Preliminary Critical P-limit Values of 0.01 M $CaCl_2$ Soil Test Procedure

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SUMMARY

In the last decade, the 0.01 M $CaCl_2$ extraction procedure was tested as a multi-nutrient extractant. In 1995-97, international joint research activities were carried out within the COPERNICUS project. Detailed calibration of conventional and the 0.01 M $CaCl_2$ extraction procedures for pH, Mg and K were published.

The amount of phosphorus extracted using a 0.01 M $CaCl_2$ solution is very low and reflects the intensity parameter of phosphorus bio-availability. As a readily desorbed P fraction of soils can reflect the soil P-supply and the $CaCl_2$-P values are in close correlation with P-fertiliser rates and P balance. However, the effects of various soil characteristics on $CaCl_2$-P values are different and their interpretation is difficult.

Relatively poor correlations were found between amounts of P extracted by conventional and $CaCl_2$ soil test methods and, therefore, P limit values could not be calculated directly. To characterise the soil P supply at different sites, the $CaCl_2$ desorbed P and the adsorbed P in a modified Baker Soil Test were also applied.

Soil test results of Hungarian long-term fertiliser experiments and recommended $CaCl_2$-P limit values, calculated on yield effects and soil characteristics, are discussed.

INTRODUCTION

The authors are engaged in investigating the 0.01 M $CaCl_2$ soil testing applicability for determination of readily available nutrient and toxic element contents of soils. Some decades ago, this soil testing procedure was recommended for determination single element by Aslyng (1954) for P and Schachtschabel (1954) for Mg. Houba et al. (1986, 1990) proposed this procedure as a multi nutrient soil extractant. This procedure has received attention because of the good relationship between nutrients extracted with 0.01 M $CaCl_2$ and with conventional soil extraction procedures Houba et al. (1986, 1991). The procedure has economical and operational advantages and is, therefore, attractive from a laboratory point of view. The ratios of the easily soluble nutrient elements can be calculated also. In the 0.01 M $CaCl_2$-extracts, the N-fractions and other macro- and micro-nutrients and pH values can be measured. Experiences with 0.01 M $CaCl_2$ soil test results obtained from long-term field fertiliser experiments are the following:

- a close correlation can be proven between $CaCl_2$-P quantities and the P-fertiliser rates (Houba et al., 1991) and P-balances (Jaszberenyi et al., 1994);
- there is a rather close correlation among P-$CaCl_2$, P-AL, P-CAL and P-water soluble quantities. However, the relationship determined on a specific site, cannot be applied to another because the soluble P-fractions depend on the soil characteristics. (Kücke et al., 1995);
- a reliable correlation can be established between soluble P values and P balances, which means that the soil P reserves, as a result of P over-fertilisation, can be characterised by capacity (P-AL, P-CAL) and intensity parameters (P-$CaCl_2$, P-water) also (Loch et al., 1995).

The applicability of 0.01 M $CaCl_2$ extractant was studied in international joint research activity. Detailed calibration of the conventional and the 0.01 M $CaCl_2$ extraction procedure for pH, Mg and K were published by Fotyma et al. (1998), Loch et al. (1998) and Baier and Baierova (1998) respectively. This soil testing program was summarised by van Erp et al. (1998).

The introduction of the $CaCl_2$ method to characterise soil P-supply poses difficulties due to a lack of reliable P-limit values. To calculate the $CaCl_2$ P limit values by conventional methods is almost impossible because of the strong influence of soil characteristics. The site-specific $CaCl_2$-P limit values can be related to that P quantity changed with added soluble P form in equilibrated soil suspension. The change in P concentration in equilibrated soil solution makes it possible to estimate the capacity of soils retain added P. The P fertiliser efficiency is also related to P adsorption and desorption capacity of soils.

The degree of P sorption saturation of soils is regarded as an important factor for predicting the risk of soluble P release into runoff and surface water (Sims, 1998).

MATERIALS AND METHODS

Calibration soil tests with an 0.01 M $CaCl_2$ extractant (Houba et al., 1990) were carried out with soil samples from long term field fertilisation trials. On 9 sites 12 NPK treatments were sampled in 28^{th} year of the experiment (Debreczeni, B. and Debreczeni, K., 1994). Soil characteristics of the 9 sites are shown in *Table 1*.

