

**THE INFLUENCE OF MANY YEARS LIMING AND FERTILIZING TO
CHANGING OF ADSORPTIVE COMPLEX COMPOSITION OF PSEUDOGLEY
SOIL**

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Abstract

Composition and characteristics of soil adsorptive complex are very important to understand physical and chemical processes which affect soil fertility and nutrients availability to plants. The paper deals with influence of many years ameliorative application of lime, manure and mineral fertilizers on adsorptive complex composition of pseudogley soil in Kraljevo valley. Soil belongs to group of extremely acid soil pseudogley type. Two – field crop rotation wheat – maize was applied. Soil samples were taken from opened profiles and numbered 1 (unfertilized variant – control), 2 (NPK) and 3 (NPK+CaCO₃+manure). Arable lands, pseudogley type, have a high degree of dealcalinization of eluvial, -Ah and Eg-, layers and B₁tg layer, too. Capacity value of cations exchange and saturation degree of exchangeable – adsorbed alkaline cations (Ca²⁺, Mg²⁺ and H⁺(+Al) ions) varied considerable. Their composition and content, especially at -Ah and Eg layers, were unsatisfactory, mainly. According to noticed V – values (< 50%), analyzed soil belongs to group of "moderately unsaturated" soils. Many years, periodically, application of pedo–ameliorative treatments as: liming, phosphatization and humification, influenced increase of degree of alkali saturation (V%) and capacity of cations exchange (T) at Ah layer for more than 40% and 10 m.ekv./100 g soil, respectively. Part of alkaline cations (Ca²⁺ and Mg²⁺) was increased, averagely, for 10 m.ekv./100 g soil or about 14.25% in relation with T values. Content of exchangeable – adsorbed K⁺, Na⁺, Ca²⁺ and Mg²⁺ ions at eluvial horizons (Ah and Eg) was rather low, at analyzed soil profiles. Calcification caused increase of content of exchangeable Ca²⁺, Mg²⁺ and K⁺ in adsorptive complex of analyzed soil.

Key words: adsorptive complex, fertilization, liming, pseudogley, soil.

Introduction

Pseudogleys cover significant areas of Serbia, accounting for about 285,000 ha or 78.73% of the total land area in Western Serbia (Tanasijevic et al., 1966). These soils are found in moderately moist to moist climates, and they have disturbed water and air relationships characterised by an occasional decrease in very moist i.e. wet and dry phases. Therefore, this soil is unfavourable for the cultivation of most plants. The unfavourable soil moisture regime is due to the compact lower Btg horizon which is poorly permeable or impermeable. Under dry conditions, the soil surface horizon undergoes intense desiccation, whereas the deeper impermeable horizon hardens. During the wet phase, reduction conditions occur in the soil, resulting in the reduction of different elements, primarily iron (Fe³⁺ to Fe²⁺), manganese, etc. Since the wet phase is short, only more susceptible substances undergo reduction. During the

dry phase, oxygen enters the soil, and oxidises the substances that were reduced during the wet phase (Fe^{2+} to Fe^{3+}).

Pseudogleys are rather poor in alkalis, being medium to strongly acid in reaction. They have a highly unfavourable structure, and a low content of organic matter. The acid reaction of pseudogley, its low humus content, and a low supply with available phosphorus and potassium are limiting factors for higher crop yields (Dugalic et al., 2005).

Absence of carbonates at pseudogley has caused its intensive acidification that is confirmed by results of many authors for active, substitute and hydrolytic acidity from different regions (Kubiena, 1953; Muckenhausen, 1975; Pivic et al., 2011). Taking into consideration heterogeneity of pseudogley type, Škoric (1986) described dystic pseudogley form with very acid reaction at top part of profile (pH 5-5.5), little adsorption capacity and low alkali saturation (20-50%), for many regions of ex – Yugoslavia. At Bt horizon, acidity is slightly less, but adsorption capacity and alkali saturation are greater. There are, at significant concentrations, Al and Fe adsorbed ions, beside H ions. Humus is present in small amount, dominating fulvo acids in its composition (Dugalic, 1997).

