

# The effect of macro- and micro-fertilizers on spring wheat productivity

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**Abstract.** The purpose of the study was to explore the effectiveness of various modifications of the preparation Megamix and complex macrofertilizers in cultivation of the spring wheat variety Ulyanovskaya 100 in the forest-steppe of the Middle Volga region. The factors used in the experiment contribute to a yield increase by 0.37 - 3.12 c / ha. The use of the Megamix-Zinc modification with complex mineral fertilizers gives the greatest yield increase compared with the control group which amounts to 11%. All modifications of the Megamix preparation have a positive effect on the structure elements of the spring wheat yield. The highest test weight is observed in the Megamix-Zinc option with previous application of mineral fertilizers. The increase in this indicator from the factors used was 4.8 - 18.7 g / l, depending on the option. Under the influence of the studied factors, the vitreousness of the spring wheat grain increases by 1.28 - 5.83%. Top dressing has a positive effect on the weight of 1000 seeds. This indicator increased by 0.49 - 2.80 grams, compared with the control option.

## 1 Introduction

At present, the studies focused on the development of adaptive technologies for cultivation of crops to get high yields, to increase plant resistance to adverse environmental factors, to decrease pesticide load and, to improve the mineral nutrition of plants with macro- and microelements are playing a significant role [1-2]. At the same time, comprehensive studies with application of microelements, growth regulators and biologically active substances of natural origin for the treatment of seeds and vegetating plants of crops were not carried out in the conditions of the Volga forest-steppe to a sufficient extent. In-depth study of this area is required to substantiate energy-saving technologies for growing high-quality agricultural products and their widespread use in agriculture.

It is difficult to combine high product quality with yield in some crops. However, there are many methods and techniques that can be applied to increase yields without compromising product quality. One of these methods is pre-sowing seed treatment, as well as foliar treatment of vegetating plants with preparations of growth-regulating and growth-stimulating action [2-4,7-9]. Such preparations are an extensive group of natural and artificial organo-mineral substances that, in small doses, activate the metabolism of cultivated plants. Activation of immune systems makes it possible to induce a total nonspecific resistance in a plant organism to many diseases of fungal, bacterial and viral

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nature, as well as to stress factors of the external environment, such as lack of moisture, temperature maximum, etc. The mechanism of action of growth regulators presupposes activation of all metabolic processes in the plant, which in turn helps to increase the yield of agricultural crops by 15-30%, reduce the amount of mineral fertilizers used, optimize the mineral composition of plant biomass, and reduce crop losses. Currently, more than five thousand preparations of growth-regulating and growth-stimulating action are known [3-11].

The Ulyanovsk region holds one of the leading places in terms of the area under grain crops in the Russian Federation, however, the prospects for expanding areas under crops and the productivity of crops are not fully used yet. Based on the foregoing, the study of the effectiveness of various modifications of the Megamix preparation and complex macrofertilizers in cultivation of spring wheat in the forest-steppe of the Middle Volga region is one of the promising areas to increase the productivity of crops.

## 2 Materials and methods

The studies were carried out in 2018-2020 on the experimental field of Ulyanovsk State Agrarian University. The experimental crop is the spring wheat variety of Ulyanovskaya 100. The plot area is 20 m<sup>2</sup>, the experiment replication was four times, the arrangement of the plots was randomized. The soil of the experimental field is leached medium loamy black soil of medium thickness. Research objects: various modifications of the preparations "Megamix" (Megamix - Nitrogen, Megamix - Zinc, Megamix - Profi). At the onset of the tillering phase, foliar treatment of crops was carried out with the studied preparations at the concentrations recommended by the manufacturer. The introduction of experimental preparations can be carried out simultaneously with the application of herbicides in the amount of 200 liters of working solution per 1 ha or as a separate technological operation. In the experiment, two types of fertilization were used: type 1 - natural fertility, type 2 - complex mineral fertilizers.

