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The Role of Mineral Fertilizer in Increasing the Productivity and Quality of Winter Wheat Grain.

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ABSTRACT

Wheat is a leading poaceae grain crop of the South of Russia. The value of wheat is that it contains gluten, which is essential for bread and bakery products, pasta, but its yield remains at the level of 2.5-3.0 t/ha, although its potential is much higher. One of the reasons lies in the inefficient use of recommendations on energy-saving technologies with the introduction of calculated norms of fertilizers and increased requirements for the selection of recommended or regionalized complex-resistant crop varieties with high potential productivity, product quality, the ability to withstand adverse environmental conditions and efficiency to use soil and climatic resources in the region. High-quality grain production is the basis of agricultural policy of our country. The level of grain production currently does not meet the country's needs in providing with high-quality environmentally-friendly food grain. Opportunities to improve the structure of areas under wheat are reduced from year to year. In this regard, the increase in the gross grain harvest is possible by increasing the productivity of crops. Modern science and best practices in the European countries show that the rational use of land, the use of advanced technology improve soil fertility and productivity of crops, respectively [1,2]. Improvement of the highly efficient technological methods for flat lands of Dagestan which can ensure the preservation and improvement of soil fertility and on this basis the product quality while reducing energy and economic cost is an actual problem of modern agricultural production. Winter wheat occupies a leading position in the agricultural sector of the Republic of Dagestan, so increasing its yield and production of environmentally-friendly products, based on the rational use of mineral fertilizers is closely linked with the development of fertilizer systems. The introduction of calculated doses of mineral fertilizers into the soil balances the productivity of winter wheat at a high level. Land resources of Dagestan diverse in agro-climatic and soil resources, which affects the productivity of winter wheat. The need for a precise definition of the of mineral nutrition norms for winter wheat in the conditions of the flat zone of Dagestan determines its relevance and national economic importance. Based on the above-mentioned, the main objective of agricultural producers in the production of grain is high yields of high quality products while ensuring the soil fertility, and excluding the negative impact on the environment. Compensate the removal of nutrients is possible through the application of mineral fertilizers, and the latter is reflected on the quality of the grain. In our paper, we present the results of research on the effect of mineral fertilizers on the yield and quality of winter wheat. In particular, we have studied the effect of mineral fertilizers rates on the dynamics of the protein content, wet gluten and nitrates in the winter wheat grain [8,11,12].

Keywords: winter wheat, fertilizers, variety, cultivation technology, calculated dose, yield, grain quality, protein, vitreous, wet gluten, nitrates

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INTRODUCTION

Currently, in our country and generally in the world, the strategy of adaptive intensification of agricultural production is developing due to the economic and ecological situation, which focuses on the rational use of soil resources and environment protection. In connection with the need to increase agricultural production, the impact on the soil increases: removal of nutrients increases, soil physical, biological, and other properties are deteriorated. Improvement of productivity of field crops is impossible without saving, constant maintenance and improvement of soil fertility, which is the main problem of agriculture. The key way to improve soil fertility is the use of organic and mineral fertilizers [3,5].

It should be noted that after reducing chemicals application after the reformation of land relations, the soil fertility has decreased in recent years, as well as yield of crops, while the production costs for grain cultivation process has stayed the same and even increased. As a result, an objective need to reconsider the prevailing view of the relevance of fertilization has arisen. Nowadays, the situation is improving, due to the fact that farms are interested in obtaining actual results. This is difficult to achieve without the use of the calculated doses of mineral fertilizers [4,7].

The application of fertilizers shall consider their negative influence on metabolic processes, which ultimately affects the quality of the grown grain.

A special place among the pollutants by the scale of pollution and impacts on biological objects is occupied by nitrates. Rational application of chemicals involves the right choice of fertilizer doses, which allows receiving not only high yield, but also eliminating the risk of contamination of soil and products with toxic elements and compounds [6,9].

In connection therewith, in 2013-2015, on the basis of educational and experimental farm of Dagestan SAU, the research on the effect of the calculated doses of mineral fertilizers on productivity and quality of winter wheat were carried out.

Purpose of the study is to investigate the effect of mineral fertilizers on the yield and quality of winter wheat.

