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Research Article
Spring Wheat Yield Depending on the Variety and Chelated Fertilizers

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Abstract

Background and Objective: Search for new fertilizers and their use is one of the topical issues in the cultivation of spring wheat since they provide high and stable yields. The study aims to develop a theoretical framework and agrotechnical methods for the formation of highly productive crops of various spring wheat based on the use of chelated fertilizers. **Materials and Methods:** The study used chelated fertilizers (Izagri vita, Izagri nitrogen and Izagri phosphorus) produced by Izargi company and a microbiological fertilizer BioVice in various combinations. The study took place under the Southern forest-steppe conditions in the Republic of Bashkortostan. **Results:** According to the studies' results during the period from 2018-2020, Izagri chelated fertilizers proved to affect the grain yield of various spring wheat varieties used in the experiment. The greatest increase in spring wheat yield was noted when using Izagri nitrogen+Izagri vita+Izagri phosphorus+BioVice. Ekaterina spring wheat variety was the most responsive among experiment variants (2.64-3.49 t ha^{-1}, compared to 2.73-3.29 t ha^{-1} of the control variant). **Conclusion:** Tobolskaia variety was the least responsive to Izagri chelated fertilizers (2.50-2.89 t ha^{-1}). The research results can be successfully used to develop technology for spring wheat cultivation to increase the yield and grain quality.

Key words: Spring wheat, chelated fertilizer, microbiological fertilizer, variety, grain yield, two-factor field experiment, yield index

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Spring wheat is one of the most important, most valuable and high-yielding grain crops. The main problem which agricultural producers are facing in modern market conditions is the efficiency of grain production. The right choice of varieties and more effective use of soil and climate potential will increase wheat yield and reduce production costs. Research in this direction is of high relevance[1-5].

According to the Federal State Statistics Service of Russia for 2019[6], the average annual wheat yield in the Russian Federation in 2008-2018 was at the level of 17.7-31.2 c ha^{-1}. The use of fertilizers (including chelated), well-timed and proper implementation of other agricultural technologies is one of the main ways to ensure a high yield of grain crops. Polish scientists Tabak *et al.*[7] conducted research using new chelated fertilizer containing nitrogen (N) and sulfur (S) in proportions (30% nitrogen and 6% sulfur) showed that sulfur, when added in the form of chelates, significantly increased the apparent nitrogen removal. Protein yield increased from 296 kg ha^{-1} (control) to 321-343 kg ha^{-1} when using zinc chelates Zn in a dose of 20 g ha^{-1} and copper Cu in a dose of 10 g ha^{-1}. Foliar application of the complex fertilizers "Aquarin 5" and OMU "Beet" during the wheat tillering phase was more effective than applying separate trace elements in the chelated form. Water-soluble complex fertilizer "Aquarin 5" used for barley crops in doses of 1.5 and 3.0 kg ha^{-1} allowed to form a grain yield of 4.15 and 4.22 t ha^{-1}, which exceeded the control version[2]. Jalal *et al.*[8] researched the conditions of Pakistan and found that plants fertilized with 0.3% Zn and 1% Fe were able to form a higher grain yield compared to the control. Components and yield of plants fertilized with 0.3% chelated Zn and 1% Fe improved. Wheat grain quality of plants treated with 0.1% Zn and 2% Fe also improved (Zn and Fe content). Astaneh *et al.*[9] point out that using nano-chelate nitrogen fertilizer in a dose of 41 kg ha^{-1}, Rwc increased by 4%, ion leakage by 3%, protein by 52%, phosphorus by 26%, potassium by 6%. In addition, remobilization made 6% and photosynthesis speed 21% compared to the control, respectively. Ahmadian *et al.*[10], in 2 years studies the use of nano-silicon in conditions of insufficient irrigation led to an increase in wheat grain yield by 28.0 and 32.1%, respectively, compared to the control variant.