For determination of adsorbed P quantities, a modified Baker Soil Test was used (Jaszberenyi et al., 2000). The modified extractant is useful for measuring Ca, Mg, K and P adsorption and/or desorption. The composition of modified test solution is:

5 mM $CaCl_2$,
1 mM $MgCl_2$,
.25 mM KH_2PO_4,
.4 mM DTPA,
and pH = 7,3 puffered with TEA.

Table 1: **Soil properties of the nine sites in the long-term field experiment network (Csatho, 1998)**

Properties	Experimental sites								
	NA*	**IR**	**BI**	**KO**	**KA**	**PU**	**KE**	**HA**	**MO**
Soil type (FAO)	Calcaric Phaeosem	Calcaric Phaeosem	Luvic Phaeosem	Haplic Phaeosem	Luvic Phaeosem	Ochric Luvisol	Eutric Cambisol	Luvic Phaeosem	Calcaric Fluvisol
Soil type (USDA)	Mollisol	Mollisol	Mollisol	Mollisol	Mollisol	Alfisol	Alfisol	Vertisol	Vertisol
Soil texture	loam	loam	loam	clay loam	clay loam	clay loam	sandy loam	clay	loam
Soil OM, %	2.7	2.4	1.9	2.6	2.7	2.0	1.7	3.5	1.7
Soil pH_{KCl}	7.2	7.4	5.6	3.9	4.7	3.9	5.9	6.1	7.4
$CaCO_3$	6.0	8.0	-	-	-	-	traces	traces	21.0
y_1, me/100 g	-	-	-	19	24	16	-	-	-
<0.01mm particles, %	38	36	45	58	59	49	37	53	35
Clay % (<0.002 µm)	23	24	33	46	45	31	22	36	25
Minerals in clay fraction, %									
Illite	47	50	45	27	56	33	59	29	48
Kaolinite	-	-	-	20	-	14	10	-	-
Smectite	16	8	17	37	7	27	6	47	16
Illite-smectite	5	10	10	10	11	19	9	5	7

* Experimental sites: NA: Nagyhörcsök; IR: Iregszemcse; BI: Bicsérd; KO: Kompolt; KA: Karcag; PU: Putnok; KE: Keszthely; HA: Hajdúböszörmény; MO: Mosonmagyaróvár

Procedure: 5,0 g soil samples were shaken with 50 cm^3 modified Baker Test solution for 2 hours. Soil suspension were filtered with MN 640 filter paper. The P, K and Mg concentrations of the initial equilibrant and extracts were measured ICP-AES. Differences between the final and initial concentrations were calculated and expressed as dP, dK and dMg mg/kg soil. In this paper, the adsorbed P quantities are discussed in relation to soil pH and clay content.

RESULTS AND DISCUSSION

Experiences with the $CaCl_2$ method

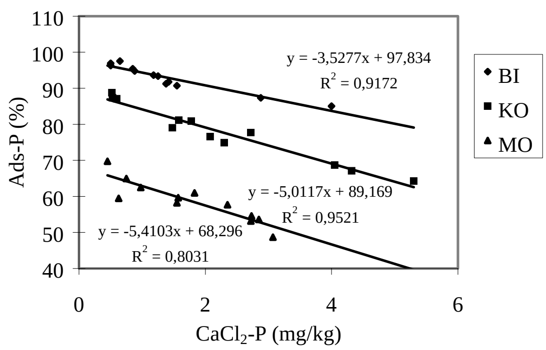
As a result of comparative studies the advantages of 0.01 M $CaCl_2$-soil test method to estimate the soil nutrient supply was proven. The $CaCl_2$-P and AL-P quantities have an increasing tendency with fertiliser P doses. Both methods are useful to detect the cumulated P fertiliser quantities in soil. The advantage of the $CaCl_2$ method is that the relative change in $CaCl_2$-P amount is higher than the relative change in AL-P_2O_5 quantities as an effect of P fertilisation. This means that the $CaCl_2$ method seems to be rather sensitive to estimate P over-fertilisation. The relationship between $CaCl_2$-P and AL-P_2O_5 can be characterised by exponential function at a number of sites.