The research objectives were to study the characteristics of growth and development of winter wheat plants, to reveal the dynamics of the content of protein and wet gluten, and to determine the nitrate content in winter wheat grain depending on the level of mineral nutrition.

MATERIALS AND METHODS OF RESEARCH

Table 1 – Two-factor experiment scheme

Varieties (Factor A)	Mineral fertilizers rate (Factor B)
Don-93	Without -B ₁ fertilizers
	N ₅₀ P ₅₀ -B ₂
	N ₆₀ P ₅₀ -B ₃
	N ₁₀₅ P ₅₀ -B ₄
	N ₁₅₀ P ₅₀ -B ₅
	N ₁₉₀ P ₅₀ -B ₆
Rostovchanka-5	Without -B ₁ fertilizers
	N ₅₀ P ₅₀ -B ₂
	N ₆₀ P ₅₀ -B ₃
	N ₁₀₅ P ₅₀ -B ₄
	N ₁₅₀ P ₅₀ -B ₅
	N ₁₉₀ P ₅₀ -B ₆

The research were conducted in 2013-2015 in the experimental field of educational and experimental farm of FSBEI HE "M.M. Dzhambulatov Dagestan State Agricultural University". The soil in the experimental

area was typical of the plane area of Dagestan, meadow-chestnut, heavy loamy soil. The plow layer contained 2.21% of humus, R_2O_5 - 1.5 mg/100 g soil, K_2O - 28.2 mg/100 g soil. plow layer density – 1.30 g/cm³, minimum moisture content (MMC) - 30.5%. The amount of water-soluble salts in the layer was 0.24%, with the chloride-sulphate type of salinity. The size of the plots - 25 m², in four replications. The standard practice (Table 1).

The research materials were varieties of winter wheat “Rostovchanka-5” and “Don-93” selected by SNUI.G. Kalinenko All-Russian Research Institute of Crops. The experiments involved investigation of plant height; plant population, mass of ear grain, grain weight from 1 m², 1000 kernel weight, productive tillering capacity, protein and gluten content, and content of nitrates.

RESULTS

Among the main plant nutrition elements nitrogen plays a leading role in improving the quality of grain. Winter wheat grows and produces a yield by virtue of nitrogen absorbed earlier. It is enough for maintenance of active photosynthesis and formation of carbohydrates, but not enough for the formation of high-quality grain. As a result, the grain becomes floury, with low protein and gluten content, especially during years with insufficient nitrogen nutrition in previous phases of development. In case of nitrogen insufficiency, wheat leaves lose their dark green color, chlorophyll content therein and further the photosynthesis productivity decreases, resulting in reduced yield and poor grain quality. Nitrogen deficiency of wheat in the corresponding phase of its growth can be eliminated by introducing the calculated rates of mineral fertilizers.

Pre-seeding soil fertilization with nitrogen in the required doses have a positive impact on the quality of winter wheat, while phosphorus fertilizers, which provide increased productivity, have no significant effect on grain protein content.

The varieties we studied have shown higher photosynthetic capacity and used well the conditions of high soil fertility, especially the increased rates of mineral fertilizers.

The results of our studies showed that the introduction of the calculated doses of nitrogen fertilizers under irrigation contributed to a significant increase in yield and quality of winter wheat. The introduction of $N_{50}P_{50}$ ensured the yield higher by 28% as compared to control. The variant $N_{60}P_{50}$ ensured increase by 52%. The maximum increase in winter wheat yield was obtained by introduction of mineral fertilizers at a rate of $N_{105}P_{50}$ and amounted to 90-101%.

