

Effect of the next-generation stimulants on the yielding capacity of winter wheat in moisture deficit conditions

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Abstract. In the conditions of the Stavropol Krai arid region the single nutrient fertilizer treatment of winter wheat does not always justify the costs expended due to the moisture deficit during the growing season. In this regard, one of current promising areas is the additional combined use of chemical fertilizers, growth-stimulating agents and micronutrients intended for seed and vegetative plant treatment. In 2018–2020 a research was conducted into the effect of the VL 77 growth stimulants and the Orakul Semena, Orakul Multikompleks, and Orakul Sera Activ micronutrient complexes at different growth and development stages during winter wheat cultivation in the volatile weather conditions of the Stavropol Krai arid region. The research establishes the effectiveness of the combined use of the next-generation stimulants during winter wheat cultivation on chestnut soils in the conditions of the Stavropol Krai arid region. The highest yield of the Idilliya winter wheat variety (4.68 t/ha) was achieved by initially dressing the seeds with the VL 77 growth stimulants combined with the Orakul Semena micronutrient complex and treating the seeds with the VL 77 growth stimulants in combination with the Orakul Multikompleks micronutrient complex during the spring growth resumption period. The second treatment of vegetative plants during the flag leaf stage stimulated their growth, but moisture deficit reduced the yields by 2.3%. Still, the yields obtained exceeded the test yields by 4.3%. On average, during the three years of research the growth stimulant and micronutrient complex treatment boosted the yielding capacity in moisture deficit conditions by 4.6–5.1%. The cost effectiveness concurrently increased from 66.0% to 89.0%.

Winter wheat is one of the most important and economically feasible food crops in Stavropol Krai. It covers an area of 1.2–1.6 million hectares on an annual basis [1].

In order to obtain high and sustainable winter wheat yields, it is essential to monitor crop status and manage crop growth and development with the help of appropriate agrotechnical measures and accessible agricultural chemicals, which allows for the reduction of negative and the promotion of positive vital factor effects.

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In regard to the winter wheat cultivation technology, producing high and sustainable quality grain depends largely on a smart application of fertilizers in combination with growth-stimulating agents and micronutrients which activate plant life processes, increase yielding capacity and product quality, reinforce protective potential, and improve tolerance towards adverse cultivation conditions [1,2].

The number of Stavropol Krai farm businesses that apply growth stimulants and micronutrients when cultivating winter wheat is constantly rising. However, the broad variety of growth stimulants and micronutrients entering the market and offered by both domestic and foreign companies may confound farmers when it comes to making a choice. Every year a considerable number of new items is added to the list of such agrochemicals. This necessitates studying the effectiveness of the next-generation stimulants when applied in specific soil and weather conditions [1,3].

The chemical constitution of plants comprises more than 60 elements, the most essential among which are nitrogen, phosphorus, potassium, sulphur, iron, calcium and magnesium. Apart from the elements listed, a high yield is obtained by providing crops with such micronutrients as boron, manganese, molybdenum, zinc and copper.

When compared to macronutrients, micronutrients are consumed by plants in small amounts. However, this does not diminish their importance. They have a beneficial effect on sowing qualities of seeds and overall crop development, as well as improve crop tolerance towards adverse cultivation conditions (droughts, cold spells, diseases, pests, etc.). They are well-adsorbed onto leaf surface, and therefore increase germinating capacity, improve nutritive conditions, enhance growth and development, and by extension, contribute to yielding high-quality grain [2].

The research objective is to study the impact of the combined use of growth stimulants and micronutrients on the yielding capacity and the grain quality of winter wheat in the conditions of the Stavropol Krai arid region.

The research was conducted during 2017–2020 in the Stavropol Krai arid region according to the official test procedure for cultivated crops (Federal State Unitary Enterprise “Prikumskaya research and selection station”, Budyonnovskiy District).

The test field soil is a chestnut calcareous light loam soil with 1.7% humus content; 20.0–23.0 ppm labile phosphorus content; 350–400 ppm exchange potassium content; pH is 8.2, mildly alkaline. The region is arid, the annual precipitation is 350–450 millimetres.

