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On the Rules of Applying Fertilizers to Red Soils

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Abstract

The article presents research results of applying mineral fertilizers to red soils. The research aimed at increasing productivity in low productive red soils, definition of optimal volume of fertilizer costs, developing the recommendations for fertilization. The agrochemical indicators were studied before applying fertilizers, also after three years since the beginning of tests. There are some changes in agrochemical indicators because of fertilization. Total nitrogen content, soil acidity indicators and a sum of absorbed bases has also remained the same. Hydrolysed nitrogen and exchangeable potassium content has been slightly increased. It was revealed that application of phosphorus fertilizers in the soils with poor phosphorus content (phosphorus oxide P_2O_5 < 30 mg/100 g) with phosphorus P180 kg/ha nitrogen N300 potassium K100 increases productivity. It is recommended to apply phosphorus and potassium fertilizers during winter digging. In the soils with low phosphorus pentoxide, an optimal dose of nitrogen is 200 kg/ha. It is advisable to apply nitrogen fertilizer - 60% from March 1st to April 1st, and the rest 40% - in July. The research also revealed that phosphorus fertilizers shall be applied once in three years with dosage 540 kg/ha. This significantly decreases the costs.

Keywords: fertilizer; soil fertilization; red soil.

Introduction

Implementation of the goals of the country and its further development perspective, our future, along with other factors significantly depend on protection of the soil, increase of productivity and rational use of fertilizers, it is particularly important for the Autonomous Republic, where an opportunity for increase of agricultural fields is almost exhausted and it depends on intensive farming development. Thus, scientific research of soil cover is of a high importance.

Immense growth of the world's population, along with other several issues, makes food security quite problematic, which is also related to increase of soil productivity. Production of agricultural crops and increase of rural population's social-economical potential highly depends on solving this problem. It may be surprising that the majority of our population in the region takes a little care for increasing productivity of "soil-breadwinner" (Kutaladze *et al.* 2019).

Adjara is one the unique regions in the world by its natural landscape conditions. There is an interesting changing pattern of climate, soil flora and fauna on small plots of territory. Natural contrasts are astonishing, as in any period of time one might enjoy a green blossoming flower bed and snowy mountains at the same time in Adjara. Agricultural activities of a Georgian man, and specification of Adjara agriculture, are harmonized and absorbed with this natural characteristic. Considering current soil-climate conditions, focused on unique southern crops (tea, citrus, tung-tree, laurel), the variety of fruit grows wonderfully (Tsintskiladze *et al.* 2022).

Considering complex geological-terrain and climate conditions, even a minor mistake in agricultural activity might cause irreparable impact. This is evidenced by an activation of natural-geological processes in the recent years in Adjara, such as erosion, floods, landslide, rocks - avalanches, snow avalanches, hundred hectares of agricultural fields are severely damaged, financial damage is huge. Plough made in steep slopes, uncontrolled cutting down of woods bring irretrievable damage with sparse forests and destroyed forest tracts, decreased or disappeared watery mountain streams, mountain slopes are gradually slipping off the source of our existence - soil cover (Urushadze *et al.* 2015).

Currently, in all regions of Georgia, including Adjara, the tea and citrus plantations are mainly planted in acidic red soils, characterized by a low productivity. Agricultural product production in any type of the soil, depends on natural productivity of soil, which impoverishes and exhausts the soil. An increase of the soil productivity directly relates to the intensive use of mineral and organic fertilizers. In this regard, mineral fertilizers have an important role (Kutaladze 2006; Kutaladze 2009).

Uneven and sometimes high-volume application of phosphorus fertilizers in the red soils caused different content of phosphorus pentoxide. Four categories were differentiated in the red soils of western Georgia: 1. Very poor with phosphorus pentoxide. 2. Poor. 3. Averagely supplied. 4. Increased. 5. High. 6. Very high. Phosphorus pentoxide transferred to sulfuric acid extract with 0,1 normalcy, for those soils, amounts to: 1) less than 8 ml, 2) 8-15 ml, 3) 15-30 ml, 4) 30-45 ml, 5) 45-60 ml, 6) more than 60 ml/100 g of soil (Kutaladze *et al.* 2003; Margvelashvili *et al.* 2009).

