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A scientifically based system of fertilizers and chemical soil reclamation

N.G. Kurmasheva*, *F.F.* Avsakhov, *R.G.* Yagafarov, *R.Sh.* Irgalina, and *R.M.* Yakhutova

Federal State Budgetary Educational Institution of Higher Education Bashkir State Agrarian University, 34 50-letiya Oktyabrya str., 450001, Ufa, Russia

Abstract. The research was carried out in the agricultural production cooperative SEC "Ural" in the Askinsky district of the Republic of Bashkortostan, where soil samples became the object of research. According to the data obtained from the agrochemical analysis, the following quantitative indicators were obtained: the weighted average indicator of soil humus content was 4.1–7.6%, the weighted average indicator of mobile phosphorus content was 34-130 mg/kg of soil, and exchangeable potassium was 51.1 mg/kg of soil. The potassium balance was 16-113 mg/kg of soil. The pH of the aqueous extract of the soil ranged from 4.5 to 5.7, i.e. it varied from strongly acidic to neutral.

1 Introduction

The maintenance and reproduction of a fertile layer of soil cover is one of the important agrotechnical elements associated with obtaining stable and high crop yields [1]. Humus-rich soil has the most saturated compounds of many organic acids in its structure, such as humic and fulvic acids, which in turn are supported by available forms of mineral elements. A high percentage of humus content makes it possible to maintain an optimal microbiome, both in the whole structure of the soil cover and in the rhizosphere of a single plant [2]. As the statistical data of many studies show, the dynamics of negative growth of the fertile soil layer is observed in many production fields, i.e. its depletion occurs. The reason for this is several factors. The first aspect is the influence of abiotic factors: water and wind erosion, high salinity and swampiness of soils. The second aspect is the influence of anthropogenic factors, i.e. human economic activity. Due to these urgent problems, there is a growing need for the development and implementation of scientifically based fertilizer application systems, optimization of mechanized techniques, as well as the development of new chemical soil reclamation systems. [3, 4, 5, 6].

To this day, an important component of agricultural production is the introduction of a proper fertilizer system and the development of a chemical soil reclamation system with proven effectiveness and scientific validity. By carrying out scientifically based agrotechnical and technological measures, it is possible to achieve an optimal balance in the soil with the best physical and chemical properties.

* Corresponding author: n.kurmasheva@mail.ru

To implement such a system in the SEC Ural of the Askinsky district, the following tasks were solved:

1. To consider the features of the soil cover of the SEC "Ural" of the Askinsky district of the Republic of Bashkortostan;
2. To study agrochemical properties of soils of SEC "Ural";
3. To develop recommendations for the conservation and improvement of soil fertility.

2 Method

Using maps with a scale of 1:25000, a comprehensive survey of the farm's soils was conducted. Thanks to the use of digital platforms, statistical data processing was carried out. The sampling process was carried out according to the methodology of a comprehensive survey, where 20 point soil samples were taken from a total area of 20 hectares, and then an average sample was prepared from the studied area. During the research, 622 hectares of land were studied.

3 Research results and their discussion

The development of a scientifically based fertilizer and soil reclamation system is a complex and multifaceted process that requires in-depth knowledge in the field of soil science, agrochemistry, and agricultural technology. The selection of optimal fertilizers that consider the needs of specific crops and the characteristics of the soil cover plays a crucial role in increasing the yield and quality of agricultural products.

Before creating a proper fertilizer system, the company should take appropriate measures to regulate soil acidity, considering the biological characteristics of cultivated crops in crop rotation.

The soil cover is one of the components of the natural environment, which has its own morphological features that make it possible to describe the soil cover in the studied area. The granulometric composition, coloration (color) of the soil, its structure, the nature of the transition from one horizon to another, neoplasms, vegetation, the spread of plant root systems, thickness, etc. characterize the morphological features [7, 8, 9, 10].

The granulometric or mechanical composition of soils is characterized by the weight ratio of particles of different sizes, which is one of the important soil characteristics.

In the conducted soil analysis in SEC Ural, the granulometric composition ranges from light loamy to heavy loamy according to N.A. Kachinsky. According to Diagram 1, light loamy soils occupy 456.9 hectares, and heavy loamy soils occupy 165.1 hectares.

