SOIL PHOSPHORUS AND POTASSIUM SOLUBILIZATION IN AN EXPERIMENT WITH FIELD CROPS IN THE GREAT BRĂILA ISLAND

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Abstract

Along with nitrogen, phosphorus and potassium are the most important nutrition elements for plants; they are to be found in all their organs, are components of the needed substances for vital processes, and have important roles in many biochemical reactions. Accessible fractions for plant nutrition are but small fractions of the total phosphorus and potassium soil contents. The influence of soil reaction (pH), humus content, and total forms upon phosphorus and potassium solubilization in the ammonium acetate lactate solution at pH 3.7, down to a 50 cm soil depth, was studied in an agro-chemical experiment carried out in six farms of the Great Brăila Island, with seven field crops diversely fertilized with nitrogen, phosphorus, sulphur, and – for only one of the crops and in small quantities – potassium; phosphorus available contents for plants were also computed as in neutral – slightly alkaline soils as it is the case they are not the same with the contents analytically determined in the used extractant. Phosphorus and potassium solubilization degrees were very significantly influenced by soil reaction and in the case of potassium by the organic matter content too. Because of the neutral – slightly alkaline soil reaction phosphorus soluble in the ammonium acetate lactate solution and the one available for plants, found out by computing, were differently influenced. Effects registered under each crop were very significant for phosphorus and less for potassium following the diverse fertilization systems.

Key words: solubilization, phosphorus, potassium

Along with nitrogen, phosphorus and potassium are the most important nutrition elements for plants. They are to be found in all their organs, are components of the needed substances for vital processes, and have important roles in many biochemical reactions. Their shortage causes metabolic disorders with consequences upon vegetal yield and its quality (Lăcătușu R., 2016). Soil phosphorus comes from minerals that contain it, especially those of the apatite's group, following alteration processes, microbiologic activity, and physical and chemical reactions (Voiculescu N., 1999). Only 0.5-1.0% of the total soil phosphorus content is available for plants as its soil mobility is low (Lăcătușu R., 2016).

Total soil phosphorus contents range between 0.01 and 0.15%. In Romania soil phosphorus varies from 0.026 (Albic Luvisols) and 0.093% (Chernozems). It can be noticed that the more genetically evolved the soil (Albic Luvisols) the less total phosphorus content it has as compared to less evolved soils (Chernozems).

Mobile phosphorus content soluble in the ammonium acetate lactate solution at pH 3.7 is the one that gives the picture of the soil supply level with phosphorus available for plant nutrition *(table 1).*

Table 1

Phosphorus supply state characterization

Values range*	Phosphorus supply state characterization
≤ 8.0	very weak
8.1-18.0	weak
18.1-36.0	average
36.1-72.0	good
72.1-108.0	
108.0-144.0	very good
≥144.0	excessive for some plants

* For soils with pH_{H_2O} ≥ 6,41 the values have been corrected with the mentioned correction factor (CF)

Agrochemical practice considers that analytical values of soluble phosphorus in the ammonium acetate lactate solution at pH 3.7 don't correctly describe this element's availability for plant nutrition is soils with pH over 6.0. So, in such cases a correction factor is used: CF = 1.3·pH – 0.1105·pH– 2.819 so that the analytical values obtained in soils with different pH values can be interpreted using the same limits for different soil supply classes; the factor takes the following values:

Soil pH	6.00	6.50	7.00	7.50	8.00	8.50
CF values	1.00	0.96	0.87	0.72	0.51	0.25

The highest total phosphorus content is in the soil A horizon due to the bioaccumulation and

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applying fertilizers effect, and then it decreases in depth.

Organic phosphorus represents 30-50% of the total content and inorganic forms – 50-70%. Most of the organic phosphorus is contained by humus and also in the organic matter not decomposed or being decomposed. Different produces resulted from microorganisms' activity contain certain amounts of organic phosphorus. Humus contains 0.17-1.09% P, depending on the soil type.

Phosphorus mobility in soil mainly depends on the soil characteristics and also on the applied agricultural technologies.

Soil reaction is a determinant factor; in the slightly acid reaction domain (pH = 5.8-6.2) phosphorus mobilization and its preservation in solution take place at maximum intensity. In moderately and strongly acid as well as in the neutral and alkaline domains soil solution phosphorus concentration decreases due to its fixation in hardly soluble forms.

Organic matter positively influences phosphates mobility in soils as it protects soil solution soluble phosphates against fixation processes by forming complexes between organic anions and Al^{3+}, Fe^{3+} or Ca^{2+}. And some organic ions can let off phosphate ions fixed on soil particles.