The role of calcium in soil is well known. First of all, together with soil organic matter it influences on formation of stable structure and favorable conditions for microbiological processes in soil. In highly acid soils application of calcium maintain conditions for high efficiency of all agro-technical measures aimed for protection and increase of soil fertility. Application of Ca-containing materials and decrease of soil acidity reduce possibility (due to formation of insoluble forms) of higher uptake of toxic elements, which have tendencies of increased accumulation in soil due to anthropogenic pollution (Kabata-Pendias & Pendias, 2001). In addition to reducing acidity, application of lime, together with manure and conventional NPK fertilizers, affects increasing of sum of alkali cations at adsorptive soil complex (S), decreasing of potential acidity and increasing cation exchange capacity (CEC) as well as degree of saturation by exchangeable – adsorbed alkali cations (V%) (Pivic et al., 2011).

The aim of this investigation is to evaluate influence of many years application of some ameliorants to adsorptive complex composition at pseudogley in term of widely use of marked pedo – ameliorative treatments and fertilization for reducing acidity of that soil type in Serbia.

Materials and methods

Investigation was conducted on stationary field fertilization trial, based at experimental field of the Dr. or e Radic Secondary School of Agriculture and Chemistry in Kraljevo 1995. Soil belongs to group of extremely acid soil pseudogley type. Two – field crop rotation wheat – maize was applied.

Experiment was set up by block system, in three replications, with area of elementary experimental plot 100 m^2 . Amounts of nutrients, applied in trial, were: 120 kg N ha^{-1} , $100 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ and $80 \text{ kg K}_2\text{O ha}^{-1}$, used in form of NPK fertilizer (8:24:16), superphosphate (17% P_2O_5) and ammonium-nitrate (AN=17% N). Lime fertilizer "Njival Ca", as product of Serbian glass factory from Paracin, was applied in experiment, too, at amount of 4.0 t ha^{-1} . Entire amounts of lime, phosphate and potassium fertilizers, together with 1/3 nitrogen one, were applied at per – sowing soil preparation, while the rest of nitrogen fertilizer was applied at spring beginning. Lime fertilizer was used periodically, each fifth year (1995, 2000, 2005 and 2010). Well burned out manure was used in amount of 30 t ha^{-1} . Other care procedures, implemented during vegetative period, were standard.

Soil samples were taken from opened profiles and numbered 1 (unfertilized variant – control), 2 (NPK) and 3 (NPK+CaCO₃+manure). Samples were taken after wheat harvest 2012, from humus (Ah = 0-15 cm), underhumus, eluvial – pseudogley (Eg = 15-40 cm) and part of transitional B₁tg horizons (60-80 cm).

Soil samples analyzes were done by standard chemical methods:

pH in water and KCl – electrometric method with glass electrode in suspension 1:2.5

humus content – Kodzmann method

sum adsorbed alkali cations – Kappena method

hidrolitic acidity – with Ca-acetate, Kappena method

degree of soil saturation by exchangeable – adsorbed cations – by calculating, by Hissink

exchangeable Ca and Mg ions and Na and K ions – by compleximetric and flamephotometric, respectively.

Results were presented by average values and statistically proceed by analyze of variance (Mead et al., 1996).

Results and discussions

Agrochemical properties of pseudogley are very unfavorable (Table 1). Studied soil has high acidity. Active acidity at surface layer (0-20 cm) is relatively low (pH in H₂O 5.24), while it is significantly decreased at the deepest soil layers (pH in H₂O 6.04). Exchangeable acidity (pH in KCl) vary from 4.48 to 4.80, through soil depth. Value of hydrolytic acidity (Y¹) at surface horizon (0-20 cm) is relatively high (15.47 ccm), while it is significantly decreased at deeper layers (7.35).

Table 1. Agrochemical properties of Pseudogley

Depth (cm)	Humus (%)	Y ¹ (ccm)	N (%)	T	S	T-S	pH		P ₂ O ₅ (mg 100 ⁻¹)	K ₂ O (mg 100 ⁻¹)
							H ₂ O	KCl		
0-20	2.18	15.47	0.14	16.71	8.08	8.63	5.24	4.48	8.0	13.8
20-40	1.84	13.98	0.13	16.69	9.79	6.90	5.55	4.58	7.0	13.6
40-60	0.66	12.45	0.09	26.24	20.02	6.22	5.46	4.42	1.3	8.5
60-80	0.71	9.97	0.07	26.29	21.31	4.98	5.64	4.52	1.0	7.6
80-100	0.63	7.35	0.02	25.62	22.02	3.60	6.04	4.80	0.8	4.3

Studied soil type is characterized by very unfavorable composition of adsorptive complex (Table 1). Namely, values of adsorptive capacity, sum adsorbed alkali cations as well as degree of adsorptive complex saturation by alkalis are very low. Humus content at surface layer (0 – 20cm) is low, too, (2.18%) intending to decrease through soil depth. Such fact points out need to apply humification as necessary ameliorative treatment, as part of entire system of fertilization and applying pedo – ameliorative treatments.