According to the research of Sipponen *et al.*[11], slow-release fertilizers are of considerable interest. Chelation of craft black-sulphate liquor with calcium acetate at pH 13 precipitated lignin as a calcium-complex (Ca-lignin), which gave positive effects compared to the effects of lignin obtained by precipitation at low pH (acid-lignin). Zhao *et al.*[12] studied the use of chelated Zn, Zn-EDTA and inorganic Zn, $ZnSO_4 \times 7\ H_2O$ in wheat crops. According to the research, wheat sowing slowed down the Zn fixation and maintained a high concentration of the Zn fraction weakly bound to organic matter (LOM-Zn) in the soil. Zn-EDTA was a better source of Zn for wheat Zn biofortification than $ZnSO_4$.

A field experiment to study the effect of nano-NPK, micro-fertilizers and yeast extract of Saccharomyces cerevisiae on the growth and yield of Adana 99 wheat was conducted in Al-Husseiniyah. Al-Juthery *et al.*[13] found that the highest wheat yield was obtained either when foliar spraying was carried out using nano-NPK or a mixture of nano-fertilizers (NNPK+NCM).

According to Zoz *et al.*[14] foliar application of calcium (Ca) and boron (B) can increase wheat yield. Foliar application of 7.21 L ha^{-1} of chelated fertilizer containing 125 g L^{-1} of Ca and 6 g L^{-1} of B significantly increased the number of spikelets per ear (9.1%), the number of grains per ear (24.2%), the weight of grain per ear (28.3%), the ear weight (14.0%) and the grain yield (30%) in comparison with the control variant. Rossini *et al.*[15] indicate that, it is critical to make allowance for both the yield and grain quality. Naumkin *et al.*[16] revealed that, administrating micro fertilizers, such as ZhUSS-2 (Cu-32-40 g L^{-1}, Zn-17-22 g L^{-1}) and ZhUSS-3 (Cu-16.2-20 g L^{-1}, Zn-35-40 g L^{-1}), in combination with macro fertilizers, such as $N_{60}P_{60}K_{60}$, enhances the growth of crops.

A review of the studies on various chelated fertilizers used for spring wheat cultivation shows a high interest in this problem. These studies (2018-2020) aim to develop a theoretical framework and agrotechnical methods for the formation of highly productive crops of various spring wheat based on the use of chelate fertilizers produced by Izargi company, in particular Izagri vita, Izagri nitrogen and Izagri phosphorus and microbiological fertilizer BioVice in various combinations in the conditions of the Southern forest-steppe of the Republic of Bashkortostan. The experiments of scientists from different regions of Russia[17-23] confirm the relevance of these studies on different wheat varieties.

Thus, the research aimed to solve several problems, such as determining the elements of the spring wheat crop structure and determining the grain yield.

MATERIALS AND METHODS

Study area: Field experiments to study the effect of Izagri chelated fertilizers of three brands Izagri vita, Izagri nitrogen and Izagri phosphorus and microbiological fertilizer BioVice on the formation of grain yield of spring soft wheat were conducted in the Ufa district of the Republic of Bashkortostan on the experimental field of the Department of Agriculture,

Agrochemistry and Precision Agriculture of the Bashkir State Agrarian University in 2018-2020. The soil of the experimental site is leached chernozem of heavy loamy granulometric composition. The agrotechnics used in the experiments were generally accepted for the zone. Winter rye was used in the experiment as a predecessor.

Research object: The object of research was soft spring wheat. Released varieties of spring soft wheat recommended for the southern forest-steppe zone of the Republic of Bashkortostan were used for the experiment. They are Arhat, Ekaterina, Iren, 4. Tobolskaia, Ulianovskaia 100, Ulianovskaia 105. The seeding rate was 5.0 million seeds per ha. The sowing depth was 4-6 cm. According to the agro-climatic zoning, the territory of the experimental field belongs to a relatively warm, medium-wet area. The climatic conditions are continental with dry air and a high level of solar energy. There are sometimes sharp weather fluctuations and a change in air temperature.

Experimentation: Scheme of a two-factor field experiment. Factor A: A variety of spring soft wheat. 1: Arhat, 2: Ekaterina, 3: Iren, 4: Tobolskaia, 5: Ulianovskaia 100, 6: Ulianovskaia 105. Factor B: Chelated fertilizers. 1: Control, 2: Izagri vita, 3: Izagri vita+BioVice, 4: Izagri nitrogen+Izagri vita+Isagri phosphorus, 5: Izagri nitrogen+Izagri vita+Isagri phosphorus+BioVice.