While assessing soil on the plant nutrition elements, along the content of moving forms, it is very important to consider synergy and antagonism in the process of transferring nutrition elements to plants. It is defined that excessive nitrogen in plants decreases intensity of phosphorus transfer and on vice versa, absorption of excessive phosphorus reduces nitrogen transfer. Thus, the creation of a physiologically balanced solution requires regulation of the dosage of nitrogen fertilizers according to the content of the phosphorus pentoxide in soil. If this pattern is violated, then a plant may not use it for generating organic substances but increase the nitrate forms of nitrogen fertilizers instead, which are eventually transferred to fruit. For a transfer regulation of nitrate forms to a plant, we thought about application of nitrogen fertilizers with a consideration of a volume of phosphorus pentoxide in the soil. For this purpose, the different content of phosphorus pentoxide in the red soils, influence of nitrogen fertilizers over productivity and quality of tea green leaf were studied. The research of this topic has a huge importance for a rational application of nitrogen fertilizers and reduction of nitrates in tea production (Kutaladze *et al.* 2005a; Kutaladze *et al.* 2005b).

Application of N, P, K fertilizers to the red, low productivity soils, promotes complex chemical and biochemical reactions in the soil. A solubility and adoption of food substances, the elements' fixation in sparingly soluble or insoluble forms after chemical degradation and evaporation depends on the progression of those reactions (Kutaladze et al. 2003).

Material and methods

Field testing

The aim of the research was to study and substantiate the rational methods of applying mineral fertilizers to the red soils occupied by the tea plantations in Adjara ensuring high and stable harvest with a high-quality production.

The purpose of the research was to study the following topics:

- Phosphorus transformation in the red soils of Adjara through applying phosphorus fertilizers in different dosages.
- Influence of mineral fertilizers application methods over the harvest and quality of tea plant.
- Impact of mineral fertilizers regular application over productivity of red soils.
- Economic efficiency of applying phosphorus fertilizers in tea plantations. Definition of perspective, economically profitable variations, and their implementation in production.

The experiments were carried out on typical red soil in the testing station in Chakvi (2019-2021). The research used stationary field testing and laboratory research methods. A tea plantation on the sample plot was planted in 40s of the previous century: breed "Kolkhida 257".

The plot has been divided into sections for field testing. The samples for agrochemical description of the sample plot soil were taken prior to applying fertilizers. The samples were taken from the soil sections 0-10, 10-20, 20-30, 30-40, 40-50. The same works were carried after three years upon finalizing the field experiment.

Research methods

The agrochemical analysis of the soil samples were carried according to the following methods (Margvelashvili 2019; Margvelashvili *et al.* 2021; Mikeladze *et al.* 2021).:

- Total humus by Tyurin's method;
- Total nitrogen, phosphorus, potassium by Ginsburg-Shcheglova-Vul'fius accelerated method;
- Exchangeable acidity - Sokolov method;
- Hydrolytic acidity - Kappen's method;
- Absorbed bases - Trilonometric method;
- In extract of pH KCI - Potentiometer method (with pH meter);
- Phosphorus pentoxide - Oniani's method;
- Exchangeable potassium - Maslova's method;
- Hydrolytic nitrogen - Tyurin's and Kononova's method.

Results

Scheme of the field experiment

The experiment was carried out four times. Total area of the section is 48 square meters, which is isolated by 2 protection zones.

The field experiment was carried in the following scheme:

(1) Unfertilized (control)

(2) N300 K100 background

(3) NK+P60- annual application

(4) NK+P120 - annual application

(5) NK+P180 - annual application

(6) NK+P240 - annual application

(7) NK+P360- application once in 3 years

(8) NK+P540 – application once in 3 years.

Agrochemical characterization of the sample plot

Soil on the sample plot is characterized by the following agrochemical indicators (Table 1): an average content of humus and nitrogen in 0-15 cm layer of the plot soil it is 6,2-6,3%, while total nitrogen is 0,31-0,32%, which decreases in the depths of the soil. There is no decent difference between variations of humus and total nitrogen content. Total phosphorus content in 0-15 cm layer is 0,15-0,16%, phosphorus pentoxide content is low and in the same soil layer does not exceed 10,5 mg/100 g. Its content reduces in the depths of the soil.