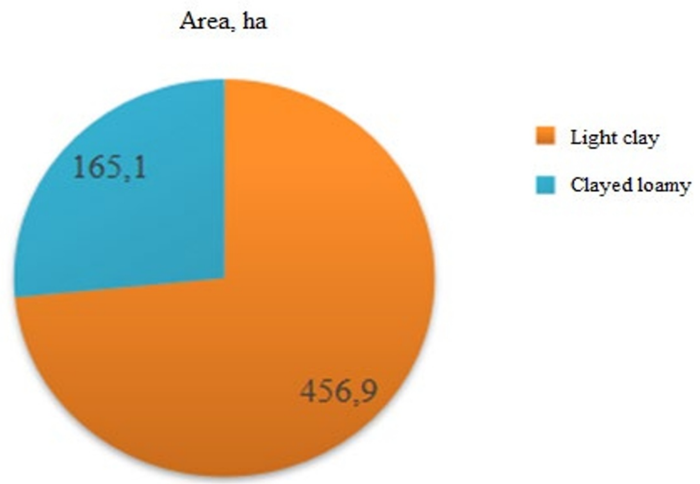

Fig. 1. Grouping of soils by mechanical composition. SEC Ural of the Askinsky district of the Republic of Bashkortostan.

The vegetation cover is mainly characterized by forest stands of birch, pine, willow, spruce, fir, and other trees. The grass tier is represented by wolf's bane, meadow fescue, meadow bluegrass, colonial bent grass, awnless brome, quick grass, and other plants.

The farm's soils have a special color scheme, including shades of gray, brown, brownish black, green, and black.

Soil structure is the ability of particles to form into stable lumps. The lumps vary in size and shape, with air flowing between them, which affects the respiration of the roots, as well as moisture passing through the lumps. In SEC Ural, the soil is granular at a depth of 7 to 25 cm, granular-lumpy - from 26 to 40 cm, and nutty - from 41 to 65 cm.

Neoplasms in soils are called accumulations of chemical and biological origin, of various shapes, which are composed and formed in soils. No neoplasms were found in the soils of the farm.

The distribution of plant root systems at a depth from 7 to 25 cm is an abundance of roots, from 26 to 40 cm – rare roots. The nature of the transition from one horizon to another is noticeable.

The value of a chemical compound called humus is undeniable. In the course of fulfilling its function of forming the soil, it, exchanging with various elements of the environment around us, enters into a direct relationship with the system where the plant and animal (animals, microorganisms) parts of the ecosystem function. In our biosphere, humus, which has the unique feature of accumulating solar energy and exchanging it with natural organic compounds, creates a dynamic system that forms organic matter in the soil for plant growth and development. Humus is primarily associated with processes such as synthesis and decomposition, it is a combination of changes in the soil of organomineral and natural compounds.

The level of soil fertility is related to the total humus content in the soil. If we focus on improving the biochemical, chemical, and biological properties of the soil, the humus content in it will be directly improved. Soil is a valuable carbon resource, which in turn proves its huge role in the global carbon cycle.

In the studies, the thickness of the humus horizon was average (depth 20-24 cm). All the studied soil samples had a relatively average humus content. The results obtained for determining the humus content are presented in Diagram 2.

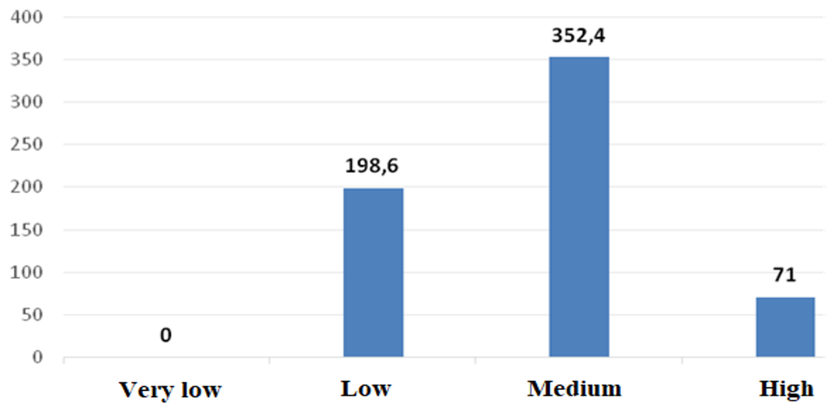

Fig. 2. Grouping of soils by humus content. SEC Ural of the Askinsky district of the Republic of Bashkortostan.