Analyzed pseudogley profiles show medium nitrogen providing at humus – accumulative horizon. It is estimated that is average nitrogen content at surface layer 0.14%, decreasing significantly by soil depth increase (0.02%). This soil type is weakly provided by easy – available phosphorus (7.0-8.0 mg 100⁻¹ g, at 0 - 40 cm depht). On the contrary, content of easy – available potassium is satisfactory, putting this soil type in group of well – provided soil (13.8 mg 100 g⁻¹).

Results for sum of alkali cations (S- values) point to high degree of dealkalization of studied profile part, with values below 21 m.e. 100 g⁻¹ (Table 2). Many years application of fertilizers

has led to minimal changes S – values at all horizons of studied soil. However, many years application of lime, manure and mineral fertilizers has caused noticeable increase of sum of exchangeable – adsorbed alkali cations (3.5-4.1 m.e. 100 g⁻¹ or 17.2-42.7%) in relate to control.

Capacity of cations exchange (T – values) varied significantly in pseudogley, in dependence to soil depth and fertilization variant (Table 2). T – values significantly increased going from Ah to B₁tg profiles, due to the fact that it, at the low humus content, is the most dependent on clay content and composition. Namely, maximum capacity of cations exchange occurs at B₁tg profile. Dugalic (1997) got similar results, investigating capacity of cations exchange at various pseudogley varieties in Kraljevo valley.

Table 2. Composition of adsorptive complex

Trea- Tment	S (m.e. 100 g ⁻¹)			T (m.e. 100 g ⁻¹)			T-S (m.e. 100 g ⁻¹)			V%		
	Horizons			Horizons			Horizons			Horizons		
	Ah	Eg	B ₁ tg	Ah	Eg	B ₁ tg	Ah	Eg	B ₁ tg	Ah	Eg	B ₁ tg
1.	9.6	20.3	20.9	19.4	29.6	33.1	9.8	9.3	12.2	47.7	50.5	62.8
2.	9.9	20.6	21.7	21.4	31.6	33.4	11.5	11.0	11.7	46.8	49.8	60.7
3.	13.7	23.8	24.7	27.9	38.4	34.6	14.2	14.6	9.9	58.0	58.6	60.0
Lsd 5%	0.31	1.03	0.16	0.24	0.94	1.76	1.41	1.05	1.01	3.42	0.05	0.91
1%	0.51	1.71	0.27	0.40	1.55	2.29	2.34	1.74	1.67	5.66	0.08	1.50

Many years application of fertilizers has caused increase of T – values at Ah and Eg horizons, while combined application of lime, manure and mineral fertilizers, through longer period, caused increase of T – values at Ah and Eg horizons for 43.8% and 29.7%., respectively, in relate to control. However, changes of T – values at B₁tg horizon were minimal, under many years fertilization.

It can be seen (Table 2) that changes of T – values at all horizons of analyzed soil, are results of changes of capacity of cations exchange and sum of exchangeable – adsorbed alkali cations. Degree of saturation by exchangeable – adsorbed alkali cations (V%) is under 50% at humus – acumulative (Ah) horizon, on untreated land (control). Such date qualifies this soil type as "moderately unsaturated" soil. There is not significant difference between Eg and Ah horizons (50%) of analyzed soil profile in saturation by adsorbed alkali cations, on control plot. Significantly increase of V% value (62,8%) is noticed until at B₁tg horizon (Table 2). So, it is, however, relatively low degree of saturation by adsorbed alkali cations, being, averagely, below 63%. Influence of many years, combined, application of lime, manure and mineral fertilizers on change degree of saturation by alkali cations is registered at Ah and Eg horizons of analyzed soil. These results are in accordance with results other authors about influence of combined fertilization on decrease soil acidity, increase adsorbed alkali cations and degree of saturation adsorptive complex by alkali cations (Dugalic, 1997; Pivic et al., 2011).