The variants in the experiment are placed systematically by arranging the plots in one-tier. The experiment replication is fourfold. The plot length is 20 m, the width is 1.5 m, the distance between the variants is 40 cm, the border is 2 m. The total area of variant 1 is 30 m^2, the record plot area is 1 m^2. The area of the experiment plot is 3,686.4 m^2. Before sowing, the seeds were treated according to the experimental scheme. A fungicide protectant Polaris (1.5 L t^{-1}) and a seed mordant Klion-PSB-0.1 were used. Sowing was carried out with a Klion-1.5 planter. After sowing, the compacting was carried out using ZKKSH-6A (three-section star-wheeled roller) as part of the DT-75M (caterpillar tractor) aggregate. Treatment was carried out according to the scheme of the experiment: The control plot was treated without using chelated fertilizers, Izagri vita-1 L ha^{-1}; 3. Izagri vita (1 L ha^{-1}) + BioVice (0.3 kg ha^{-1}), 4. Isagri nitrogen (0.6 L ha^{-1}) + Isagri vita (0.3 L ha^{-1}) + Isagri phosphorus (0.6 L ha^{-1}), 5. Isagri nitrogen (0.6 L ha^{-1}) + Isagri vita (0.3 L ha^{-1}) + Isagri phosphorus (0.6 L ha^{-1}) + BioVice (0.3 kg ha^{-1}). The flow rate of the working fluid was 300 L ha^{-1}. Treatment was carried out during the tillering phase at the beginning of the spring wheat stem elongation. Crop tending was carried out using a carbamide tank mixture (5 kg ha^{-1}) + Lontrel (0.16 L ha^{-1}) + Ovsiugen super (0.4 L ha^{-1}) graminicide. The flow rate of the working fluid was 300 L ha^{-1}.

The southern forest-steppe belongs to the zone of insufficient moisture. The sum of the effective temperatures is 2,110-2,281°C. Precipitation is extremely uneven. The annual precipitation is 473-562 mm. The hydrothermal coefficient is 1.11-1.21. The amount of photosynthetically active radiation ranges from 1,925-2,883 kcal ha^{-1}. The thickness of the humus horizon was 41-46 cm, the total moisture reserves in the meter layer of the soil reached 315-349 mm. The average humus content in the arable layer was 8.0-9.1%, total nitrogen-0.48%, phosphorus-0.16% and potassium-0.65%.

The following observations were made based on generally accepted methods. 1: The determination of the elements of the structure of the spring wheat crop was carried out using the method of the state variety testing of crops, 2: Grain yield was determined by mowing the plots with a TERRION SR2010 selection combine. Then, the yield was weighed.

RESULTS AND DISCUSSION

Such factors of the research (2018-2020) as soil and climatic conditions, the varieties used, the Izagri chelate fertilizer and the BioVice microbiological fertilizer, affected the formation of the spring wheat crop indicators.

The main elements of the wheat crop are the number of plants per unit area and the productivity of one plant. Productivity consists of the following elements: The number of productive stems, the number of seeds in an ear, the mass of a thousand grains and the mass of a grain per ear. Depending on the soil and climatic conditions of the research year, each of these yield elements can change for the better or the worse.

The analysis of the data on the effect of chelated fertilizers on the elements of the structure of the spring wheat crop, depending on the variety, showed that changes in the nutritional conditions of different varieties of spring wheat when using chelated fertilizers affected some of these indicators in different ways (Table 1).

The research results showed that, on average, in 2018-2020, various types of Izagri chelated fertilizers and their combined use affected the number of spring wheat plants per 1 m^2. In the control variant, the average number of plants over the years of research was 390-410 pcs m^{-2}. The use of Izagri vita contributed to an increase in the number of plants by 1.67-1.76%, Izagri vita+BioVice-1.44-2.50%, Izagri nitrogen+Izagri vita+Izagri phosphorus-2.38-2.74% and Izagri nitrogen+Izagri vita+Izagri phosphorus+BioVice by 2.61-3.70%. The above data shows that the last variant of the experiment provided the greatest increase in the number of

Table 1: Effect of chelated fertilizers on the structure of the spring wheat crop depending on the variety (Ural Scientific Centre, Bashkir State Agrarian University, 2018-2020)

