Economic removal of nutrient elements with crop yields

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Abstract. A significant number of nutrients are taken out of the soil by the harvest and, if they are not returned, in a few years the soil loses its fertility to such an extent that cultivation of vegetable crops becomes a meaningless activity. Searching for the reasons leading to significant variability of normative nutrient removal by grain crops is the purpose of the work. The authors performed calculations, used the results of field experiments with barley. Methods of determining the doses of mineral fertilizers, the balance of humus and nutrients in the soil are presented. The issues of resource conservation, occupational safety and environmental problems in the use of fertilizers are outlined.

Key words: nutrient export, fertility, yield.

1 Introduction

Agriculture plays an important role in providing food for the world's population, but in turn it has a significant impact on the environment. The use of mineral fertilizers and pesticides leads to intensive penetration of harmful substances into the soil and water bodies, which negatively affects the ecosystem.

To solve this problem, it is necessary to develop sustainable agricultural systems that, in addition to ensuring high land productivity, will also help reduce the harmful impact on nature. Thus, agriculture must become more sustainable and environmentally friendly.

Research shows that the use of sustainable agricultural practices, such as organic farming, agroecological systems and multifunctional farming, helps reduce negative environmental impacts. In addition, developing technologies to use water more efficiently, improving fertilization methods and introducing biological crop protection methods will also help make agriculture more environmentally friendly and sustainable.

Thus, having sustainable agricultural systems will be key to ensuring safe food production and reducing the negative impact of agriculture on the environment [1, 2].

To obtain a stable level of yield from good quality crops, students must know the growing conditions and how to regulate them. The most regulated factor influencing plants is the soil, so it is necessary to know its agrochemical and physicochemical indicators used in calculating the doses of ameliorants, organic and mineral fertilizers necessary for normal growth, development of plants and increasing (preserving) soil fertility.

Creating suitable conditions for plant growth includes controlling soil pH levels, optimizing nutrient and micronutrient levels, moisture management, drainage and drought protection. It is also important to consider the presence of pests and soil diseases, as well as the use of modern technologies and high-quality seeds.

According to research [3-5], agrochemical and physicochemical soil parameters have a significant impact on the quality and quantity of crops. It is also important to take into account climate change and its impact on soil resources, which requires additional measures to be taken to maintain soil fertility levels.

Studying this topic also involves familiarizing yourself with various methods of soil fertilization and reclamation, such as mineral and organic fertilizers, composting, biological methods of soil improvement, increasing its fertility and other innovative technologies in the field of agriculture.

2 Materials and methods

A balance method allows calculating fertilizer doses. The method is proposed by I.S. Shatilov and M.K. Kayumov. According to the method, the dose of mineral element is determined by the formula:

$$\text{D.v.} = \frac{100 \times \text{B} - C \times KIP}{KIU}$$

where D.v. – dose of a mineral fertilizer, kg/ha d.c.;

B – removal of a mineral nutrition element by the planned crop, kg/ha d.m;

KIP – coefficient of nutrient element utilization from soil, %;

KIU – coefficient of nutrient element use from fertilizers, %;

C – content of an available nutrient element in soil, kg/ha.

Economic yield is determined by the amount of absolutely dry matter in the crop (Us.w., c/ha) and the

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content of mineral nutrients in the absolutely dry mass of the crop (C, %):

$$B_x = U_{s.w} \times C. \quad (1)$$

Barley is an important fodder (forage), technical (beer) and food (cereal) crop. Barley grain from steppe areas of cultivation is especially valuable in fodder and food relations, because the aridity of the climate favors the accumulation of protein in the grain. Due to the expanding opportunities for animal husbandry, the need for the production of high quality barley grain for fodder is increasing in modern society.

Barley is often cultivated according to the same technology for different purposes, although the requirements for grain quality indicators differ significantly. Barley grain intended for the technical industry should have a low protein content, while in the case of fodder and cereal it should have a high protein content. The amount of protein in the grain is not stable over the years and is strongly related to weather conditions and agricultural practices. For barley, which requires loose soil, the optimal plowing depth is 20–22 cm, and in some fields of crop rotations it is 14–16 cm.

Barley is the crop that is most responsive to fertilizers. With their proper use, barley yield significantly increases; plant resistance to drought, diseases, pests increases; grain quality improves. With the lack of nutrition elements at the beginning of vegetation (15–30 days after sowing), growth and development of plants are delayed. The normal process of carbohydrate formation and formation of generative organs are disturbed, resistance to lodging and diseases is weakened, the yield is significantly reduced. Fertilizer application rates are calculated by balance or other method, taking into account the size of the planned yield, soil fertility, economic yield of fertilizers, etc.

3 Results and discussion

The paper considers the calculation of economic nitrogen removal by barley crop.

The grain dry matter yield ($Us.in_1$) is 28 c/ha; straw ($Us.in_2$) is 34 c/ha; chaff ($Us.in_3$) is 2.8 c/ha.

Dry matter content of grain (C_1) is 3.6 %; straw (C_2) is 0.6 %; chaff (C_3) is 0.7 %:

Vz= 28× 3.6= 100.8 kg;

Vs= 34× 0.6= 20.4 kg;

Wm= 2.8× 0.7= 1.96 kg;

Inh= 100.8+ 20.4+ 1.96= 123.16 kg.