Relations between adsorbed P and $CaCl_2$-P content of soils

The *Figure 1* shows the relationship between adsorbed P percentage and $CaCl_2$-P values at different sites.

The adsorption curves have different slopes with different P adsorption capacities of soils. It can be concluded that the more fertiliser P enriched in soil, the more P remains soluble with decreasing P adsorption and enhanced P fertiliser efficiency.

Figure 1: **Adsorbed P% - $CaCl_2$-P**



Calculations of P limit values based on yields

For estimation of $CaCl_2$-P limit values at different sites, the yield effects of P fertilisation were calculated. The yield differences (Y_{max} - Y) were related to the soil $CaCl_2$-P amounts as follows:

$$Y_{max} - Y = a + b * \ln CaCl_2 - P$$

The interception point of the regression line on x-axis is the theoretical $CaCl_2$-P limit value. Practically the $CaCl_2$-P limit at 90% of Y_{max} can be regarded as acceptable. In a year, the yield effect of P-fertilisation has great uncertainty. Therefore, the $CaCl_2$-P contents of soils were related to 20 year yield averages. Trend of yields and the $CaCl_2$-P values allow to estimate the limits on different sites. The estimated and calculated $CaCl_2$-P limit values stand in good correlation.

The effect of soil characteristics on calculated $CaCl_2$-P limit values

The pH values and clay content of soils were related to the P-limits. Because of the few number of sites the regressions have low level of signification.

However, the relation between regression curves and the trend of points are good. On soils with strongly acidic and basic pH values, the $CaCl_2$-P limits are higher than on soils with slightly acidic or neutral pH range (*Figure 2*). A similarly well-defined trend can be observed as an effect of clay content (*Figure 3*).

With increasing soil clay content, the $CaCl_2$-P limit values decrease. Based on our experience, the preliminary $CaCl_2$-P limit values are recommended (*Table 2*). For verification of these $CaCl_2$-P limit values, additional results of P-fertiliser yield effects are required.

Figure 2: **$CaCl_2$-P limits and pH (KCl) 90% of Yield$_{max}$**

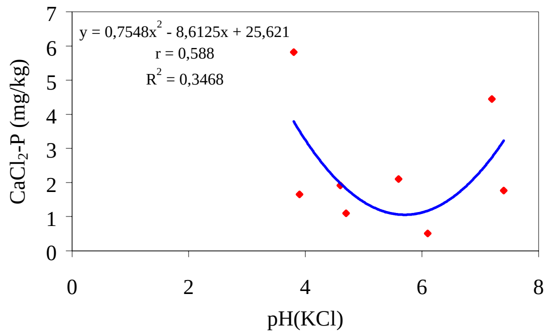


Figure 3: **$CaCl_2$-P limits – clay content 90% of Yield$_{max}$**

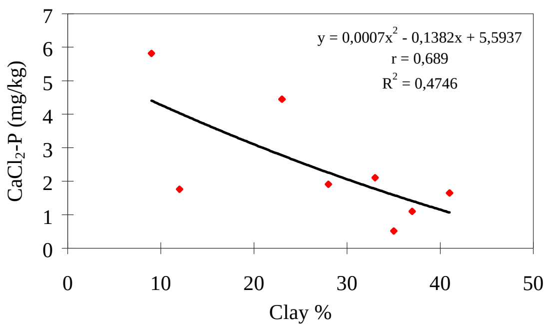


Table 2: **Preliminary P limit values (mg P/kg) (0.01 M $CaCl_2$ extraction, 1:10 w/v)**

Soil testure	pH-KCl		
	<6,0	6,0-7,0	>7,0
Sand	3,0-5,0	2,0-3,0	3,0-5,0
Loam	2,0-3,0	1,0-2,0	2,0-3,0
Clay	1,0-2,0	0,5-1,0	1,0-2,0

ABSTRACT

Results of comparative studies on soils of Hungarian long-term field fertiliser trials, show that the 0.01 M $CaCl_2$ soluble P quantities characterise the soil P supply. P over-fertilisation can be established by this soil test method. Preliminary P limit values are recommended based on P yield effects and soil characteristics. Verification the recommended P limit values requires additional results of field experiments.

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