Variant	No. of plants (pcs m^{-2})	No. of productive stems (pcs m^{-2})	Productive tilling capacity	Weight of 1,000 grains (g)	No. of grains per ear (pcs)	Weight of grain per ear (g)
Arhat variety						
Control	410.0	434.0	1.05	25.5	27.0	0.64
Izagri vita	417.0	443.0	1.06	27.0	25.0	0.67
Izagri vita+BioVice	416.0	448.0	1.07	28.2	24.0	0.67
Izagri nitrogen+Izagri vita+Izagri phosphorus	420.0	452.0	1.07	32.1	23.0	0.70
Izagri nitrogen+Izagri vita+Izagri phosphorus+BioVice	421.0	458.0	1.08	33.4	24.0	0.72
Ekaterina variety						
Control	407.0	427.0	1.04	25.9	25.5	0.62
Izagri vita	413.0	435.0	1.05	30.5	23.0	0.69
Izagri vita+BioVice	414.0	445.0	1.06	28.0	26.0	0.72
Izagri nitrogen+Izagri vita+Izagri phosphorus	419.0	451.0	1.07	28.5	27.0	0.77
Izagri nitrogen+Izagri vita+Izagri phosphorus+BioVice	421.0	460.0	1.09	27.7	28.0	0.76
Iren variety						
Control	404.0	433.0	1.07	29.2	20.0	0.58
Izagri vita	403.0	437.0	1.08	29.8	21.25	0.63
Izagri vita+BioVice	406.0	440.0	1.08	29.5	22.25	0.64
Izagri nitrogen+Izagri vita+Izagri phosphorus	410.0	446.0	1.08	30.5	21.0	0.64
Izagri nitrogen+Izagri vita+Izagri phosphorus+BioVice	412.0	446.0	1.08	28.8	23.0	0.66
Tobolskaia variety						
Control	400.0	419.0	1.04	29.6	21.0	0.60
Izagri vita	403.0	430.0	1.06	30.7	20.0	0.61
Izagri vita+BioVice	405.0	439.0	1.08	30.5	21.0	0.63
Izagri nitrogen+Izagri vita+Izagri phosphorus	410.0	441.0	1.07	30.6	21.0	0.64
Izagri nitrogen+Izagri vita+Izagri phosphorus+BioVice	412.0	446.0	1.08	30.6	21.0	0.65
Ulianovskaia 100 variety						
Control	404.0	418.0	1.03	30.0	21.7	0.63
Izagri vita	406.0	427.0	1.06	30.5	21.0	0.64
Izagri vita+BioVice	402.0	429.0	1.06	31.0	20.0	0.65
Izagri nitrogen+Izagri vita+Izagri phosphorus	408.0	430.0	1.05	32.0	20.5	0.66
Izagri nitrogen+Izagri vita+Izagri phosphorus+BioVice	409.0	434.0	1.06	32.55	21.0	0.67
Ulianovskaia 105 variety						
Control	390.0	413.0	1.05	28.0	22.0	0.61
Izagri vita	397.0	424.0	1.06	29.0	21.0	0.63
Izagri vita+BioVice	400.0	429.0	1.07	31.0	21.0	0.64
Izagri nitrogen+Izagri vita+Izagri phosphorus	401.0	431.0	1.07	31.0	23.0	0.65
Izagri nitrogen+Izagri vita+Izagri phosphorus+BioVice	405.0	439.0	1.08	31.0	22.0	0.67

spring wheat plants. The Arhat (410-421 pcs m^{-2}) and Ekaterina (407-421 pcs m^{-2}) varieties of spring wheat were the most responsive to fertilizers. The Ulianovskaia 105 variety was the least responsive to Izargi chelated fertilizers (390-405 pcs m^{-2}). The conducted studies showed a different reaction of spring wheat varieties to chelated fertilizers ($r = 0.845$-0.910).