The research soil is characterized by the following characteristics: a high content of potassium 0,92% and low content of exchangeable potassium 12-15 mg/100 g. As it was revealed by the agrochemical research, the research soil is characterized by a low content of absorbed bases and a high exchangeable acidity, which is caused by a high volume of potassium, this is typically normal for tea; reaction of soil is acid, 3,6-3,7 in pH KCI suspension, which is completely normal for tea.

A regular application of the fertilizers increases not only productivity and number of nutrient substances required for a plant, but their ratio in the soil. Applied fertilizers have a huge influence over physical, chemical, and other properties of the soil. Long term application of the fertilizers promotes profound changes, which increase productivity.

During three years (2019-2021) after the field experiment, nitrogen 900 kg/ha, potassium 300 kg/ha and phosphorus 180-720 kg/ha has been applied to the soil (Table 2).

Table 1: Agrochemical description of the sample plot before the field experiment (Chakvi red soil, tea plantation. 2019)

Sample	Depth of taking a sample (cm)	pH (KCL)	Humus %	Exchangeable acidity mg.equiv/ 100 g soil	Hydrolytic acidity mg.equiv/ 100 g soil	Total absorbed bases mg.equiv/ 100 g soil			Total %			Hydrolytic N mg/ 100 g soil	Movable P_2O_5 mg/100 g soil	Exchangeable K_2O mg/100 g soil
						Ca	Mg	Total	N	P	K			
Unfertilized	0-15	3,6	6,2	7,8	15,7	3,1	1,3	4,4	0,32	0,15	0,91	5,8	8,5	13,5
control	15-30	3,6	4,5	8,0	12,3	2,8	1,1	3,9	0,22	0,09	0,90	3,2	6,5	11,8
sample	30-45	3,7	3,4	8,2	11,0	2,3	0,9	3,2	0,16	0,06	0,89	1,8	2,5	9,5
N-300	0-15	3,6	6,3	8,0	18,0	2,6	1,4	4,0	0,32	0,16	0,91	6,2	10,2	14,0
K-100	15-30	3,6	4,6	8,5	16,2	2,6	1,0	3,6	0,22	0,11	0,90	3,6	6,7	11,2
	30-45	3,7	3,5	8,2	13,3	2,2	0,8	3,0	0,16	0,07	0,89	1,8	2,4	9,4
NK+P60	0-15	3,7	6,2	8,4	16,2	3,0	1,3	4,3	0,31	0,15	0,92	5,7	9,5	13,8
	15-30	3,7	4,2	8,7	12,5	2,6	1,1	3,7	0,21	0,10	0,91	3,3	6,3	11,0
	30-45	3,8	3,3	8,8	11,4	2,2	0,9	3,1	0,17	0,06	0,90	1,7	2,5	9,9
NK+P120	0-15	3,6	6,3	8,2	18,3	3,0	1,5	4,5	0,32	0,16	0,91	6,0	8,2	12.0
	15-30	3,6	4,5	8,3	16,8	2,6	1,2	3,8	0,22	0,09	0,90	3,5	6,5	8,8
	30-45	3,7	3,4	8,6	13,5	2,4	0,8	3,2	0,16	0,06	0,89	1,8	2,4	6,2
NK+P180	0-15	3,7	6,3	7,8	17,7	2,9	1,4	4,3	0,31	0,15	0,92	5,8	10,5	14,5
	15-30	3,7	4,4	8,0	15,0	2,5	1,1	3,6	0.21	0,10	0,91	3,4	6,4	11,2
	30-45	3,8	3,6	8,5	12,9	2,5	0,8	3,3	0,16	0,07	0,90	1,9	2,5	9,1
NK+P240	0-15	3,7	6,3	8,1	19,0	3,1	1,3	4,4	0,32	0,16	0,91	6,0	8,1	15,0
	15-30	3,7	4,4	8,3	15,5	2,5	1,2	3,7	0,21	0,11	0,91	3,4	6,3	11,0
	30-45	3,8	3,5	8,5	13,0	2,5	0,9	3,4	0,16	0.06	0,90	1,8	2,5	9,0
NK+P360	0-15	3,7	6,2	8,1	18,9	3,1	1,3	4,4	0,31	0,15	0,91	6,0	9,0	15,0
once in 3 years	15-30	3,7	4,6	8,2	15,4	2,5	1,2	3,7	0,21	0,10	0,91	3,5	6,5	11,1
	30-45	3,8	3,5	8,6	12,9	2,5	0,9	3,4	0,16	0,07	0,90	1,4	2,5	8,0
NK+P540 once	0-15	3,6	6,2	8,2	18,6	3,0	1,5	4,5	0,31	0,15	0,90	6,2	9,5	14,2
in 3 years	15-30	3,7	4,5	8,4	14,8	2,3	1,3	3,6	0,21	0.10	0,90	3,6	6,4	11,3
	30-45	3,7	3,6	8,7	13,2	2,4	0,8	3,2	0,16	0,07	0,89	1,5	2,4	7,0

