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INVESTIGATION OF PHOSPHATE-ION RETENTION STRENGHT IN SOME TYPES OF KAKHETI SOILS

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ABSTRACT

The presented article describes the soil types existing in east Georgia, particularly in several villages of Gurjaani Municipality-Vazisubani, Kalauri, Mukuzani, Shashiani. Meadow-brown and brown soils represent good soil types for viticulture development in Kakheti. The vineyards cultivated on these soils produce such well-known wines as Tsinandali, Vazisubani, Mukuzani, Akhasheni, Gurjaani, Manavi. The study explores brown carbonate and meadow-brown soil lab tests to examine the absorption of phosphate ions by them. The study showed that the amount of phosphorus deposited through soils is sufficiently absorbed under various conditions, having a positive effect on the amount of crop. Was compared the rates of phosphate absorption in these soils with the efficiency of phosphorus fertilizers, which showed that the higher the absorption of phosphorus, the lower the amount of phosphorus available to the plant and the lower the yield, and the lower the strength of phosphorus retention, the higher the amount of phosphorus to be consumed by the plant and the higher the yield. But under the conditions of high cultivation degree, the strength of phosphorus absorption became weak, resulted in a large amount of exchangeable and movable phosphates already existing in the soil, which is available to the plant. So, the efficacy of phosphorus fertilizers on such soil is weak. The speed of phosphorus absorption in the soil of Gurjaani municipality villages is satisfactory. However, in case of a high degree of cultivation (or in case of excess fertilization), the degree of phosphorus retention decreases. Accordingly, phosphorus-containing fertilizers should be used within strictly controlled limits.

Keywords: *Soil, Environmental chemistry, absorbtion of phosphate ions;*

1. INTRODUCTION

In the 21st century, the UN Commission has put a special emphasis on the fight for cleanliness, elimination of hunger and poverty in the presented agenda for Sustainable Development (Orgill, 2019; Mahaffy, 2019). Haber-Bosch process for the synthesis of ammonia is considered to be one of the basic discoveries of the twentieth century, as the crop productivity is a true way to fight against hunger, that can be achieved by proper and moderate use of fertilizers. Therefore, the chemical composition of the soil from environmental chemistry is of particular importance, as the expected amount of the crop and cleanliness of food products are directly related to its composition (McMurry, 2015).

Georgia is a mountainous country in the Caucasus, neighboring Russia, Azerbaijan, Armenia, and Turkey. Georgia is characterized by a great variety of soil types on its small territory , which includes nearly all soils of the world (Sabashvili, 1965; Urushadze, 2014; Guide of Georgian Soils, 2014; Guide of Soils, 2015).

Specifically, types of soil in Georgia: Mountain-meadow, reddish, yellowish, marshy, brown, black, salt marshy, saline soils, and more. The following soils are spread all over the East of Georgia: valley-brown, black, bushy, alluvial soils; Carbonated, mountain black, mountain-forest-meadow, and mountain-meadow soils (Urushadze, 2015; Sabashvili, 1965). Meadow-brown and brown soils represent good soil types for viticulture development in Kakheti. The vineyards cultivated on these soils produce such well-known wines as Tsinandali, Vazisubani, Mukuzani, Akhasheni, Gurjaani, and Manavi.

Brown soils are characterized by granular-rocky structure, skeletal structure, good physical, thermal, watery and biological properties; high content of carbonates, up to 93%, with a neutral and alkali reaction of PH-7.0-8.0); Clay and light clay mechanical composition, high absorption capacity; Humus - 3-7%; Total nitrogen - 0.05-0.4%; 0.8% of total potassium, with a low content of iron and manganese. Lately, more attention has been paid to organic phosphorus of the soil, as a potential supply of phosphorus to the plant. 10-80% of the total phosphorus is in the arable soil. The speed and amount of organic phosphorus production depend on the type of soil production, environmental conditions, and anthropological factors. The systematic application of fertilizers increases organic content of phosphorus. According to available data, phosphorus content in soil does not change by adding mineral fertilizers (Wandruszka,2006; Solomon, 2000; Whalen, 2001). Generally, phosphorus-rich soils are almost absent. The amount of movable phosphorus is low in Georgian soils. It can be found in the form of calcium and magnesium phosphates in carbonate soils. They are then converted to semi-soluble and soluble phosphates and thus are absorbed by plants. The progress of this process is very limited, so phosphorus-containing mineral and organic fertilizers are needed (Pierzynski,2000).