The number of productive stems in the control variant over the years of research was 413-434 pcs m^{-2}. The number of productive stems increased by 2.10-2.63% when using Izagri vita, by 3.21-3.84% in the case of Izagri vita+BioVice use, by 3.92-4.01% when applying Izagri nitrogen+Izagri vita+Izagri phosphorus and by 4.91-5.72% when using Izagri nitrogen+Izagri vita+Izagri phosphorus+BioVice. The last variant of the experiment showed the greatest increase in the number of productive stems of spring wheat. Once again, Arhat (434-458 pcs m^{-2}) and Ekaterina (427-460 pcs m^{-2}) were the most responsive to fertilizers. The Ulianovskaia 105 variety was the least responsive to the chelated fertilizers of the Izagri company (413-439 pcs m^{-2}).

The productive tilling capacity of the experimental variant was 1.03-1.09. The spring wheat tilling capacity was the highest when using Isagri nitrogen+Isagri vita+Isagri phosphorus+BioVice and amounted to 1.06-1.08. The Iren variety of spring wheat was the most responsive to fertilizers among experimental variants (its average response indicator was 1.078, while the same indicator in the control variant was 1.066). The Ulianovskaia 100 variety was the least responsive to the chelated fertilizers of the Izagri company (its average response indicator was 1.052).

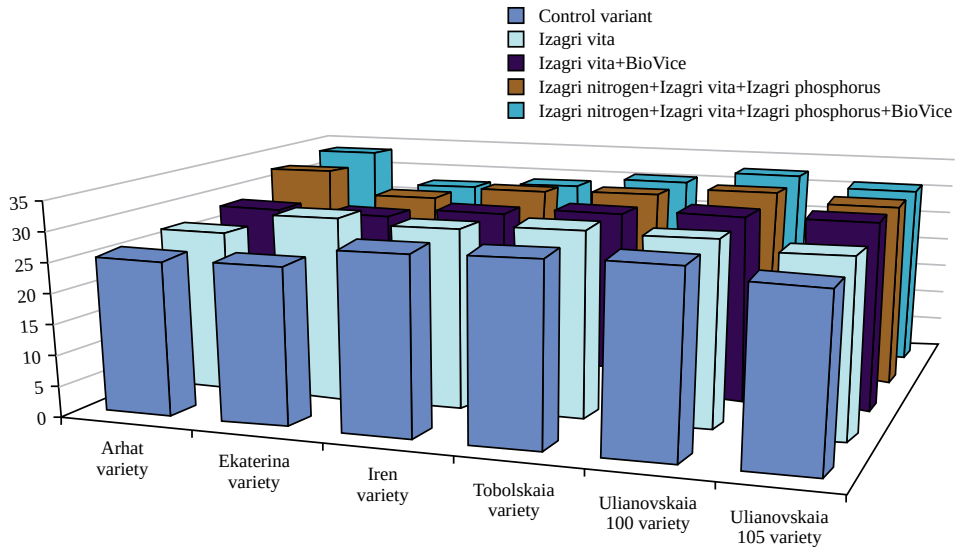

Fig. 1: Effect of chelated fertilizers on the mass indicator of 1,000 grains, depending on the variety (Ural Scientific Centre, Bashkir State Agrarian University, 2018-2020)

The mass of 1,000 grains in the experimental variant was 25.5-33.4 g (Fig. 1). The same indicator in the control variant over the years of research amounted to 25.5-30 g. The second experimental variant showed an increase in this indicator by 2.29-5.61%. The mass of 1,000 grains also increased by 3.34-8.89% when using Izagri vita+BioVice, by 6.62-10.41% in the case of Izagri nitrogen+Izagri vita+Izagri phosphorus use and by 10.20-11.51% when applying Izagri nitrogen+Izagri vita+Izagri phosphorus+BioVice.

The last experimental variant showed the maximum indicators. However, the Isagri nitrogen+Isagri vita+Isagri phosphorus variant showed the best effect on this indicator in the whole experiment (on average 30.8, while the same indicator in the control variant was 28.0). The Ulianovskaian 100 spring wheat variety was the most responsive experiment variant (30.0-32.55 g). The variety Ekaterina showed the lowest indicators (25.9-30.5 g).