There are several modifications of the Megamix preparation. "Megamix-Profi" is a liquid mineral fertilizer for top dressing with a rich content of trace elements (g / l): B - 1.7; Cu - 7.0; Zn - 14; Mn 3.5; Fe - 3.0; Mo - 4.6; Co - 1.0; Cr - 0.3 and macronutrients (g \ l): N - 6; S - 29; Mg -15. The wide and rich composition of the fertilizer is aimed at extensive stimulation of all processes in the plant. Synergy and antagonism of individual nutrients was also taken into account. The purpose of the preparation "Megamix" is to eliminate the lack of microelements; prevent and treat endemic diseases; to stimulate root nutrition, activate enzymes and replenish missing nutrients; to increase the yield due to the stimulation of enzymatic processes and prolongation of the growing season; to improve the quality of the crop [12].

"Megamix-Zinc" has a high content of zinc and is used, as a rule, for top dressing of crops with an increased removal of this element. It increases water retention and absorption of phosphorus, prevents the development of signs of zinc deficiency - interveinal chlorosis, a slow growth. The preparation has also a high sulfur content which increases the efficiency of tank-contained mixtures with nitrogen fertilizers. The composition gram per liter is N-70.0, S-68.5, Zn -140 [12].

"Megamix-Nitrogen" is a liquid mineral fertilizer for top dressing with a high nitrogen content and micro and macro elements. The nitrogen of mineral fertilizers is very mobile in the soil - nitrate is washed out with excessive moisture, and ammonium evaporates when the soil dries. Its fractional application helps to reduce nitrogen losses where various types of top dressing with high assimilation efficiency occupy a special place. However, with this

technology, there are restrictions on the concentration and, accordingly, the application rate, which makes us look for the ways to increase the efficiency of nitrogen dressings. “Megamix-Nitrogen” is a fast-acting fertilizer for eliminating nitrogen deficiency. “Megamix-Nitrogen” is a unique preparation in which nitrogen is in a form that is perfectly assimilated by the leaves of a crop - much faster and easier than when applied to the soil. The trace elements contained in this fertilizer help the plant to absorb nitrogen better and have an overall positive effect. This fertilizer is effectively applied in the initial phase of the growing season, and especially during the period of rapid growth of the crop, as well as in early spring for winter crops. The use of the complex of fertilizers “Megamix-Nitrogen” has a preventive effect and suppress diseases, makes it possible to realize the potential yield and quality of the grown products. The high efficiency of this fertilizer was also noted in unfavorable weather conditions, due to increased photosynthesis and sugar content in cells which prevents water loss during drought, freezing during frost and contributes to regeneration in case of damage already inflicted. When using the preparation “Megamix-Nitrogen”, the processes of nitrogen fixation are intensified, which is an additional source of nitrogen for the crop. At the same time, it is worth noting especially the enhancement of non-symbiotic nitrogen fixation in non-leguminous crops. With foliar treatment, the preparation “Megamix-Nitrogen” replenishes the lack of biogenic microelements during the growing season. Nutrients, penetrating into the intercellular space and the conducting system are actively involved in plant metabolism. The efficiency of photosynthesis, respiration and growth processes increases. Root secretions increase that stimulate beneficial soil microorganisms in the rhizosphere [12].

Analyzes, records and observations in the experiment were carried out in accordance with generally accepted methods and state standards [13]. Field and laboratory experiments were followed by appropriate observations, counts and analyzes: the plant density determination and preservation of plants before harvesting was carried out by counting the number of plants on three counting areas of the plot with a total area of 1m<sup>2</sup>; in the plant material selected before harvesting, the productive tillering, grain content and ear productivity were determined, and the ratio of grain to straw was calculated. Phenological observations were performed in accordance with GOST 10842–64 according to the technique of state variety testing. The plant density was determined on the basis of 2 rows on counting plots in 3 places of a plot with a row length of 111 cm in all repetitions of the experiment. The registration of the actual yield was conducted from the area of the whole plot, recalculated to 100% of purity and 14% of moisture content (GOST 27548-97). The weight of 1000 seeds was determined according to (GOST-12042–80); the test weight according to GOST 5060-86, grain vitreousness according to GOST 10987 - 76.