2. MATERIALS AND METHODS

In order to explore carbonaceous and meadow-brown soils of eastern Georgia, we conducted laboratory tests to study the absorption of phosphate ions. In 2018, soil samples were taken in the villages of the Gurjaani district of Kakheti: Vazisubani, Kalauri, Mukuzani, Shashiani (Figures 1 and 2). Gurjaani is a municipality of Kakheti region in eastern Georgia (Kartlis tskovreba, 2014). The territory of Gurjaani municipality belongs to moderate humid subtropical climate district. The moderately humid climate is formed on the plain in the east, with mild winters and hot summers. The climate on Gombori Range is moderately humid, with a long summer. The average annual temperature is 12.4 ^{0}C, the average temperature in January, coldest month of the year, is 0.11C, and in August, the hottest month - the annual temperature is 35.8 ^{0}C. A.The average annual volume of precipitation in the major part of the area is up to 800 mm and decreases to 500-600 mm upstream. In the article (Kupatadze, 2018) is presented the studies on water samples from these villages. Naturally, soil investigation was also an issue of interest. The samples were taken at a depth of 0-40 cm.

2.1. Method of experiment

We placed 10 g soil sifted through 1mm diameter sieve in a conic flask and added 50ml of an aqueous solution of calcium $Ca(H_2PO_4)2{\bullet}H_2O$. We took the series of a solution with different concentrations 20, 40, 60, 80, 160, and 200mg P_2O_5 in one litre of water, i.e. we added 10, 20, 30, 40, 60, 80 and 10mg P_2O_5 per 100gr of soil. The first batch of weight was delayed for one day, the second batch – for three days, the third batch – for six days. We used to shake the flanks periodically. We added 7 drops of 0.2% sodium azides solution as an antiseptic to each flask. After passing some time, we shook the suspension for five minutes and filtered. The phosphorus was determined by calorimeter method (Williams, 2012. VanLoon, 2011) and the phosphorus moving in the residual soil was defined by Lorenz - Schaefer method (Daughton, 2004; Liu, 2009; Pierzynski, 2000; Turner, 2003; Lehmann, 2005.) (Tables 1, 2, 3).

The studied soils are characterized by a high absorption capacity of phosphate ions. After three days of interaction, the absorbed phosphorus was more than 99% of the input and more than 99.5% after six days.

Indicators of P_2O_5 concentration (mg/L) given in Table 1,2,3 characterize the degree of movement of the absorbed phosphorus, i.e., its ability to move from soil to saline (intensity factor). We conducted a second laboratory test to study phosphate absorption in red, brown carbonate, and meadow-brown soils. We prepared the compost in a glass container of 500g soil capacity. we added calcium monophosphate (as a solution) to the soil by 10, 20, 30, 40, 60, and 80 mg of P_2O_5 per 100 g of soil. Phosphates in soil were defined in 0.01N $CaCl_2$, 0.01N H_2SO_4, and 1% $(NH_4)_2CO_3$ solutions, one day, 1.5, 3, 6 months and 1 year after phosphate application. We calculated the phosphorus retention strength by the percentage of phosphorus excreted and deposited (Table 4,5,6). The intensity of phosphate absorption depends on the dosages of phosphorus added. At low doses (10-40mg / 100g), the phosphorus retention strength is high and after one year of composting, it ranges between 74.2-80% for all three types of soils. At high dose levels (60-80mg / 100g) it varies between 62.6-70%. These values are relatively high in red soil - 65-70%. 62.6-65.5 and 63-66% are in brown-carbonate and meadow-brown soils. In the range of 10-40mg concentration per P_2O_5/100g of soil, we got practically identical phosphorus retention strength indicators for all three types of soil. This allows us to use any of these doses (10 to 40 mg) to determine the strength of the phosphorus retention.

