available phosphorus, criteria.

INTRODUCTION

The systematic soil testing scheme in the Czech Republic was established in 1961, founded on a long tradition of soil testing (Čermák et al, 2017).

The Mehlich 3 extractant has been used since 1999 for determination of phosphorus (P), potassium (K), magnesium (Mg) and calcium (Ca). This universal soil extractant was chosen especially for its simple and universal use but also for its ability to produce relatively good correlations between the amount of nutrients extracted from the soil and the plant response. 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 for right determination of available

phosphorus content in carbonate soils, i.e. soils with pH value 7.2 and higher and simultaneously with content of available calcium 3500 and more mg.kg^{-1} of soil (Kunzová, 2009).

MATERIAL AND METHODS

In the past there were studied relationships between the Mehlich 3 extractant and some other extractants for determination of micronutrients (DTPA extraction for determination of copper, zinc, iron and manganese; hot-water extraction for boron determination) to find a possibility to widen the Mehlich 3 scope also for micronutrient determination (Zbíral and Němec 1998, 2000, 2009). It was proved that Mehlich 3 could be used also for determination of B, Cu, Zn, Mn and Fe if the criteria for evaluation of the results are available. Based on comparison different analytical method (i.e. Mehlich 3 versus DTPA and hot water) and through simple calculation of relationship between these extractants theoretical criteria for available copper, zinc, iron, manganese and boron content in soil were suggested.

Because the criteria for essential nutrients (P, K, Mg, Ca) valuation were confirmed and adjusted using results from long-term field experiments and pot experiments covering representative soil and climatic conditions of the Czech Republic, so it was necessary in the same way to verify and to adjust these theoretical criteria micronutrients valuation in soils. Therefore analytical results from field and pot experiments (Mühlbachová et al., 2016) were used for determination of micronutrients (B, Cu, Zn, Mn, Fe) in soil by method Mehlich 3. 252 results from different (representative) soil types: i) haplic chernozem; ii) haplic luvisols; iii) dystric cambisols (International soil classification system for naming soils and creating legends for soil maps; WRB – World Reference Base for Soil Resources 2014; World Soil Resources Reports No. 106, FAO, Rome) and 84 results from long-term experiments were used for the evaluation.

In frame of soil testing system upgrade, simultaneously more accurate corrections for phosphorus determination in carbonate soils by method Mehlich 3 were made. Extraction method Mehlich 3 used for determination of available phosphorus, usually doesn´t indicate real phosphorus content in carbonate soils. There is content of available phosphorus more or less undervalued according to valid limits (criteria) for all soils (ÚKZÚZ, 2018). New, updated criteria of valuation of available phosphorus content in carbonate soils will be used for elimination of this incorrectness. Analytical results from monitoring of different soils in practice (totally 288 soil samples with different parameters – i.e. pH value, content of available

phosphorus and calcium; from that 39 samples showed parameters of carbonate soils) and from vegetative experiments (pot and field) on different soils under graded application rates of phosphorus show correctness to divide soils into two parts, i.e. carbonate and non-carbonate soils – based on statistical valuation – SW Program STATISTICA version 12.0 (Stat-Soft Inc., Tulsa USA, StatSoft ČR s.r.o. 2014). For each part it is optimal to use individual criteria of valuation of available phosphorus content. Both aims, i.e. verification of criteria of micronutrient valuation in the soil and simultaneously valuation of available phosphorus content in carbonate soils were made under project No.: QJ 1530171 supported by Czech National Agency for Agriculture Research (NAZV) under Ministry of Agriculture of the Czech Republic.

Experiments (2015, 2016, 2017):

A. <u>Pot experiments</u> (Mitcherlich pots) on MENDEL University in Brno and in Crop Research Institute in Prague – there were used three soil types, i.e. haplic chernozem, haplic luvisols and dystric cambisols in both experimental places;

B. <u>Field experiments</u> in Crop Research Institute – experimental place Humpolec with dystric cambisols:

Experiment design (for pot as well as field experiments):

1) graded doses of phosphorus and sulphur (in ratio 0.5 – 1.0 – 2.0)
2) nitrogen and potassium fertilisation – uniform doses based on nutrient uptake by the harvest of tested crops
3) three tested crops (spring barley 2015 – oil seed rape 2016 – winter barley 2017)
4) 7 combinations of fertilisation
5) 4 replications for each combination
6) extraction method Mehlich 3 was used for determination basic nutrients (content of available phosphorus, potassium, calcium, magnesium & microelements (Cu, Zn, Mn, Fe, B)
7) simultaneously available fraction of the same microelements (Cu, Zn, Mn, Fe, B) in the soil by NH_4 acetate extraction was provided

RESULTS

Statistical valuation of results for determination of micronutrients

Available data and statistical results (Table 1) showed high correlation between both used methods and subsequently possibility and suitability of Mehlich 3 method (together with ICP-OES) for boron, copper, zinc, manganese and iron determination in the soil.