During all the years of the study, winter wheat was the predecessor. The technology of cultivation of spring wheat was based on the agrotechnical methods generally accepted in the Ulyanovsk region.

### **3 Results**

The yield level is a single indicator that combines the realization of the crop productivity potential embedded in the plant genome with the condition of environmental factors and modern technological practices used as a means for a more complete manifestation of the metabolic capabilities of a particular cultivated crop.

The yield of crops, apart from the enumerated factors, depends on a number of other agrotechnical measures: the quality and methods of tillage, the placement of crops in crop rotation, the methods and timing of crop tending, the use of biological and chemical crop

protection, liming, gypsum application, etc. A significant reserve for increasing crop production is to improve the structure of sown areas, i.e. to increase the share of more productive crops in the total sown area. An important resource for increasing crop production is to raise the return on fertilizers, which, in turn, depends on the dose and quality of fertilizers, their structure, terms and methods of application to the soil. Avoiding losses during harvesting is an important factor in increasing production. Among the most important resources for increasing the productivity of agricultural crops, the leading place is taken by the introduction of the most productive crops and varieties and the improvement of the direct agrotechnology of their cultivation. In plant growing, special attention has recently been paid to the introduction of technologies for the use of physiological - biochemically active substances (directly liquid fertilizer mixtures of a growth-stimulating and growth-regulating nature) in cultivating crops, including spring wheat. The studies of many authors have shown the positive effect of such preparations on the production processes and the yield of many grain crops [9-11].

The data obtained as a result of the study show that the preparations used in the experiment with spring wheat significantly activate the physiological - biochemical and production processes during ontogenesis. As a result, we observe an increase in the yield of the experimental crop.

The studies show that, on average, over the years of our experiments, the used modifications of the preparation “Megamix” contribute to an increase in the yield by 0.37 - 1.43 c / ha in the unfertilized soil, and by 1.41 - 3.12 c / ha in the fertilized soil. The best result in comparison to the control group is provided by the use of the modification “Megamix-Zinc” together with complex mineral fertilizers, which is 11% (Table 1).

**Table 1.** Effect of various modifications of the Megamix (M) preparation on the yield of the spring wheat variety Ulyanovskaya 100 (2018 - 2020), c / ha.

Option	Yield			Increase		
	2018	2019	2020	Mean	c/ha	%
Control	30,34	24,28	30,58	28,40	-	-
M - Profi	30,79	24,85	30,66	28,77	0,37	1,3
M - Nitrogen	32,00	25,12	30,99	29,37	0,97	3,4
M - Zinc	32,85	25,50	31,15	29,83	1,43	5,0
Control + NPK	32,22	25,66	31,54	29,81	1,41	4,9
M - Profi + NPK	32,40	25,90	31,79	30,03	1,63	5,7
M - Nitrogen+ NPK	32,41	26,42	31,99	30,27	1,87	6,6
M - Zinc+ NPK	34,10	26,98	33,48	31,52	3,12	11,0
LSD <sub>05</sub>	1,53	0,21	0,38			

The quantity of the formed yield of any grain crop is made up of the following elements of the yield structure: the number of productive stems, plant height, ear length and weight of 1000 seeds, the number of grains per ear, and the weight of grain per ear. As a rule, a higher grain weight is formed in years with a low air temperature during the grain filling phase and a long period of grain formation. The fundamental factors that contribute to the best grain filling are the maximum required soil moisture and low air temperature during these phases of ontogenesis.

**Table 2.** Effect of various modifications of the Megamix (M) preparation on the elements of the structure of the spring wheat yield (average for 2018-2020).