In the experimental variant, the number of grains in the ear ranged from 20-28 pcs. The Tobolskaia and Ulianovskaia 100 varieties were the least responsive to chelated fertilizers for this indicator (the average indicator was 20.8 and 20.84, while the same indicator of the control variant was 21.00 and 21.70). The spring wheat variety Ekaterina was the most responsive (the average indicator was 25.9). Among the chelated fertilizers, variant Izagri nitrogen+Izagri vita+Izagri phosphorus+BioVice showed the best result.

Analysis of the grain mass indicator of one ear shows that during the experiment it was on average 0.58-0.77 g. This indicator increased by 5.01-7.24% when applying Izagri vita, by 7.99-11.80% when using Izagri vita+BioVice, by 9.31-16.30% in the case when Izagri nitrogen+Izagri vita+Izagri phosphorus was used and by 10.95-15.71% when using Izagri nitrogen+Izagri vita+Izagri phosphorus+BioVice. The last experimental variant showed the greatest increase. The variety of spring wheat Ekaterina was the most responsive among the experimental variants (the average indicator was 0.712, while the same indicator of the control variant was 0.68). According to this indicator, the Tobolskaia variety was the least responsive to the Izagri chelated fertilizers (the average indicator was 0.62).

The use of chelated fertilizers in various combinations for treating different varieties of spring wheat affected the grain yield of the studied crop (Table 2).

The research results showed that, on average, over the years 2018-2020, various types of Izagri chelated fertilizers and their combined use for treating different spring wheat varieties resulted in a grain yield of 2.50-3.49 t ha^{-1}. The yield over the years of research in the control variant was 2.50-2.73 t ha^{-1}. The use of Izagri vita increased the yield by 4.61-14.70%, Izagri vita+BioVice by 9.42-14.72%, Izagri nitrogen+Izagri vita+Izagri phosphorus by 10.80-21.35% and Izagri nitrogen+Izagri vita+Izagri phosphorus+BioVice by 13.70-21.88%. Similar studies also demonstrate an increase in spring wheat yield after the application of chelate fertilizers. More precisely, they indicate that the use of chelate mixtures at the stages of tillering and earing in alike natural and climatic conditions raises the yield and profitability of grain production and lessens production cost[24-26]. In this respect, researchers found that the application of Izagri nitrogen enhanced the yield of spring wheat of the "Daria" variety by 28.77%, which is fully consistent with the outcomes of this study[27].

Table 2: Effect of chelated fertilizers on the spring wheat yield depending on the variety (Ural Scientific Centre, Bashkir State Agrarian University, 2018-2020)

Variant	Arhat variety	Ekaterina variety	Iren variety	Tobolskaia variety	Ulianovskaia 100 variety	Ulianovskaia 105 variety
Control	2.73	2.64	2.52	2.50	2.62	2.51
Izagri vita	2.96	3.00	2.75	2.62	2.73	2.67
Izagri vita+BioVice	3.00	3.20	2.81	2.76	2.78	2.74
Izagri nitrogen+Izagri vita+Izagri phosphorus	3.16	3.47	2.85	2.82	2.83	2.80
Izagri nitrogen+Izagri vita+Izagri phosphorus+BioVice	3.29	3.49	2.94	2.89	2.97	2.94
Least significant difference factor A (variety)	0.01	0.01	0.02	0.03	0.03	0.02
Factor B (fertilizer)	0.03	0.01	0.02	0.04	0.02	0.04
Relation AB	0.04	0.02	0.04	0.07	0.05	0.06

Statistical data on the harvest and the processes that determine the harvest formation show that grain yield is in close dependence with the number of productive stems per unit area (r = 0.724-0.756), the grain weight got from a spike (r = 0.612 and 0.674) and the number of grains per spike (r = 0.535-0.591).

The problem of increasing the productivity of wheat and its quality is of high relevance. Scientists from different countries and agricultural producers are increasingly giving their attention to the use of chelated fertilizers. Popova *et al.*[2] used foliar spraying of zinc and copper chelates in their experiments during the tillering phase of spring wheat in the conditions of the southern forest-steppe of the Omsk Irtysh region, which positively affected the yield, food and sowing qualities of the spring wheat grain. Zinc and copper foliar application at a dose of 20 and 10 g ha^{-1} showed the best results when used on meadow-chernozem soil during the tillering phase (the yield increase at a dose of 20 g ha^{-1} made 0.20 and 2.2 t ha^{-1} in the control variant, at a dose of 10-0.2 t ha^{-1}).