Table 2: Agrochemical description of the sample plot after 3 years of the field experiment (Chakvi red soil, tea plantation. 2021)

Sample	Depth of taking a sample (cm)	pH (KCL)	Humus %	Exchangeable acidity mg.equiv/ 100 g soil	Hydrolytic acidity mg.equiv/ 100 g soil	Total absorbed bases mg.equiv/ 100 g soil			Total %			Hydrolytic N mg/ 100 g soil	Movable P_2O_5 mg/100 g soil	Exchangeable K_2O mg/100 g soil
						Ca	Mg	Total	N	P	K			
Unfertilized control sample	0-15	3,6	6,2	7,7	15,5	3,2	1,3	4,5	0,32	0,15	0,91	5,0	8,2	13,0
	15-30	3,7	4,4	8,0	12,2	2,8	1,2	4,0	0,21	0,08	0,90	3,0	6,2	11.0
	30-45	3,7	3,4	8,0	11,1	2,4	1,0	3,4	0,16	0,06	0,89	1,7	2,5	9,4
N300 K100	0-15	3,5	6,3	8,2	18,2	2,9	1,4	4,3	0,32	0,15	0,92	12,0	8,9	17,2
	15-30	3,5	4,7	8,6	16,3	2,6	1,0	3,6	0,22	0,11	0,91	6,5	6,3	13,2
	30-45	3,7	3,4	8,2	13,0	2,3	0,9	3,2	0,16	0,07	0,89	2,0	2,4	9,5
NK+P60	0-15	3,6	6,3	8,5	16,4	3,3	1,3	4,6	0,30	0,16	0,92	12,0	15,5	18,0
	15-30	3,6	4,7	8,7	12,6	2,7	1,1	3,8	0,22	0,10	0,91	6,1	8,0	13,3
	30-45	3,7	3,4	8,8	11.5	2,2	1,0	3,2	0,17	0,06	0,90	2,0	2,7	10.0
NK+P120	0-15	3,7	6,5	8,3	18,7	3,0	1.5	4,5	0,32	0,16	0,92	12,8	18,0	17,6
	15-30	3,6	4,6	8,4	16,8	2,7	1,1	3,8	0,23	0,10	0,91	6,0	10,5	13,0
	30-45	3,6	3,4	8,6	13,5	2,4	0,7	3,1	0,16	0,06	0,89	2,0	3,3	8,3
NK+P180	0-15	3,6	6,5	8,0	17,8	3,1	1,3	4,4	0,32	0,15	0.92	13,0	22,1	18,5
	15-30	3,7	4,5	8,2	15,0	2,6	1,2	3,8	0,22	0,10	0,91	5,8	12,8	13,4
	30-45	3,7	3,6	8,5	13,1	2,5	0,9	3,4	0,16	0,07	0,90	1,9	4,0	9,0
NK+P240	0-15	3,6	6,5	8,3	19,4	3.1	1,3	4,4	0,32	0,16	0.92	13,0	23,4	18,5
	15-30	3,6	4,5	8,3	15,5	2,6	1.2	3,8	0,21	0,11	0,91	6,5	13,5	13,5
	30-45	3,7	3,6	8,5	13,0	2,5	0,9	3,4	0,16	0,06	0,90	1,8	4,5	9,0
NK+P360 once in 3 years	0-15	3,7	6,4	8,3	19,4	3,2	1,3	4,5	0,31	0,16	0,91	13,5	17,3	18,1
	15-30	3,7	4,7	8,3	15,4	2,6	1,2	3,8	0,21	0,10	0;91	6,4	10,0	13,3
	30-45	3,8	3,5	8,5	13,2	2,5	0,6	3,1	0,16	0,07	0,90	1,8	3,0	9,0
NK+P540 once in 3 years	0-15	3,6	6,4	8,3	18,8	3,2	1,4	4,6	0,31	0,16	0.91	13,0	18,2	18,3
	15-30	3,7	4,5	8,4	14,9	2,4	1,4	3,8	0,21	0,11	0,90	6,5	11,8	13,4
	30-45	3,6	3,6	8,7	13,2	2,4	0,8	3,2	0.16	0,07	0.89	1,8	3,5	9,1