Option	Plant height, cm	Ear length, cm	Number of grains per ear, pcs.	Weight of grain per ear, g	Weight of 1000 grains, g
Control	69,91	8,80	24,75	0,84	34,07
M -Profi	72,88	9,12	25,77	0,87	34,56
M - Nitrogen	72,95	9,34	25,95	0,91	34,78
M - Zinc	73,07	9,76	26,30	0,99	35,09
Control + NPK	73,42	9,96	26,51	1,23	35,41
M - Profi + NPK	75,87	10,05	27,18	1,27	35,53
M - Nitrogen+ NPK	78,66	10,32	27,52	1,33	36,37
M - Zinc+NPK	79,14	10,65	28,15	1,40	36,87

From the data presented (Table 2) it follows that the height of plants and ear length of spring wheat under the influence of the factors used increased in comparison with the control option by 12.9 - 9.2 cm and 0.32 - 1.85 cm, respectively, depending on the option. The ear productivity, that is, the number of grains per ear and the weight of grain per ear, also increased when using growth regulators and complex mineral fertilizers. The maximum value was found in the “Megamix - Zinc + NPK” option.

Thus, the use of various modifications of the Megamix preparation and the introduction of complex mineral fertilizers have a positive effect on production processes, which ultimately contributes to an increase in the yield of spring wheat.

The grain quality of crops is made up of the combination of the action of “internal factors” - the genetic characteristics of the plant organism and “external factors” - soil and climatic conditions and a set of agrotechnical operations.

Grain quality assessment of crops is carried out on the basis of the following typical indicators: “general quality indicators” - are mandatory, are determined in all grain batches for all crops: indicators of freshness (appearance, color, smell, taste ), grain pest infestation, moisture, percentage of weed and grain impurities; “special” or “target” ones are indicators of grain quality of crops, characterizing the technological (consumer) properties of grain. They are determined in batches of grain of some crops sent for processing. Such indicators are the following: filminess and yield of pure grain (for cereal crops), vitreousness (for wheat, rice), quantity and quality of raw gluten (for wheat), test weight or bulk weight (for wheat, rye, barley, oats), germination energy (for barley used for brewing). “Additional” quality indicators are determined if required - the chemical composition of the grain, the residual amount of pesticides (after treatment against pests, diseases and weeds), contamination by microorganisms, radiation contamination, etc.

The quality of the grain depends on many factors. They can be divided into two groups: the first one is factors that cannot be influenced (weather and climatic conditions of the growing season) and the second is factors that can be controlled (plant nutrition, plant protection from pests, diseases and weeds, and quality grain). Let us dwell on only some of them. In order for the level of protein and gluten content in the grain to be high, plants must receive the required amount of nitrogen during the critical phases of development -

tillering, stem growth and immediately before the ear formation. Diseases of the ear (dark mildew, septoria and fusarium) lead to a decrease in the content of protein and gluten, a decrease in the test weight and weight of 1000 grains and contamination with mycotoxins. Damage to leaf diseases (spots, various types of cereal rust and powdery mildew) also reduces the content of protein and gluten, reduces the test weight, the weight of 1000 grains and flour yield. Lodging leads to germination of grains, a decrease in the number of fallen grains and flour yield [14-15].

Wheat grain quality is standardized by GOST 9353–2016. According to this GOST, one of the indicators of the quality of wheat grain, by which the class and the purchase price are determined, are vitreousness and grain test weight.

The test weight, or bulk weight of grain, is included according to the existing State standard (GOST R 9353 - 2016) in the number of mandatory indicators when assessing wheat grain. The test weight is one of the most ancient quantitative indicators of the properties of the grain mass. The test weight is an expression of the “plumpness” of the grain.

**Table 3.** Effect of various modifications of the Megamix (M) preparation on the test weight of the spring wheat variety Ulyanovskaya 100, g / l (2018 - 2020).

Option	Test weight (bulk weight), g/l			
	2018	2019	2020	Mean
Control	725,4	705,6	743,1	724,7
M -Ptofi	733,3	711,4	743,9	729,5
M - Nitrogen	733,5	714,9	745,0	731,1
M - Zinc	734,4	717,0	747,2	732,9
Control + NPK	738,2	723,5	751,5	737,7
M – Profi + NPK	742,8	724,4	753,6	740,3
M - Nitrogen+ NPK	744,3	725,1	754,4	741,3
M - Zinc+NPK	748,7	726,3	755,2	743,4

“Filled”, “heavy”, well-formed grain is characterized by a directly higher concentration of endosperm. More “flour yield” is obtained from “high-grade” grain, as a rule, than from “low-grade” grains, where there is a greater yield of bran (shells).