The importance of zinc in human life is mentioned in the studies of Read *et al.*[18]. Zinc deficiency (Zn) affects half of the world's arable land and one-third of the world's population. Zn foliar fertilizers used for wheat treatment can result in a zinc increase in the grain, often leading to leaf scald. Zinc oxide nano-particles (ZnO-NP) may be an efficient and economically viable alternative. However, the mechanisms of Zn uptake and its movement in the plant are little studied. This research was focused on the use of Zn-EDTA in the composition of the applied fertilizers.

The experiments presented in the paper showed that the effective use of Izagri chelated fertilizers such as Izagri vita, Izagri nitrogen and Izagri phosphorus and the microbiological fertilizer BioVice in various combinations for spring wheat treatment depends on the variety. The research results are consistent with the studies of Rempelos *et al.*[20], which revealed different effects of contrasting fertilization and plant protection regimes depending on the variety. The authors point out that breeding programs focused on low-cost agriculture can be implemented using varieties like Aszita. Though they have lower yield potential, their grain is richer in protein.

Karpova *et al.*[22], in their research, made a morphometric assessment of seedlings. Seeds and plants had the minimum values of the symmetry coefficients 17.96 and 17.30 when treated before sowing, during the tillering and earing phases using preparations "Megamix semena" and "Megamix - Profi" containing macro and micro chelated fertilizers. The maximum yield indicators in these variants were 3.87 and 4.01 t ha^{-1}, respectively. The largest number of developed primary roots was in the variants where Megamix-seeds and Megamix-Profi preparations were used together. This is consistent with the results of this research since the co-use of preparations resulted in the greatest effectiveness of the variants.

Spring wheat varieties combined with chelated fertilizers in various combinations affected increasing grain yield compared to the control. The greatest increase in spring wheat yield was noted when using Izagri nitrogen+Izagri vita+Izagri phosphorus+BioVice. Ekaterina spring wheat variety was the most responsive among experiment variants (2.64-3.49 t ha^{-1}, compared to 2.73-3.29 t ha^{-1} of the control variant). Tobolskaia variety was the least responsive to Izagri chelated fertilizers (2.50-2.89 t ha^{-1}).

Today's agribusiness needs more comparative quantitative studies concentrating upon the ways to improve spring wheat yield. This work makes it possible to choose the right type of fertilizer when growing wheat within territories characterized by similar physical and chemical soil properties and climatic conditions. Unfortunately, we had no opportunity to trace changes in wheat yield parameters after applying fertilizers on different types of soils and in different climatic conditions. It is a kind of limitation of the present research. However, the data collected are enough to enable agronomists to choose appropriate spring wheat varieties and achieve effective yields by using chelated and microbiological fertilizers.

CONCLUSION

According to the studies' results during the period from 2018-2020, Izagri chelated fertilizers proved to affect the grain yield of various spring wheat varieties used in the experiment. The use of Izagri vita, Izagri vita+BioVice, Izagri nitrogen+Izagri vita+Izagri phosphorus and Izagri nitrogen+Izagri, vita+Izagri, phosphorus+BioVice increased the yield. The greatest increase in spring wheat yield was noted when using Izagri nitrogen+Izagri, vita+Izagri phosphorus+BioVice.

SIGNIFICANCE STATEMENT

This study found that the spring wheat variety used has a large effect on increasing the effectiveness of the chelated fertilizer. The best responsiveness in the experiment was characterized by the spring wheat variety-Ekaterina (2.64-3.49 t ha^{-1}, with control 2.73-3.29 t ha^{-1}). The least of all chelated fertilizers from Izagri in terms of this indicator showed themselves on the Tobolskaya variety (2.50-2.89 t ha^{-1}). The influence of the variety on the yield (r = 0.828-0.854). The greatest increase in the yield of spring wheat was noted in the application of Izagri Azot+Izagri vita+Izagri phosphorus+BioVice. This study will help to establish the correct selection of Izagri chelated fertilizers for complex application with BioVice microbiological fertilizer. Thus, a new highly effective variant of using Izagri chelated fertilizers on spring wheat crops has been obtained.

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