Content of exchangeable – adsorbed cations at profile of analyzed pseudogley varied significantly, as it can be seen in Table 3. So, content of exchangeable K⁺ was increasing in line with increasing of soil depth. The lowest content (0.47 m.e. 100 g⁻¹) was registered at Ah horizon, but the highest (0.58 m.e. 100 g⁻¹) at B₁tg one.

The part of exchangeable K⁺ in adsorptive complex of Ah horizon has been increased for 31.9% in relate to control (1) as result of many years application lime, manure and NPK fertilizers (3). The most pronounced changes of exchangeable K⁺ content have occurred at Ah and Eg pseudogley horizons.

Observing the depth profile, changes of part of exchangeable – adsorbed Na^+ in soil, were relatively little, under the influence of many years fertilization. However, significantly varying of content of exchangeable – adsorbed Ca^{2+} ions at eluvial Ah and Eg pseudogley horizons were noticed.

Table 3. Exchangeable cations in the adsorptive complex (m.e. 100 g^{-1})

Treat- ment	K^+			Na^+			Ca^{2+}			Mg^{2+}		
	Horizons			Horizons			Horizons			Horizons		
	Ah	Eg	B ₁ tg	Ah	Eg	B ₁ tg	Ah	Eg	B ₁ tg	Ah	Eg	B ₁ tg
1.	0.47	0.52	0.58	0.23	0.23	0.23	16.2	17.9	21.9	5.90	6.00	7.60
2.	0.59	0.59	0.62	0.21	0.21	0.28	16.4	18.2	22.3	5.40	7.20	9.80
3.	0.62	0.60	0.62	0.22	0.22	0.28	26.5	28.9	31.4	8.23	10.95	14.40
Lsd 5%	0.10	0.09	0.08	0.03	0.03	0.02	1.62	0.73	0.13	0.61	0.79	0.57
1%	0.17	0.15	0.13	0.06	0.06	0.03	2.68	1.22	0.22	1.02	1.30	0.94

Part of exchangeable Ca^{2+} ions in adsorptive complex of analyzed soil is rather low showing tendency to increase with increasing soil depth. The highest content of exchangeable Ca^{2+} at Ah and Eg horizons was result of many years, periodically application of lime, manure and NPK fertilizers. Achieved increase of exchangeable Ca^{2+} on mentioned fertilization variant (3) ranged over 60% in relate to control (1). The similar changes of content of exchangeable cations were obtained for Mg^{2+} ions, too (Tab. 3). It is evident calcification on extremely acid pseudogley cause increase of pH values of soil solution, leading to further generation of negative charge at surface of colloidal particles at adsorptive soil complex and, at the same time, increase of Ca, Mg and K cations adsorption (Ferreira Fontes and Ferracciú Alleoni, 2006).

Conclusion

On the base of achieved results about composition of adsorptive complex of cultivated pseudogley variety and results about its improving by many years implementation of calcification, humification and fertilization, can be drawn following conclusions:

Analyzed pseudogley is very poor with exchangeable – adsorbed alkali cations, especially its humus – accumulative horizon (Ah), which is characterized by low average S - values ($9.6 \text{ m.e. } 100 \text{ g}^{-1} \text{ soil}$) and T - values of capacity of cations exchange ($19.4 \text{ m.e. } 100 \text{ g}^{-1} \text{ soil}$) increasing in line with soil depth. Many years combined application of lime, manure and NPK fertilizers resulted with increase S- values for 43.8% (Ah) and 29.7% (Eg) in relate to control and T- values from 17.2 to 42.7%.

Degree of soil saturation by exchangeable – adsorbed alkali cations (V%) was low, with average values 47.7% and 50.5% at Ah and Eg horizons, respectively. According to noticed V – values ($< 50\%$), analyzed soil belongs to group of "moderately unsaturated" soils. Many years, combined application of lime, manure and mineral fertilizers affected significantly increase degree of soil saturation by alkali cations, especially at Ah and Eg horizons.

Content of exchangeable – adsorbed K^+ , Na^+ , Ca^{2+} and Mg^{2+} ions at eluvial horizons (Ah and Eg) was rather low, at analyzed soil profiles. Calcification caused increase of content of exchangeable Ca^{2+} , Mg^{2+} and K^+ in adsorptive complex of analyzed soil.

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