During the research years the weather conditions differed in terms of both total precipitation and temperature behaviour, which allowed for a more objective appraisal of the biologies under study. The arid region is characterized by its low moisture level during the vegetative period, which averages 370 millimetres per year. The test period saw a 120–170 millimetres precipitation shortage. The rainfall distribution in vegetative periods is also of importance, and in this regard, 2019 proved to be the most favourable year.

The Idilliya recognized variety of common winter wheat was sowed for the research purposes using the traditional arid region technique.

The following agrochemicals were studied:

- VL 77 – a combined natural-synthetic product of contact-systemic effect for seed and vegetative plant treatment, which promotes growth and development and enhances adaptive capacities of crops;
- Orakul Semena – a combined liquid micronutrient for treatment of field crop seeds with the purpose of rooting;
- Orakul Multikompleks – a combined general-purpose liquid micronutrient for field crop foliar dressing;
- Orakul Sera Aktiv – a high-potency sulphur micronutrient for field crop foliar dressing.

Three variants of product application at different winter wheat growth stages were examined. The test arrangement is presented in Table 1.

Table 1. Test arrangement

No.	Seed treatment (ST)	Spring tillering stage treatment (PT ₁)	Flag leaf stage treatment (PT ₂)
1	Base fertilizers (N ₁₀ P ₅₀ + N ₃₀ + Dospek-3, KC (0,4 litre per tonne)) (test crops)	–	–
2	Base fertilizers + VL 77 (0,5 litre per tonne) + Orakul Semena (1 litre per tonne)	VL 77 (0,5 litre per tonne) + Orakul Multikompleks (1 litre per hectare)	–
3	Base fertilizers + VL 77 (0,5 litre per tonne) + Orakul Semena (1 litre per tonne)	VL 77 (0,5 litre per hectare) + Orakul Multikompleks (1 litre per hectare)	VL 77 (0,5 litre per hectare) + Orakul Sera Aktiv (1 litre per hectare)

Recordings and observations were conducted according to the conventional procedures:

- phenological observations, structural determination and yield tracking were carried out by the official crop variety testing procedure [4];
- working grain quality – GOST P52554-2006;
- grain hardness, % – GOST 10987;
- protein content, % – GOST 13586.1;
- gluten content, % – GOST 13586.1;
- gluten deformation index, relative units – GOST 13586.1.

During all research years winter wheat seeding was conducted at the most reasonable time for the region. However, the sprouting period and the number of sprouting crops were determined by the moisture content of the seeding layer.

In 2017 and 2019 the metre-deep layer contained between 65 and 70 millimetres of productive moisture, while the seeding layer contained between 9 and 10 millimetres, which allowed the sprouting to begin on the 10th–15th day and enter hibernation at the 2nd–3rd stem shoot stage.

The autumn of 2019 can be characterized as hyperarid, and the precipitation shortage in September–October amounted to 65,5 millimetres as against the mean annual readings. Due to the overdried surface soil the sprouting did not begin until February.

During the research years the germinating energy of winter wheat that was dressed with the use of VL 77 and Orakul Semena exceeded the test yield energy by 3–8% on average, which occurred due to active growth of the root system.

The VL 77 and micronutrient treatment has a significant positive effect on the yielding capacity of winter wheat by intensifying the processes of photosynthesis, substance translocation and growth. This is accompanied by the formation of an agroecosystem of plants with the highest assimilatory capacity (which is determined by leaf surface and duration of plant life processes). While photosynthesizing, plants produce an organic substance that determines grain yields at the ripening stage [5].

High morphological potential, which dictates plant performance, is indicated by the size of photosynthesizing organs [6, 7]. A number of authors point at a direct relation between linear index of plant growth and yielding capacity of winter wheat [8].

During the research period the following criteria were set in order to determine the rate of crop growth: the height, the wet weight and the number of sprouts.

In terms of springtime moisture content all years can be characterized as hyperarid. Moreover, 2020 was aggravated by the return of spring frosts, which exacted a serious toll on the vegetative apex and the subsequent forming of grain mass (Table 2).