Table 2 - Influence of mineral fertilizers on the yield and quality of winter wheat (average for 2013-2015)

Variant of experiment	Yield, t/ha	Yield increase, %	Vitreous, %	Content, %		Nitrates, mg/kg
				kernel protein	flour gluten	
Don-93						
Without fertilizers (control).	2.85		72	13.90	23.9	122.5
$N_{50}P_{50}$	3.59	125	74	16.02	25.0	129.3
$N_{60}P_{50}$	4.26	150	80	16.23	26.7	133.5
$N_{105}P_{50}$	5.33	187	86	17.50	30.1	140.2
$N_{150}P_{50}$	5.18	181	85	16.76	30.0	150.0
$N_{190}P_{50}$	4.96	174	84	16.15	29.7	155.0
Rostovchanka-5						
Without fertilizers (control).	2.95		72	14.10	24.1	122.0
$N_{50}P_{50}$	3.85	131	75	16.08	25.8	127.0
$N_{60}P_{50}$	4.82	163	79	16.28	27.3	131.6
$N_{105}P_{50}$	5.95	202	87	17.80	30.7	139.1
$N_{150}P_{50}$	5.70	193	86	16.90	30.4	145.0
$N_{190}P_{50}$	4.89	166	85	16.29	29.3	150.3

Further increase in rates of nitrogen fertilizers directly for winter wheat does not ensure a substantial increase, and sometimes even reduces yield as compared to the control, which results in needlessly high and direct production costs. This is due to the fact that higher rates of nitrogen fertilizers lead to the formation of a large vegetative mass of winter wheat, which in turn leads to smothering of crops and disruption of the correlation between the capabilities of the root system and the number of vegetative mass. So, upon introduction of $N_{190}P_{50}$ a decrease in yield and deterioration in the quality of winter wheat is observed (Table 2).