As a result of the conducted research, it can be seen that 352.4 hectares of soil in the SEC Ural of the Askinsky district have an average supply of humus (the humus content ranges from 5.1 to 6.0%). With a low humus content of 198.6 hectares of soils, and 71 hectares with a high degree of humus supply.

The average humus content (57% of the territory) was determined on the main part of the soil. The humus content was low in 32% of the soils, and high in 11%.

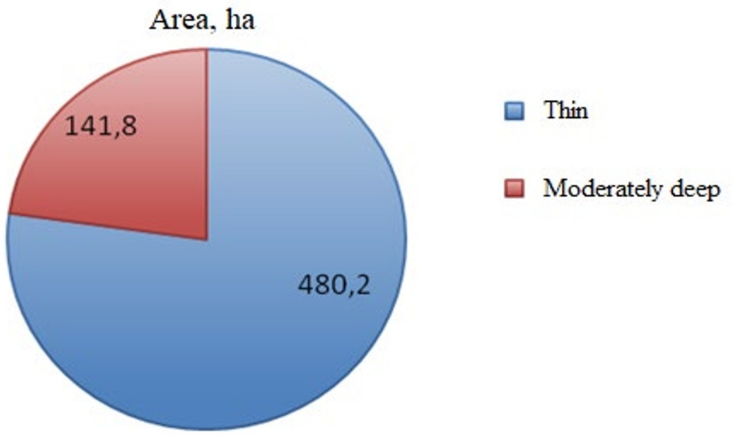

Fig. 3. Grouping of soils according to the humus horizon thickness. SEC Ural of the Askinsky district of the Republic of Bashkortostan.

Diagram 3 shows that most of the soils belong to the average humus horizon - 480.2 hectares, and the low-yield humus horizon was 141.8 hectares.

According to the conducted research, we have determined that the farm's soils have an average organic matter content. It is extremely important to prevent any additional loss of humus. Unfortunately, as a result of the active activity of modern agricultural machinery on the fertile soil layer, a decrease in the amount of organic fertilizers and the use of irrational and scientifically based crop rotation, humus is being lost. According to the main indicators of soil fertility, first of all it is necessary to pay attention to the change in soil density. It is necessary to compensate for the removal of nutrients from plants during their harvesting. The decrease in humus affects the intensity of the microbiological living phase of the soil.

Soil fertility determines the availability of nitrogen to plants and their nutritional quality. Humus deficiency affects the reserves of productive moisture in the soil, which in turn affects the availability of nutrients for plants.

To compensate for the loss of humus in the soil, it is necessary to provide it with nutrients, which is achieved by applying mineral and organic fertilizers. To improve the functioning of microorganisms that convert compounds inaccessible to plants into available ones, it is necessary to replenish the amount of organic matter in the soil by applying organic fertilizers (manure) and embedding plant residues (straw) in the soil. To enhance their functioning, introduce sideral crops and conduct enhanced control over the proper management of crop rotation. It should not be forgotten that it is necessary to control the quality of tillage and use only scientifically sound agricultural technologies.

Depending on the soil condition, the crop being cultivated, the crop rotation used and the available agricultural machinery in the farm, the introduction of new technologies or the sowing of "sustainable" crops can be considered. It is possible that the option of ploughing in stubble using biologics and complex preparations with active strains with high evidence-based effectiveness will be effective. It should also be borne in mind that good results in improving soil fertility have been proven by liming acidic soils and applying rational doses of nitrogen fertilizers.

Special attention should be paid to such a macronutrient as phosphorus. We know firsthand about this element effectiveness, as it plays a huge role in the formation of the root system of plants and the entire vegetative mass. This element must always be present in the soil for proper plant growth and development, especially during flowering and harvest formation.