The studies have shown that the highest grain test weight is observed in the Megamix-Zinc option with previous application of mineral complex fertilizers, which is higher than the control option by 23.3 g / l in 2018, in 2019 by 20.7 g / l and in 2020. by 12.1 g / l%. On average, over the years of studies, the increase from the factors used was 4.8 - 18.7 g / l, depending on the option (Table 3).

Since the bulk weight cannot always accurately characterize the physical grade of the analyzed grain sample, the weight of 1000 grains is additionally determined in laboratory research practice. The weight of 1000 grains shows the amount of substance contained in the grain, its “large size”. The large-sized grain will definitely have a higher weight of 1000 grains. The chemical composition of grain is characterized by the ratio of carbohydrates and proteins in the endosperm. The ratio of the embryo and endo-sperm in the grain is of great importance in the “total chemical composition”, which depends directly on the degree of “filling” or “plumpness” of the grain during its formation.

The ratio of the number of shells and the weight of the embryo to the nucleus in the “large-sized” grain is the smallest. The weight of 1000 grains is an irreplaceable characteristic of the seed material, since “large” seeds form more viable and even seedlings and, more productive plants.

Top dressing of spring wheat plants of the variety Ulyanovskaya 100 with experimental preparations has a positive effect on the weight of 1000 seeds. On average, for 2018-2020, this indicator increased by 0.49 - 2.80, compared with the control option (Table 2).

The vitreousness of the wheat grain is associated with its protein content. High vitreous wheat is known to contain more protein and high quality gluten which ultimately improves baking properties. The vitreousness of the grain depends on various factors: the type of grain, geographic and soil factors, agricultural techniques for cultivation of grain crops. The vitreousness of the grain is also closely related to the lack of moisture and nitrogen content in the soil during the growing season of the crop. It has been found that the consistency of the endosperm is a form of link between protein substances and starch grains, due to which wide layers of the so-called attached protein are formed, which is not removed from them during intensive mechanical processing. The vitreousness in soft wheat varieties can be different and fluctuate within a very wide range from 10 to 90-95%.

The results obtained show that a higher glassiness of spring wheat grain was observed in the option Megamix - Zinc + NPK, compared with the control option, the increase was 4.95% (2018), 3.21% (2019), 9.33% (2020).

**Table 4.** Effect of various modifications of the Megamix (M) preparation on the vitreousness of the grain of the spring wheat variety Ulyanovskaya 100, %.

Option	Vitreousness, %			
	2018	2019	2020	Mean
Control	40,82	35,77	51,14	42,58
M -Profi	41,85	36,21	53,53	43,86
M - Nitrogen	43,15	36,87	54,76	44,90
M - Zinc	43,22	37,04	55,06	45,11
Control + NPK	43,88	37,45	56,13	45,82
M – Profi + NPK	44,75	38,11	57,18	46,68
M - Nitrogen+ NPK	45,54	38,67	57,88	47,36
M - Zinc+ NPK	45,77	38,98	60,47	48,41

A significant change in the vitreousness of grain directly depends on meteorological conditions, which were unstable over the years of the studies (Table 4). The year 2018 was characterized by a lack of moisture in the initial period of plant growth and development. In 2019, with generally favorable weather and climatic conditions, there was an excess of moisture (prolonged rains) during the grain filling period. The year 2020 is the most favorable year in terms of the nature of the temperature and water regimes and their distribution over the phases of plant growth and development.



## 4 Conclusions

Thus, the positive role which was found when using the growth-regulating and growth-stimulating preparations in the experiment is manifested in the intensification of the growth functions of spring wheat, the processes of formation of the photosynthetic apparatus, both in the initial and subsequent periods of development. This, ultimately, leads to an increase in plant resistance to unfavorable environmental factors (high temperature, low moisture supply, weed infestation of crops) and allows one to obtain high yields of crops even in the zones of risky farming which the Middle Volga region can be related to.

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