Most of the soil potassium (90-98%) is contained by the primary (micas, feldspars) and secondary minerals (illite, chlorite, vermiculite, smectite) crystalline lattice. The 2-10% difference is potassium fixed between minerals layers, adsorbed on the mineral and colloids surface (exchangeable potassium), and in soil solution.

Potassium concentration in soil solution is 0.1-0.3 mg/l and in the soils well supplied with this element its soil solution content is between 0.4 and 4 mg/l, representing 1/5-1/10 of the adsorbed potassium. Soluble and exchangeable potassium represent the immediate nutrition source for plants.

As the potassium concentration in soil solution decreases following its absorption by plants the equilibrium is restored by cationic exchange reactions that transfer exchangeable potassium into soil solution (Lăcătuşu R., 2016).

Fertilization, especially when it includes phosphorus and potassium, and liming definitely influences these elements concentrations in soil solution and also their solubility in soils. It was found that application of citric acid, *Bacillus polymyxa*, and lime may enhance P availability to plants by reducing the fixation of applied P and releasing fractions of already fixed P in acid soil (Chatterjee D. *et al*, 2022). Nitrogen and potassium fertilizers contribute to the dissolution of phosphate rock in acid soils (Chien S., 1979). Certain bacteria also solubilize phosphorus (Ponnaiah Paulraj *et al*, 2020) or both phosphorus and potassium (Basavesha K.N., Savalgi V.P., 2015). Some rhizosphere microorganisms enhance potassium ions availability in agricultural soils (Vijay Singh Meena *et al*, 2014).

This paper presents a particular situation of available vs. total phosphorus and potassium contents in the frame of an experiment with different fertilizers with nitrogen, phosphorus, sulphur, and potassium

MATERIAL AND METHOD

The soils of the Great Brăila Island were changed by men from their natural status through diking, drainage and intensive cultivation; their physical and chemical characteristics have been modified and they are continuously changing. The organic matter content is rapidly shrinking in the absence of river alluviums and the nutrition elements (nitrogen, phosphorus, potassium) contents decrease by repeated exports (Dumitru M., *et al,* 2021).

Experiments were carried out with different fertilizers containing nitrogen, phosphorus, sulphur and, in one case, potassium, in six farms of the Great Brăila Island, with seven field crops: barley, wheat, alfalfa, maize, sunflower, soy, and pea. Soil samples were collected at the end of the experiment and chemical analyses were performed according to the dedicated standardized methods frequently used in the ICPA Bucharest and county pedological offices laboratories; soil reaction (pH), humus, total nitrogen, total and mobile phosphorus, total and mobile potassium were determined. When soil pH was over 6 the mobile phosphorus content was corrected (P*) with the factor discussed above. Computations and graphics were carried out using Excel.

RESULTS AND DISCUSSIONS

Correlations drawn for all the samples *(table 2)* (n = 105) showed very significant values for soluble potassium depending on reaction and humus content.

Table 2

Correlations between pH and humus on one hand, soluble phosphorus and potassium on the other for all the samples

	P_{AL} % of total P	P_{AL}^* % of total P	K_{AL} % of total P
pH	-0.096	-0.316 **	-0.392**
Humus	-0.117	0.030	0.430**

Soluble phosphorus didn't appear dependent on either parameter but the corrected values showed very significant dependence on soil reaction. (The index ”AL” means ”soluble in ammonium acetate lactate solution at pH 3.7; the Asterix indicates values that have been corrected as shown before).

A pattern cannot be identified showing a clear dependence of the soluble phosphorus and potassium contents on the soil reaction or organic matter content *(table 3)*.

Table 3

Correlations between pH and humus on one hand, soluble phosphorus and potassium by the other, by depths

	P_{AL} % of total P	P_{AL}^{*} % of total P	K_{AL} % of total P
0-10 cm; n = 20			
pH	-0.214	-0.403	-0.219
Humus	-0.478*	-0.357	0.399
10-20 cm; n = 20			
	P_{AL} % of total P	P_{AL}^{*} % of total P	K_{AL} % of total P
pH	0.217	0.089	-0.495*
Humus	-0.505*	-0.437	0.470*
20-30 cm; n = 20			
	P_{AL} % of total P	P_{AL}^{*} % of total P	K_{AL} % of total P
pH	0,311	-0,063	-0,541*
Humus	-0,555*	-0,266	0,400
30-40; n = 20			
	P_{AL} % of total P	P_{AL}^{*} % of total P	K_{AL} % of total P
pH	0,095	-0,521*	-0,194
Humus	-0,026	0,389	0,279
40-50; n = 20			
	P_{AL} % of total P	$P_{AL}^{1)}$ % of total P	K_{AL} % of total P
pH	-0,249	-0,699**	-0,497
Humus	0,189	0,509*	0,536*

That is because of the fertilizers intervention which modifies all the parameters under discussion. The fact can be noticed though that potassium seems to be more dependent on soil reaction and humus content and that correlation indices, especially for phosphorus, seem to be more significant in the soil depth, where fertilizers influence diminishes.