Table 2. Winter wheat yielding capacity depending on the application of growth stimulants and micronutrients, t/ha

Variant	Year			Average
	2018	2019	2020	
Test crops	3,55	4,39	2,46	3,47
Base fertilizers + ST* + PT ₁ **	3,73	4,68	2,48	3,63
Base fertilizers + ST* + PT ₁ **+ PT ₂ ***	3,84	4,58	2,52	3,65
Least significant difference 05	0,12			

Please note: *ST – seed treatment, **PT₁ – spring tillering stage plant treatment, ***PT₂ – flag leaf stage treatment.

The table shows that 2019 was the most favourable year. All variants under research exhibited the yield of more than 4,0 t/ha, but the application of growth stimulants and micronutrients provided a 4,3–6,6% gain compared to the test crops. The largest gain of 0,28 t/ha was observed in the variant that applied the VL 77 growth stimulants combined with the Orakul Semena micronutrient complex during the initial seed dressing and the VL 77 growth stimulants in combination with the Orakul Multikompleks micronutrient complex during the spring growth resumption period.

The application of the Orakul Multikompleks micronutrients intensifies the nutrient absorption from the soil, and by extension, makes the crops stress-resistant and promotes higher yields.

The application of growth stimulants and the Orakul Sera Aktiv micronutrient complex at the flag leaf stage provided a 0,19 t/ha yield gain compared to the test crops. However, there was no observable difference with the variant in which the agrochemicals were used during the spring tillering stage. It should be assumed that the applied agrochemicals provoked an intense grain formation at the beginning of the ripening stage, but the hyperarid conditions, total absence of precipitation and hot dry winds reduced the grain size.

When analyzing the less favourable year 2018 and the completely unfavourable year 2020, it may be noted that in both of these research years the one-time application of agrochemicals upon dressing and two-time application during the vegetative period provided the yield gain of 0,18–0,29 t/ha depending on the year. The one-time application of agrochemicals during the vegetative period produced the gain of 0,03–0,11 t/ha, which is a minor difference.

However, 2020 appeared to be the least yielding year, which is explained by the hyperarid conditions lasting from September till July and a strong impact upon the growth and development of wheat during the return of the spring frosts, which seriously damaged the vegetative apex at the IV–V stages of organogenesis, when the spike was intensely differentiating into spine primordia.

The yielding capacity of the Idilliya variety winter wheat was determined by the formation of the individual yield formula elements, which were influenced by weather conditions and application of growth stimulants and micronutrient complexes (Table 3).

Table 3. The effect of growth stimulants and micronutrients on the yielding capacity and structure elements of winter wheat (average for 2018–2020)

Variant	Yielding, t/ha	Number of spikes, pcs	Number of grains per spike, pcs	Grain weight per spike, gram	1000 grain weight, gram
Test crops	3,47	379	34	0,97	36,6
Base fertilizers + ST* + PT ₁ **	3,63	409	36	1,03	37,6
Base fertilizers + ST* + PT ₁ **+ PT ₂ ***	3,65	414	37	1,06	37,9

Please note: *ST – seed treatment, **PT₁ – spring tillering stage plant treatment, ***PT₂ – flag leaf stage treatment.

The research found a consistent size change pattern of the individual yield formula elements, which depends on the application of agrochemicals. On average, over the three years the largest number of yielding winter wheat spikes was formed by using the VL 77 growth stimulant and the Orakul Semena micronutrient complex upon dressing; using the VL 77 growth stimulant and the Orakul Multikompleks and Orakul Sera Aktiv micronutrient complexes at different growth stages – 414 pieces per square metre, which exceeds the test amount by 8,5 %. Using the micronutrients once during the vegetative period produces a minor difference of 1,2 %.

An important element of the winter wheat grain yield formation is the thousand grain weight.

In 2019, we registered the maximum number of grains per spike (36–41 pieces) and the maximum thousand grain weight (43,0–44,5 grams). The highest results were obtained when dressing the seeds and treating the crops with the growth stimulant and the micronutrient complex at the spring tillering stage.