Plants consume large amounts of nutrients to produce a crop. The need for nutrients depends on the hereditary nature of the plant and environmental conditions. It is determined by the removal of nutrients from the soil with crop yield, i.e. by the total amount of nutrients concentrated in various plant organs. The removal includes two parts: economic and residual [18–20].

The economic part is the removal of nutrients by the main and by-products (in cereals, these are grain and straw; in root crops, these are roots and leaves, etc.). The residual part of removal is concentrated in crop and root residues, fallen leaves and nutrients transferred from roots to soil in the second half of vegetation. The economic yield is usually lower than the total nutrient demand of the plant [10–15].

The economic return when developing a fertilizer application system is an important aspect for practical application. One of the key indicators is the removal of nutrients (N, P_2O_5, KgO) per 10 kg of main products, taking into account by-products, which depends on the yield. For crops that produce large amounts of organic matter per unit area, removal will also be higher. This data on the removal of nutrients is important when developing the balance of nutrients on the farm and when calculating fertilizer rates.

Our research shows that determining the economic return of a fertilizer application system can significantly improve fertilizer use efficiency and improve crop yields. For example, nitrogen removal can be determined based on the level of yield and the size of nitrogen installations, which in turn allows optimizing the use of nitrogen fertilizers to achieve maximum economic effect.

The use of accurate nutrient runoff data also helps reduce the negative impact of fertilizers on the environment, as excess fertilizer that is not absorbed by plants can contaminate soil and water. Accurate calculations of economic returns and optimal application of fertilizers can help reduce the consumption of fertilizers and agrochemicals, which in turn affects production costs and economic efficiency of agriculture.

Overall, the use of nutrient runoff data is important for optimizing fertilizer application, improving crop yields, reducing fertilizer costs, and ensuring sustainable agriculture.

The yield of the same crop can vary significantly depending on soil and climatic conditions. For example, wheat yields in average fertile soils with a temperate climate may be around 3-4 tons per hectare, while in drier or poorer soils this figure may drop to 1-2 tons per hectare.

As our research shows, the removal of nutrients from the soil has a direct impact on crop yields. Deficiencies in key nutrients such as nitrogen, phosphorus and potassium can reduce yields by 20-30% or more. Therefore, it is important to provide the soil with the necessary nutrients through crop rotation and the use of mineral and organic fertilizers. The nutrient requirements of crops may vary depending on their stage of development. For example, plants need nitrogen more during the period of active growth, and phosphorus and potassium are especially important for the formation of the root system and fruiting.

Research also confirms that the use of mineral fertilizers plays a key role in providing crops with the necessary nutrients. For example, regular application of mineral fertilizers can significantly increase soil fertility and productivity, which in turn helps to increase agricultural productivity.

It is known that if a more favorable set of external conditions positively influencing plant yields is created, then the removal of nutrient elements from the soil is higher. In a number of cases, the amount of individual nutrients used to create yields is not covered by fertilizers, and then there is a negative balance of

elements freely alienated from soil reserves. Assessment of the state of the balance of nutrient elements in the system “fertilizer – soil – plant”, thus, is an important characteristic of the efficiency of the use of mineral and organic fertilizers [5, 14–17, 25].

Therefore, knowing how much nutrients were in the soil before and how much remained after harvest, we can plan the fertilization system and calculate the average removal of elements from the soil. There are many methods for calculating fertilizer rates based on carryover. A number of methods rely on removing nutrients from the entire crop. The method of setting the dose of fertilizers is often used based on the removal of nutrients by the planned crop, taking into account the coefficients of use of fertilizer nutrients for different conditions. One of the methods for calculating doses of fertilizers is the nutrient balance method, which is based on determining the needs of plants for certain elements and calculating their required concentration in the soil. To do this, data on the level of nutrients in the soil and fertilizer costs is used to achieve the optimal concentration of elements. There is also a method for calculating fertilizer doses based on an analysis of yield and nutrient content in products, which allows you to optimize the use of fertilizers depending on the removal of nutrients from the crop. To do this, analyzes are carried out on the content of elements in the soil and plants, as well as calculations are carried out on the optimal dose of fertilizers to achieve maximum productivity at minimum costs. Thus, methods for calculating fertilizer doses play an important role in optimizing fertilizer application and increasing crop yields. They make it possible to accurately determine the required amount of fertilizer and ensure sufficient nutrition for plants, which in turn helps to increase agricultural production. Generally accepted limits of assimilation are 40–60% for nitrogen, 10–25% for phosphorus, 40–60% for potassium

Most of all nitrogen, phosphorus and potassium are taken out of the soil by rape and corn. The next on the list are winter wheat and sunflower. Barley depletes the soil less.

4 Conclusion

To increase the productivity of agricultural crops, improve their quality and soil fertility, it is necessary to study the processes of nutrient transformation in the soil, their supply to plants and regulation of methods of influence on these processes. It is necessary to learn how to manage the cycle of chemical elements and maintain the unity of organisms and habitats.

Today, the use of mineral fertilizers in crop rotation should be, first of all, optimized according to the needs of agricultural crops [13, 21–24]. It is necessary to strictly observe the norms and doses of mineral fertilizers application to avoid their residual accumulation in the soil. The removal of nutrient elements by crops from the soil is not a negative process. On the contrary, it is possible to determine how many of necessary substances the plant has received during its development, and, therefore, how good our harvest is.

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