Correlations by crops *(table 4)* reveal a more significant aspect. Both phosphorus and potassium appear to be very significantly dependent on both soil reaction and humus contents. The homogeneity of the results has to do more with the fertilization systems than with crops themselves.

Table 4

Correlations between pH and humus one hand, soluble phosphorus and potassium by crops

	P_{AL} % of total P	P_{AL}^{*} % of total P	K_{AL} % of total P
Barley, n = 15			
pH	-0,700**	-0,838**	-0,523*
Humus	0,891**	0,943**	0,526*
Wheat; n = 15			
	P_{AL} % of total P	P_{AL}^{*} % of total P	K_{AL} % of total P
pH	-0,758**	-0,888**	0,456
Humus	0,826**	0,765**	-0,211
Alfalfa; n = 15			
	P_{AL} % of total P	P_{AL}^{*} % of total P	K_{AL} % of total P
pH	-0,712**	-0,774**	-0,170
Humus	0,803**	0,818	0,522*
Maize; n = 15			
	P_{AL} % of total P	P_{AL}^{*} % of total P	K_{AL} % of total P
pH	-0,161	-0,551*	-0,142
Humus	0,277	0,256	-0,270
Sun flower; n = 15			
	P_{AL} % of total P	P_{AL}^{*} % of total P	K_{AL} % of total P
pH	-0,260	-0,819**	-0,166
Humus	-0,424	-0,037	-0,210
Soy; n = 15			
	P_{AL} % of total P	P_{AL}^{*} % of total P	K_{AL} % of total P
pH	-0,723**	-0,859**	-0,646**
Humus	0,839**	0,859**	0,739**
Pea; n = 15			
	P_{AL} % of total P	P_{AL}^{*} % of total P	K_{AL} % of total P
pH	-0,708**	-0,830**	-0,438
Humus	0,742**	0,772**	0,586*

Other correlations drawn for mobile phosphorus and potassium dependence on their total contents *(tables 4, 5 and 6)* have expectedly shown very significant coefficients. The fact can be noticed that absolute values of mobile phosphorus and potassium (mg/kg) seem to be more dependent on their total contents than the percentage values deeper in the soil.

Table 5

Correlations of soluble phosphorus and potassium depending on their total contents

	P_{AL} mg/kg	P_{AL}^{*} mg/kg	K_{AL} mg/kg	P_{AL} % of total P	P_{AL}^{*} % of total P	K_{AL} % of total P
Total P	0,602**	0,648**		0,428**	0,504**	
Total K			0,135			-0,761**

Table 6

Correlations of soluble phosphorus and potassium depending on their total contents by depths (n = 21)

	P_{AL} mg/kg	P_{AL} 1) mg/kg	K_{AL} mg/kg	P_{AL} % of total P	P_{AL} 1) % of total P	K_{AL} % of total P
0-10 cm						
Total P	0,732**	0,755**		0,553**	0,611	
Total K			-0,566**			-0,951
10-20 cm						
Total P	0,577**	0,626**		0,438*	0,477*	
Total K			0,278			-0,834**
20-30 cm						
Total P	0,347	0,467*		-0,007	0,024	
Total K			-0,285			-0,891**
30-40 cm						
Total P	0,785**	0,842**		0,042	0,425	
Total K			-0,100			-0,797**
40-50 cm						
Total P	0,806**	0,767**		0,496*	0,535*	
Total K			-0,282			-0,894**

CONCLUSIONS

Soil phosphorus and potassium availability for plant growth is controlled by many factors of which their solubilization degree is very important. In natural un ploughed soils it depends on the soil and its clay minerals nature, reaction, humus content. Ploughing, fertilizing, growing crops changes very much the way and the degree in which these elements are solubilized. It is important that fertilizing, liming, and soil works ensure the nutritive elements availability for plants on one hand and not exceed their needs so that elements in excess left after harvest could rise concerns for the environment.

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