The findings show that the best results were obtained with fertilizer $N_{105}P_{50}$.

Adding high doses of mineral fertilizers, especially nitrogen, can result in an adverse effect on the environment. One of the reasons of such an effect is a violation of the principles of fertilizers application, which can lead to reduced productivity and quality of winter wheat. In experiments for determining the application rates of mineral fertilizers the data of agrochemical analyzes and biological features of winter wheat were taken into account. The proper use of the means of environment protection from the adverse effects of pesticides and fertilizers will ensure the purity of the environment, conservation of the natural capacity of ecosystems and biodiversity, as well as protection of human health from the adverse effects of chemicals.

Pilot experiments aimed at studying the effect of mineral fertilizers on the state of winter wheat crop indicate a sufficiently high efficiency of this method in the improvement of grain quality.

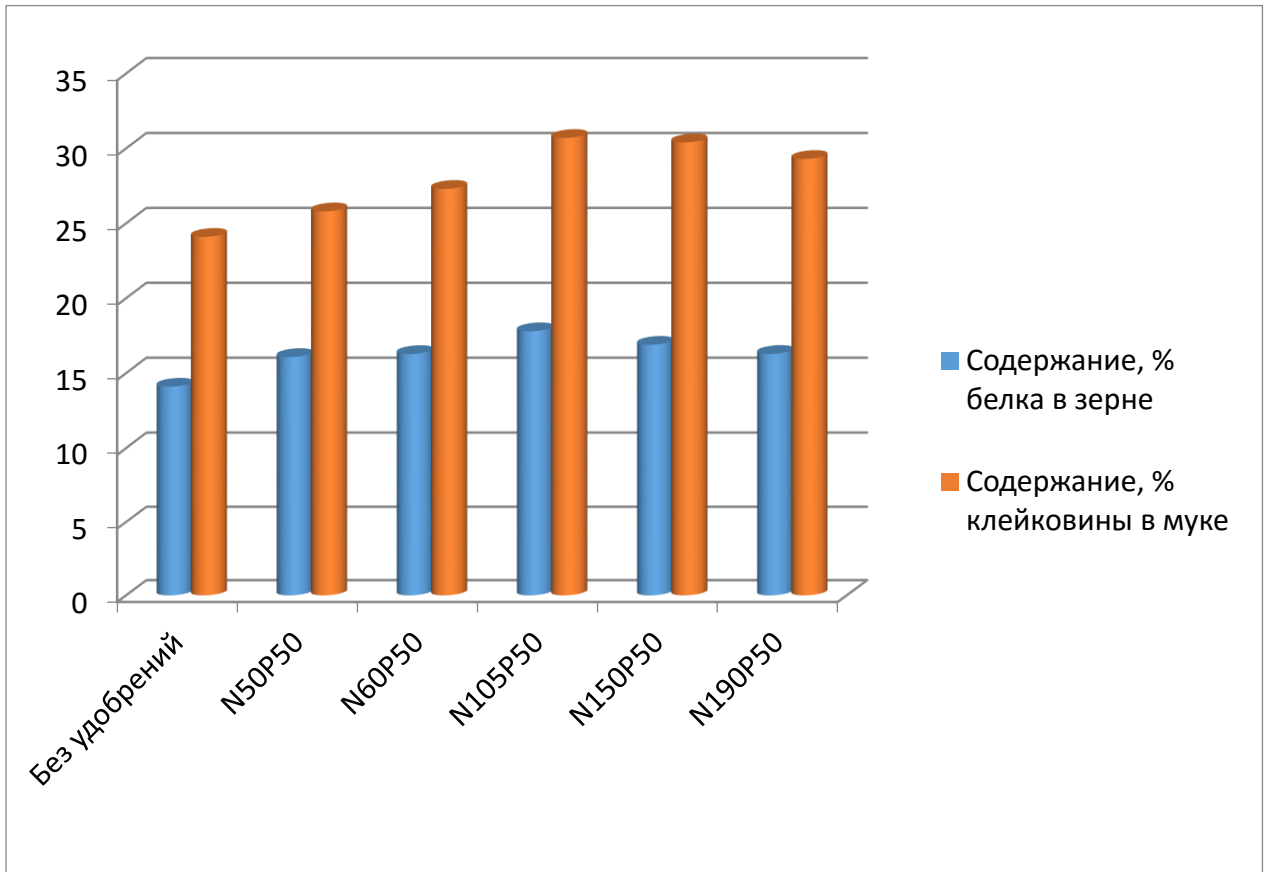
In addition to the effect of different rates of mineral fertilizers on the productivity of winter wheat, we also determined their impact on quality indicators such as natural weight, crude protein and gluten content. The average protein content in control variant was 13.90-14.10%. The maximum protein content was observed with introduction of $N_{105}P_{50}$ and was 17.50 for Don-93 and 17.80% for Rostovchanka-5.