3. RESULTS AND DISCUSSION:

We compared the rates of phosphate absorption in these soils with the efficiency of phosphorus fertilizers, which showed that the higher the absorption of phosphorus, the lower the amount of phosphorus available to the plant and the lower the yield, and vice versa, the lower the strength of phosphorus retention, the higher the amount of phosphorus to be consumed by the plant and the higher the yield. (Table 7). Based on the indicator of phosphorus retention strength, obtained on these soils, we consider it possible to make a qualitative assessment of these indicators;

Specifically, it corresponds to the amount of phosphorus excreted, expressed as a percentage of deposited fertilizer, calculated as 10-40 mg P_2O_5 in 100 g of soil, by 6-month interaction with the soil under the conditions of 60% humidity and $20–25^0$C. Diagnostic Table 8 has been developed to determine the quality of soil caltivation and efficiency of phosphorus fertilizer according to the phosphorus retention strength indicator. If P_20_5 excretion is less than 30%, then the soil intensively absorbs phosphorus, and they are firmly bonded. Under the following indexes: 30 - 50% firm; 50 - 70% average, 70 - 80% weak. As for the phosphorus movement, the same will change in the opposite order. Therefore, under the conditions of high cultivation degree, the strength of phosphorus absorption is very weak, resulted in a large amount of exchangeable and movable phosphates already existing in the soil, which is available to the plant. Therefore, the efficacy of phosphorus fertilizers on such soil is weak.

4. CONCLUSIONS:

According to the study, the consumption rate of phosphorus in the soil of Gurjaani municipality villages is satisfactory. However, in case of a high degree of cultivation (or in case of excess fertilization), the degree of phosphorus retention decreases. Accordingly, phosphorus-containing fertilizers should be used within strictly controlled limits.

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Figure 1. *Gurjaani district*

Figure 2. *Villages in Gurjaani district*

Table 1. *Interaction of the soil with phosphate solutions and indicators of the movement of absorbed phosphates*

Giving P_2O_5 (solution) mg/100g soil	P_2O_5 mg /l 0,01N$CaCl_2$ solution			P_2O_5 mg /100 l soil		
	After 1 day	After 3 day	After 6 day	After 1 day	After 3 day	After 6 day
1	2	3	4	5	6	7
reddish (uncultivated)						
Without phosphorous; Control						
10	0,008	0,008	0,008	2,2	2,2	2,2
20	0,020	0,016	0,016	6,6	6,4	6,2
30	0,036	0,028	0,026	13,0	11,0	8,7
40	0.040	0.032	0.030	18,4	15,0	13,0
60	0.050	0.037	0.035	28,0	22,5	18,0
80	0.070	0.046	0.042	42,8	35,0	26,0
100	0,080	0,056	0,050	64,0	50,0	40,0
	0,11	0,075	0,072	85,0	70,0	52,0

Table 2. *Interaction of the soil with phosphate solutions and indicators of the movement of absorbed phosphates*

Giving P_2O_5 (solution) mg/100g soil	P_2O_5 mg /l 0,01NCaCl$_2$ solution			P_2O_5 mg /100 l soil		
	After 1 day	After 3 day	After 6 day	After 1 day	After 3 day	After 6 day
1	2	3	4	5	6	7
Brown Carbonated (uncultivated)						
Without phosphorous; Control						
	0,012					
10	0,027	0,012	0,012	1,2	1,2	1,2
20	0,054	0,018	0,018	9,4	8,1	7,2
30	0.11	0,040	0,037	18,4	15,5	11,4
40	0.19	0.59	0.053	26,7	20,5	16,9
60	0.43	0.1	0.075	34,3	29,0	24,5
80	1,1	0.038	0.036	46,7	43,4	40,9
100	1,5	0,68	0,59	78,7	69,9	52,5
		0,75	0,73	97,4	82,5	65,7

Table 3. *Interaction of the soil with phosphate solutions and indicators of the movement of absorbed phosphates*