Phosphorus has a number of properties in the soil, for example, its reserves in the soil are unstable and can be in both organic and inorganic forms. It is found in deeper soil layers. Anyway, some of the phosphorus that has been absorbed by plants is removed from the soil with the harvest, so phosphorous fertilizers should be applied, considering the remaining available phosphorus and soil acidity. There is also a problem with the release of a certain part of phosphates during the application of organic fertilizers. But to date, the problem of an imbalance in the phosphorus content in the soil has not been solved, because the amount of removal exceeds the amount of phosphorus fertilizers applied. And this is a consequence of a slowdown in plant growth and development, which leads to a decrease in crop yields. Severe phosphorus deficiency manifests in the form of the formation of small leaves of plants and inhibition of the process of flowering and maturation of crops.

Plants move quickly transit to reproductive development, which reduces yields. The presence of large amounts of phosphorus in the soil can lead to a lack of elements such as Mn, Fe, Zn, and Ca.

With optimal phosphorus nutrition, plants increase their winter hardiness, accelerate development and maturation, increase yields and improve the quality of products. In addition, the root of plants develops better, the process of tillering and deep penetration into the soil occurs better. All this improves the supply of nutrients and moisture to plants, which is especially important in dry years.

In the SEC Ural of the Askinsky district of the Republic of Bashkortostan, the mobile phosphorus content averages 49.5 mg/kg of soil, which refers to a low degree of availability.

Figure 4 shows the results on the content of mobile phosphorus.

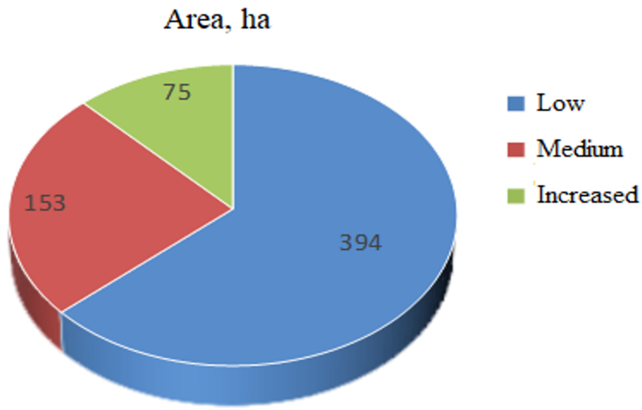

Fig. 4. Grouping of soils by mobile phosphorus content. In the SEC Ural of the Askinsky district of the Republic of Bashkortostan.

The phosphorus content was 34-130 mg/kg of soil and depended on the depth of sampling and the soil difference. The area of 394 hectares had a low availability of mobile phosphorus. The rest of the soil had an average supply of 153 hectares and an increased supply of 75 hectares. Thus, the soils of SEC Ural in the Askinsky district mainly had a low availability of mobile phosphorus (63% of the territory), while 25 and 15% of the territory had an average and increased supply, respectively. As a result of numerous studies, it can be confidently stated that to preserve and increase the content of mobile phosphorus in the soil, it is necessary to apply mineral and organic fertilizers.

The soils of SEC Ural were well supplied with exchangeable potassium rather than nitrogen and mobile phosphorus, which is typical for the conditions of our republic and is mainly due to the mechanical composition.

Potassium in the soil has a number of properties. For example, it becomes easily accessible to plants after its transition to an ionic form; potassium from soil minerals cannot be used by plants; it does not form insoluble compounds in plants and is present in the soil as part of primary and secondary clay minerals. Potassium is quickly washed out of plant residues. For plants, only the available form of potassium is valuable in the form of potassium in the soil solution, exchangeable and absorbed forms. At the same time, all forms of potassium are valuable for the entire system in the soil, since they form dynamic stability in it.

All forms of potassium are interconnected, so its non-exchangeable forms participate in the restoration of its water-soluble and exchangeable form. At the same time, if the soil is periodically moistened and dried, it is possible to achieve a good fixation of potassium in the soil. If the aim is to fix non-exchangeable forms of potassium in the soil, liming acidic soils is effective. The potash utilization rate ranges from 5 to 30% and is determined by the quality of the soil and the crop being cultivated. The higher the content of exchangeable potassium in the soil and the better the granulometric composition, the higher this coefficient is.

Along with this, attention should be paid to the fact that potassium determines the quality of the products obtained in addition to increasing yields. The lack of potassium in feed and food products negatively affects the health of animals and humans.