According to the current standard, the grain that meets the requirements of strong wheat, must be (at least): natural weight - 785 g, vitreous - 70%, protein - 14%, crude gluten - 32.0%.

It should be noted that the gluten quality of and the protein content in winter wheat grain in all studied variants were significantly higher as compared with controls. Gluten content in the control variant averaged 23.9-24.1%, after fertilization the value varied in the range of 25.0% for Don-93 and 30.1% for Rostovchanka-5. The highest amount of gluten was found in the case of $N_{105}P_{50}$ for Rostovchanka-5, which was 30.7%. Hence, the studied varieties are varieties of wheat that meet the requirements for strong wheat (Figure 1).

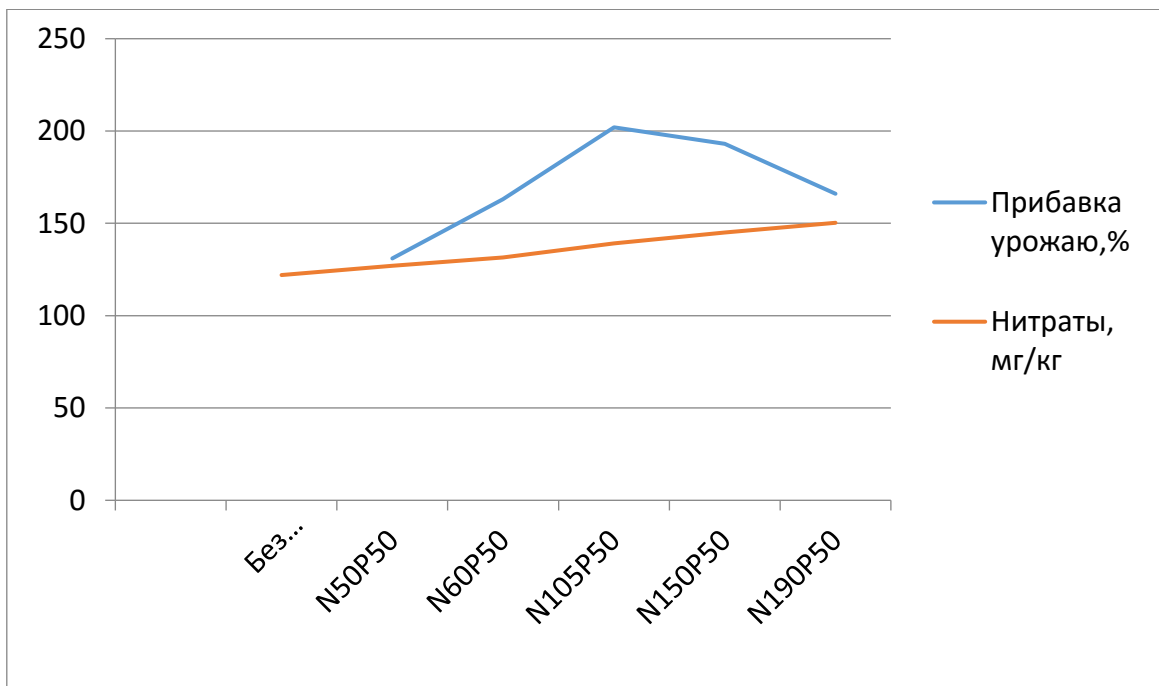
To assess the environmental impact of rates of mineral fertilizers the content of nitrate nitrogen in winter wheat grain was determined. The nitrate content in the yield due to their special harmfulness is regulated with the maximum permissible concentration (MPC). The danger of exceeding it is due to metabolism of nitrate nitrogen during nutrition process, their turning into harmful-to-health compounds with carcinogenic properties.

We have studied the nitrate content in winter wheat grain when introducing the calculated doses of mineral fertilizers. It was found that the nitrate content in winter wheat grain depended on fertilization and ranged from 122 to 150 mg/kg, while the same dependence was slightly observed in the straw. Thus, if the control variant contains 122.5 mg nitrate in 1 kg yield, then the same content in fertilized variants ranges from 127.1 to 150.3 mg/kg (Figure 2). The maximum nitrate content was in the case of $N_{190}P_{50}$ - 150.3 mg/kg. The lowest accumulation of nitrates in plants was observed at a rate of fertilizer $N_{190}P_{50}$ - 122.5 mg/kg.



Содержание, % белка в зерне – protein content in grain, %
 Содержание, % клейковины в муке – gluten content in flour, %
 Без удобрений – without fertilizers

Fig. 1. Indicators of the quality of winter wheat grain Rostovchanka-5 at different levels of mineral nutrition



Прибавка урожаю, % - Increase in yield, %
 Нитраты, мг/кг – Nitrates, mg/kg

Без удобрений – Without fertilizers**Fig. 2 Dynamics of yield increase (%) and nitrate content in the grain of winter wheat Don-93, depending on the calculated rates of mineral fertilizers**

At the same time, the influence of calculated rates of mineral fertilizers introduced simultaneously with seeding and spring fertilization on nitrate accumulation in the grain has not been established. Although, a significant relationship was observed between NO₃ content in the wheat grain and the adequate level of nitrate nitrogen and mobile phosphorus in the soil.

SUMMARY

1. NO₃ content in the wheat grain depends on the availability of nitrogen and mobile phosphorus in soil and the balanced mineral nutrition of soil. Therefore, managing the conditions of crops mineral nutrition and the methods of application of mineral fertilizers may ensure purposeful regulation of accumulation processes of nitrate nitrogen in the cultivated crops.
2. The systematic application of fertilizers for productivity and quality of winter wheat cultivated on the meadow-brown soils of the plains area of Dagestan does not impair the quality of the resulting crop production in terms of the nitrate nitrogen content. In variants with maximum doses of fertilizers, the quality of products met all environmental requirements.
3. The most productive and cost-effective variant is one with the introduction of N₁₀₅P₅₀, which ensures net income of 10063 rubles per 1 ha for don-93, and 19513 rubles per 1 ha for Rostovchanka-5. The same variant ensures maximum energy efficiency: at additional energy costs of 5.8 GJ/ha we obtained the production containing 12.61 GJ/ha. Profitability level was 77 and 151%, respectively.

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