Giving P_2O_5 (solution) mg/100g soil	P_2O_5 mg /l 0,01NCaCl$_2$ solution			P_2O_5 mg /100 l soil		
	After 1 day	After 3 day	After 6 day	After 1 day	After 3 day	After 6 day
1	2	3	4	5	6	7
meadow brown (uncultivated)						
Without phosphorous; Control						
10	0,010	0,010	0,010	1,0	1,0	1,0
20	0,025	0,016	0,016	9,0	7,9	7,0
30	0,051	0,037	0,035	18,2	15,0	11,0
40	0.1	0.055	0.054	24,8	19,7	16,3
60	0.17	0.095	0.080	32,0	27,0	23,0
80	0.42	0.35	0.32	44,9	42,5	39,8
100	1,0	0,56	0,54	76,4	67,8	52,0
	1,3	0,72	0,71	96,2	81,0	63,8

Table 4. *Strength of absorbed phosphorus retention under laboratory test conditions (composts) 2018*

Giving P_2O_5 (solution) mg/100g soil	Absorbed P_2O_5 %				
	After 1 day	After 1,5month	After 3 month	After 6 month	After 1 year
1	2	3	4	5	6
reddish					
Without phosphorous; Control					
10	36	48	65	76	80
20	32	44	64	76	80
30	28	40	62	73	78
40	24	38	59,5	72	77
60	21	31	49,5	68	70
80	18	28	48,7	63	65

Table 5. *Strength of absorbed phosphorus retention under laboratory test conditions (composts) 2018*

Giving P_2O_5 (solution) mg/100g soil	Absorbed P_2O_5 %				
	After 1 day	After 1,5month	After 3 month	After 6 month	After 1 year
1	2	3	4	5	6
Brown Carbonated					
Without phosphorous; Control					
10	32,0	44,0	62,0	74,0	78,0
20	29,0	37,0	61,0	73,0	77,0
30	23,5	32,5	59,5	71,5	74,5
40	21,5	31,5	58,0	70,0	74,2
60	17,2	26,0	45,5	62,0	65,5
80	12,5	23,0	44,0	59,5	62,6

Table 6. *Strength of absorbed phosphorus retention under laboratory test conditions (composts) 2018*

Giving P_2O_5 (solution) mg/100g soil	Absorbed P_2O_5 %				
	After 1 day		After 1 day		After 1 day
1	2	3	4	5	6
meadow brown					
Without phosphorous; Control					
10	34	45	62	74	79
20	30	38	62	74	78
30	25	34	60	72	75
40	22	30	59	71	75
60	18	27	46	63	66
80	14	25	45	60	63

Table 7. *Phosphorus retention strength per Phosphorus Fertilizer Options in Tests on Autumn Wheat and Vine Crops*

Provision of soil with phosphorus	Moving Phosphorus P_2O_5 mg/100g	Giving P_2O_5 mg/100g	Absorbed P_2O_5 % (6 month interaction)	Harvest (one hectare)
Brown Carbonated				
Low	1,15	30	71,5	23,7
Medium	4,7	30	49,7	42,8
High	6,4	30	31,5	50,9
meadow brown				
Low	1,1	30	72,0	21,8
Medium	4,6	30	50,5	38,1
High	6,1	30	32,4	47,2
Redish				
Low		30	73	3143
Medium		30	52	6770
High		30	35	7129

Table 8. *The table determining the quality of cultivation and the efficiency of phosphorus fertilizers (nitrogen-potassium background) according to phosphorus retention strength of the soil (reddish-brown soil with heavy texture, brown carbonate, and meadow brown soils)*

Strength of absorbed phosphorus retention %	Expelled Phosphorus	Grade of the strength of absorbed phosphorus retention	Movement grade	the quality of cultivation grade	The efficiency of phosphorus fertilizers
>70 50-70 30-50 20-30 <20	<30 30-50 50-70 70-80 >80	Very strong; strong; average; Weak; Very weak;	Low; Weak; average; High Very high;	Very weak; Weak; average; Aver. High; High ;	Weak; average; Good; average; Weak;