In SEC Ural, soils had an average degree of availability in terms of exchangeable potassium content (16-113 mg/kg of soil), which averaged 51.1 mg/kg of soil.

Figure 5 shows the results of our research on the content of exchangeable potassium in SEC Ural.

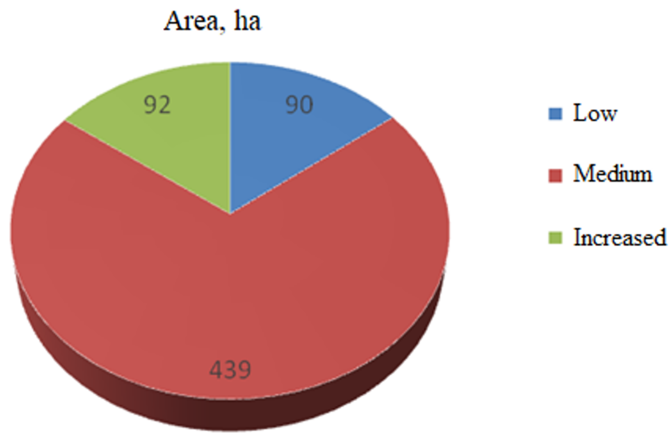

Fig. 5. Grouping of soils by the content of exchangeable potassium. In the SEC Ural of the Askinsky district of the Republic of Bashkortostan

As can be seen from Diagram 5, in SEC Ural of the Askinsky district, 71% of the territory was occupied by soils with an average availability of exchangeable potassium, and 15 and 14% of the territory are occupied by soils with high and low content of exchangeable potassium, respectively.

To improve the potassium nutrition of plants, organic and mineral fertilizers should be used, and chemical soil reclamation should be carried out, aimed at increasing the capacity of cation exchange.

Soil acidity is the ability of chemical elements to maintain an ionic state in the soil. The acidity of the soil determines the root nutrition of plants. Its condition depends on the reaction of the soil environment, because it is associated with processes such as the redeposition of nutrients and their dissolution.

Acidic soils reduce biological activity due to the weakening or complete cessation of the activity of earthworms, nitrogen-fixing bacteria, and nitrificates. Soil acidity can affect the reproduction of soil fertility, optimal availability of fertilizers, and increased crop yields.

In the farm, 67% of the soil territory (314 ha) had medium acidity, and 33% (154 ha) had low acidity. These environmental response indicators will not play a major role in shaping crop yields cultivated in this crop rotation. The total acidity was 4.5-5.7.

Almost half of the soils had a medium acidic reaction, 25% of the territory had a slightly acidic reaction, soils close to neutral acidity occupied 18% of the soils, and 7% of the soils had a strongly acidic reaction.

Soil liming should be carried out, as this will reduce the soil acidity. Many researchers believe that the use of siderates is a popular method.

In the Republic of Bashkortostan, high soil acidity is one of the main reasons for the decline in crop yields. Acidic soils cover 34.7% of arable lands, with the majority of these soils found in the northern and northeastern forest areas.

Gradual acidification of the soil is also characteristic of the conditions of the farm under study, because it is located in the northern forest-steppe of the Republic of Bashkortostan. Soil acidification is primarily due to the peculiarity of non-chernozem soils, which are easier to acidify than chernozem soils. The acidity is also related to the influence of the soil and climatic conditions of the zone and the specific precipitation in this region. The reason for soil acidification is also the introduction of large amounts of mineral fertilizers and the use of intensive farming methods.

Liming is a good method to reduce acidity. In addition to liming, the method of cultivating phytomeliorants, such as siderates, is also used to reduce acidity. Studies on the introduction of physiologically neutral fertilizers into the soil, which do not acidify the soil, have shown good effectiveness. It should also be remembered that as a result of applying organic fertilizers, it is possible to improve the soil structure and optimize acidity.

If we optimize the conditions of plant growth and development using energy-efficient and environmental technologies, one way or another it will maintain soil fertility. To improve soil fertility, it is necessary to optimize the conditions for the soil microbiota, considering all its main indicators. It should also be remembered that when choosing agrochemical measures, economic efficiency for agriculture should also be considered.

During liming, aluminum and calcium ions are released. To determine the rate of lime application, it is necessary to consider such soil indicators as: humus content, degree of saturation with bases, granulometric composition, and hydrolytic acidity. In addition, you should pay attention to the type of soil, its mechanical composition and metabolic acidity.