Table 1. Correlation coefficients (r) between Mehlich 3 and NH_4 acetate methods for microelements determination in the soil

Microelement	pot experiment (cambisol, luvisol, chernozem) r	field experiment (cambisol only) r
B	0.620***	0.374***
Cu	0.600***	0.399***
Fe	0.313***	ns
Mn	0.554***	0.483***
Zn	0.314***	0.361***

ns – non significant, $p < 0.05$*, $p < 0.01$**, $p < 0.001$***

Based on the results obtained from the vegetation experiments the following levels (confirming earlier suggested theoretical criteria – limits) for evaluation of micronutrients in the soil were postulated: i) low content, ii) middle content, iii) high content (Table 2).

Table 2. Criteria of valuation of micronutrients in soil (determined by Mehlich 3)

Microelement	Soil kind	content in soil (mg kg^{-1}) low	low	low
B	light soil	< 0,55	0,56 – 0,75	> 0,75
	middle heavy soil	< 0,70	0,71 – 1,00	> 1,00
	heavy soil	< 0,85	0,86 – 1,40	> 1,40
Cu		< 1,6 (< 2,0)[1]	1,61 – 4,5	> 4,5
Zn		< 2,2	2,21 –5,0	> 5,0
Mn		<30 (< 45,0)[2]	30,1 - 200	> 200
Fe		< 60,0	60,0 - 420	> 420

[1]recommended for cereals;
[2]manganese fertilisation on the soil with Mn content lower than 45 mg/kg

For carbonate soils presently valid criteria (limits) for valuation of available phosphorus (in all soils) are reduced by ca 10 - 35 mg.kg^{-1} depending on detected phosphorus amount in soil (Table No 3).

Table 3. Criteria valuation of available phosphorus content (arable land) determined by method Mehlich 3 (analytical instruments ICP-OES) for carbonate soils

Content	Phosphorus (mg kg^{-1})	
	others (non-carbonate) soils	carbonate soils
low	to 50	to 40
suitable	51 – 80	41 – 70
good	81 – 115	71 – 105
high	116 – 185	106 – 150
very high	above 185	above 150

CONCLUSIONS

According to evaluation levels of micronutrients in soil, the following fertilization rates can be used: 150% (for low content), 100% (for middle content) and 50% (for high content) of expected uptake of micronutrients by grown crops. New criteria for valuation of available phosphorus in carbonate soils (including optimalization of phosphorus rates for crops) can be already presently used in the Czech soil testing system.

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Poboljšani sistem za ispitivanje zemljišta u Češkoj Republici (Nova procena sadržaja mikronutrijenata u zemljišzu i fosfata u karbonatnim zemljištima)

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IZVOD: Zvanični sistem za ispitivanje zemljišta u Češkoj Republici se primenjuje skoro 60 godina - od 1961. godine predviđen je za potrebe državnog upravnog tela, a istovremeno i za poljoprivrednike. Postupak ekstrakcije Mehlich 3 je zvanična analitička metoda koja se trenutno koristi (od 1999. godine) u ovom sistemu ispitivanja zemljišta za određivanje dostupnih makronutrijenata (P, K, Mg, Ca). Na osnovu ujednačenosti, pogodnosti i relativno jeftinog procesa ovog analitičke metode, Mehlich 3 ekstrakt može da se koristiti za ekstrakciju više elemenata iz tla, uključujući i odredjivanje mikronutrijenata (B, Cu, Zn, Mn, Fe). S druge strane, ekstrakt Mehlich 3 ima određena ograničenja za ispravno određivanje sadržaja dostupnog fosfora u karbonatnim zemljištima (tj. zemljišta sa pH vrednošću 7.2 i većom i istovremenim sadržajem dostupnog kalcijuma 3500 i više mg kg^{-1}). Metoda ekstrakcije Mehlich 3 koja se koristi za određivanje dostupnog fosfora obično ne daje stvani sadržaj fosfora u karbonatnim zemljištim. Sadržaj dostupnog fosfora manje ili više potcenjen u skladu sa važećim granicama   (kriterijumima) za sva zemljišta. Za otklanjanje ove netačnosti koristiće se novi, ažurirani kriterijumi za vrednovanje dostupnog fosfora u karbonatnim zemljištima.

Ključne reči: makronutrijenti, karbonatna zemljišta, Mehlich 3, dostupni fosfor, kriterijumi.