Final result

The data reveals that during the experiment, a high volume of nitrogen, phosphorus and potassium fertilizers were applied to the soil. The soil samples were taken (in the fall of 2019, at the end of the tea bush vegetation, according to the field test options) to carry out relevant agrochemical analysis for defining the influence of mineral fertilizers applied to the soil on the agrochemical indicators (Table 2).

Discussion

There are some changes detected in the soil indicators of the experiment samples after applying nitrogen, phosphorus and potassium fertilizers (As shown in Table 2). It shall be noted that the humus content has remained almost the same for three years, with only 0,1-0,2% increase of total humus. Total nitrogen content, the soil acidity indicators and total absorbed bases also remained the same.

The content of hydrolytic nitrogen and exchangeable potassium has been increased compared to the control version of the research soil (As depicted in Table 2). If the content of exchangeable potassium is 13 mg/100 g of soil in the unfertilized sample, a volume of exchangeable potassium in the rest of the samples equals 17,2-18,5 mg/100 g. The content of hydrolytic nitrogen in unfertilized options is 5,0 mg/100 g of soil. In the rest of the samples 12-13 mg/100 g of soil. There is a distinct difference between the samples when it comes to the content of phosphorus pentoxide. The content of phosphorus pentoxide naturally grows with an increase of superphosphate. If its content in the unfertilized samples is 8,2-6,2-2,5 mg/100 g of soil according to the depth, it reaches maximum on NK+P240 sample and accordingly amounts to - 23,4-13,5-4,5 mg /100g of soil.

Thus, the content of phosphorus pentoxide in the upper layer of the soil has significantly increased on this sample. However, according to the resulting indexes, it still lacks this nutrition element, and it is important to apply phosphorus fertilizers. When reviewing Table 2, it is worth mentioning that - NK+P180, NK+P540 samples, that were applied in 2019 by the same volume of phosphorus, are essentially different by the content of phosphorus pentoxide. If the phosphorus content in the 0-15 cm soil layer of NK+P180 samples is 22,1 mg, in the NK+P540 sample it is 18 mg/100 g of soil.

This could be explained by the fact that the total volume of phosphorus in the NK+P540 kg/ha sample, was applied once and left for the following activation. Soluble phosphates applied to those samples have been transformed to sparingly soluble and less phosphorus pentoxide, while on the NK+P180 kg/ha sample phosphorus fertilizer has been applied annually. On this sample -180 kg/ha is newly applied, it is more active and soluble and has not transformed to sparingly soluble and hardly accessible form yet.

Conclusion

Red soils (Chakvi) have a heavy mechanical composition. The research soil is characterized by a low content of absorbed bases and high exchangeable acidity, average humus and total nitrogen content and a high content of total phosphorus and potassium. The soil is poor in phosphorus pentoxide and hydrolytic potassium but has average content of exchangeable potassium. The regular application of nitrogen, phosphorus and potassium fertilizers for three years does not influence the total content of absorbed bases, acidity, humus, nitrogen, phosphorus and potassium. The soil productivity increase is detected when changing the moving forms of the nutrition elements (NPK).

Regular application rule of fertilizers on account of significant cut of costs for tea leaf productivity increase and storage, transportation, application of fertilizers and labour resources is financially beneficial. Financial efficiency analysis revealed that use of phosphorus fertilizers on tea crops in the red soil of Adjara is economically efficient.

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