To date, the average dose of lime has been calculated, which has been determined in the course of numerous and lengthy studies. We will use the calculated liming data, adhering to the recommended reaction of the medium, so that the crops cultivated on the farm grow and develop with optimal soil acidity.

An increase in acidity worsens many indicators of soil quality, destroys its structure, inhibits beneficial microorganisms, slows down protein synthesis and the digestibility of nutrients. The application of lime makes it possible to change the acidity of soils in less than one crop rotation. Based on the hydrolytic acidity, the optimal dose of $CaCO_3$ should be calculated correctly, considering the needs of the plants.

In our studies, we calculated this dose by shifting to the alkaline side by 0.1 pH using the following formula:

$$\mathbf{CaCO_3\ dose,\ t/ha = \Delta\ pH \times A \times 10} \tag{1}$$

where, Δ pH is the planned pH shift;
A is the $CaCO_3$ consumption for a shift of 0.1 pH, t/ha;
10 is the coefficient for conversion to tons/ha.
The initial pH value is 4.8, the planned pH level is 6.5;
Δ pH = 6.5 - 4.8 = 1.7;
A is the $CaCO_3$ consumption for a shift of 0.1 pH, t/ha, = 0.53;
$CaCO_3$(X) dose = 1.7 × 0.92 × 10 = 15.64 t/ha [13].

Thus, the optimal dose of $CaCO_3$ was 15.64 t/ha for the conditions of SEC Ural in the Askinsky district. The need for such large doses is due to the rather significant acidification of soils and will require significant costs. To ensure that crop yields and the economic efficiency of investments in tillage do not decrease in the future, it is necessary to add the necessary amount of lime.

There are many scientific papers on the effectiveness of mineral fertilizers. Its effectiveness is undeniable both for increasing soil fertility and for increasing crop yields. Mineral fertilizers are a source of nutrients in plants that can increase crop productivity.

To obtain the greatest efficiency from the agrotechnical measures used, all aspects of their management should be considered. On acidic soils, lime must be applied, considering the characteristics of crops and soil parameters. It is necessary to introduce cereals and legumes into crop rotation. To calculate the amount of mineral and organic fertilizers in a particular field according to agrochemical soil analyses and data on the content of nutrients in the soil, and to monitor the availability of micro fertilizers to plants. Apply organic fertilizers, considering the actual fertilizer resources available to the farm, etc.

Table 1. Calculation of the need for mineral fertilizers of spring wheat for the planned yield, 2.0 t/ha.

No.	Value	Spring wheat		
		N	P	K
1	Removal of fertilizer elements per 1 ton, kg	35	12	25
2	Natural yield, t/ha	1.1	0.7	1.5
3	Required amount of mineral fertilizers per day, kg	31.5	15.6	12.5
4	Percentage of accessibility from mineral fertilizers, %	60	10	25
5	Total mineral fertilizers required in a.d., kg	52.5	156	50
6	Mineral fertilizer is required, kg/ha [13]			
	Ammonium nitrate (34.4%)	152.6		
	Double Superphosphate (46%)		339.1	
	Potassium chloride (60%)			83.3

To produce 2.0 t/ha of spring wheat, double superphosphate 339.1 kg/ha, ammonium nitrate 152.6 kg/ha, and potassium chloride 83.3 kg/ha must be added at the SEC Ural.

4 Conclusion

An agrochemical analysis of the soils of the SEC Ural in the Askinsky district made it possible to correctly assess the intra-field variability of soil fertility. To obtain high yields of agricultural crops and increase soil fertility, it is necessary to properly organize crop rotation, including siderates and perennial grasses, apply organic fertilizers, seal finely ground straw, etc.

In addition to the above, the farm is recommended to contribute 15.64 t/ha for land reclamation, as well as to use phosphorus and potassium containing mineral fertilizers to increase yields. Such measures will help to improve the soil structure, increase its fertility and improve the nutritional regime for plants.

In addition, it is recommended to regularly conduct agrochemical soil analyses to control the level of fertility and timely correction of agrotechnical measures. This will ensure optimal conditions for the growth and development of crops, ensuring stable and high yields.

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