The lowest grain weight per spike was registered in 2020 (0,85–0,98 grams). Over the three years the number of test spikes averaged 359 pieces per square metre against 409–414 pieces per square metre in research variants. Hence, the growth stimulant and the micronutrient complex increased this and other parameters of the yield formula elements. For instance, the number of grains per spike increased from 34 to 36–37 pieces, the grain weight per spike – from 0,97 to 1,03–1,06 grams, and the thousand grain weight – from 36,6 to 37,6–37,9 grams. When comparing the last parameter by year, the lowest thousand grain weight was registered in the year 2020, which was rendered hyperarid by abnormal heat and precipitation absence. The applied agrochemicals acted as a catalyst for growth processes, but compromised the formation of organic substance and led to the consequent formation of shrivelled and underweight grain.

Winter wheat treatment with the Orakul Sera Aktiv micronutrient complex and the VL 77 growth stimulant at the heading stage increased the protein content of a winter wheat grain up to 14,1 %. The combined use of macro- and micronutrients influenced the nitrogenous nutrition of the crops and, as a consequence, enhanced the protein yield. The higher protein level is primarily attributed to the increase in yielding capacity.

The quality indicators of the Idilliya variety winter wheat grain are measured by the quality and the quantity of gluten, which are characterized by the grain class. More favourable conditions formed the III and IV class grain, while in 2020 only the V class grain was produced.

The quality indicators of grain are directly related to its quantity. For instance, the gluten levels were higher in the favourable year of 2019 than in 2018 and 2020, and

amounted to 20,9-21,4 % depending on the variant. The lowest gluten levels of 11,3–12,0 % were registered in the most unfavourable year of 2020, and we did not observe any major difference between the variants.

The presence of gluten increases the nutritional value (colour, taste, smell), the baking properties (volume yield, porosity), and the market quality of bread.

The introduction of growth stimulants and micronutrient complexes boosts crude gluten levels in winter wheat grain, but it largely depends on the prevailing weather conditions during the vegetative period.

Dough properties are determined by the quality of gluten, rather than its quantity. The quality of gluten comprises such parameters as turgidity, elasticity, extensibility, and adhesion. However, the key criterion is the ability of gluten to preserve the said parameters in the process of breadmaking.

The quality of gluten is measured in a laboratory environment by the gluten deformation index meter. The turgidity readings act as the conditional units of the instrument dial, and gluten is placed into a quality category depending on the received measures. The gluten deformation index in our research is between 74,1 and 74,9, which corresponds to the first gluten quality group. Thus, the gluten is of good quality.

The favourable conditions of 2018 and 2019, as well as the application of agrochemicals yielded the highest gluten content in the variant involving one-time application of agrochemicals to the vegetative plants. Using VL 77 and Orakul Sera Aktiv at the flag leaf stage did not produce any positive effect upon the formation of yield and its quality. The reason for this is that the agrochemicals intensify the growth processes, as well as the accumulation of dry basis, but the hyperarid conditions of the research period led to the desiccation of winter wheat crops, the weakening of macronutrient outflux, and, consequently, the formation of shrivelled grain.

The economic impact of the growth stimulants and the micronutrient complexes was evaluated through a system of criteria, the key of which were operating profit and cost efficiency. The relative cost efficiency allowed to identify the most profitable pattern of application of growth stimulants and micronutrient complexes compared to the test yields. Over the research years the yield gain averaged between 0,16 and 0,18 t/ha. The corresponding economic gain amounted to 2,0–3,0 ths. rubles per hectare. The best result was achieved when dressing the seeds with VL 77 and Orakul Semena, treating the crops with VL 77 and Orakul Multikompleks at the spring tillering stage, and treating with VL 77 and Orakul Sera Aktiv at the flag leaf stage. The general cost efficiency level of using the growth stimulant and the micronutrients varied from 66,1 to 89,6 %.

The conducted research allows us to observe the positive effect that the VL 77, Orakul Semena, Orakul Multikompleks and Orakul Sera Aktiv agrochemicals have on the winter wheat development by increasing the yielding capacities and grain quality. It should also be mentioned that the application of the Orakul Sera Aktiv micronutrient depends directly on the precipitation depth and temperature behaviour. During the research period this agrochemical was unable to realize its potential due to the heat and the drought.

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