Effectiveness of microbiological preparations, growth stimulants and fertilizers in winter wheat crops on ordinary chernozem

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Abstract. The paper presents the data from two field experiments on the effect of microbiological preparations, growth stimulants and fertilizers on the yield and quality of grain of various varieties of winter wheat. In the first experiment, the following biological products were studied: Extrason, Rostock and water-soluble fertilizers Aquamix, Aquarin 5 and Aquarin 9 on winter wheat varieties Niva Stavropolya in crops according to forecrop of black fallow and Victoria 11 in crops according to the forecrop oil flax. It was found that the highest yield had Niva Stavropolya variety - 5.59 t / ha and in Victoria 11 variety - 3.97 t / ha, as well as the best grain quality were formed with the combined application of fertilizers and biological products in the following combination: P_{60}K_{40} before sowing (according to forecrop black fallow) and N_{60}P_{60}K_{40} (according to forecrop oil flax) + N_{30} for tillering + + N_{30} for heading. At the same time, before sowing, it is advisable to use the water-soluble fertilizer Aquamix (0.1 l / t) for seed treatment, - Aquamarine 5 (2 l / ha) and for the treatment of vegetative plants in tillering and Aquarine 9 (2 l / ha ) for heading. In the second experiment, the effect of microbiological preparations Emistim / biostim, Rizoagrin, Flavobacterin, Extrasol and growth regulators Rostok and Humat on the productivity of soft winter wheat varieties Yuka and Grom in crops after the forecrop black fallow was studied. It was found that the highest yield of the variety Grom - 9.24 t / ha was provided by Emistim and Yuka variety - 9.03 t / ha Humat growth regulator.

1. Introduction

In the conditions of Rostov region, many researchers were engaged in the development and improvement of the technology of cultivation of winter wheat such as I.G. Kalinenko, A.A. Gritsenko, I. M. Shaposhnikova, L.P. Beltyukov, N.A. Zelensky and others [1 ... 5]. In these studies, new varieties, doses and methods of fertilization, terms and rates of sowing and soil cultivation were studied. However, the issues of the use of biologics and growth regulators presented in this paper on new varieties of winter wheat in crops for various forecrops in the southern zone of Rostov region were understudied.

Nowadays one of economically effective agricultural practices in the technology of cultivation of winter wheat is the use of various biological products and growth stimulants, both during seed treatment and during the growing season of plants [6, 7].
Microelements in a chelated form are particularly highly effective, which, unlike mineral salts, are not fixed in soil absorbing complex, non-toxic, readily soluble in water and therefore well adsorbed on the surface. In this regard, the germination of seeds increases, the nutritional conditions improve, the growth and development rates of plants increase, which has a positive effect on the yield and product quality [8].

A number of researchers [9, 10] note varietal characteristics during the use of biological products and growth stimulants on winter wheat. Every year, the list of biological products and fertilizers used in our area is replenished and updated, which requires their testing in various soil and climatic zones.

In this regard, the purpose of our research is to assess the effect of microbiological preparations, growth stimulants and water-soluble fertilizers on the yield and grain quality of soft winter wheat varieties in the southern zone of Rostov region.

2. Research materials and methods
The research was carried out in the southern zone of Rostov region in 2016-2018 according to generally accepted methods and GOST in two field experiments.

The 1st experiment was laid in agricultural production cooperative and collective farm “Rus” of Salsk region, where the biological products Extrasol, Rostok and water-soluble fertilizers, Aquamix were studied. Aquarin 5 and Aquarin 9 were studied on soft winter wheat varieties Niva Stavropolya in crops for black fallow and Victoria 11 in crops according to the forecrop oil flax. The background of the mineral nutrition of plants in the experiment was the use of fertilizers according to the forecrop black fallow P60K40 before sowing and two nitrogen fertilizers according to N30 during the tillering and heading phase, according to the forecrop oil flax N60P60K40 before sowing as well as also two nitrogen fertilizers according to N30 during the indicated phases of the growing season.

The 2nd experiment was carried out at Azov-Black Sea Engineering Institute of Donsk State Agrarian University (Zernograd) with microbiological preparations Emistim, Rizoagrin, Flavobacterin, Extrasol, growth regulators Rostok and Gumat and varieties of soft winter wheat Grom and Yuka after black fallow.

The soil of the experimental plots was represented by ordinary chernozem, warm, freezing for a short time. The granulometric composition was heavy loamy. The soil profile was characterized by a dark gray, almost black, gradually turning brownish color downwards and had a well-defined granular or lumpy - granular structure.

The thickness of the humus horizon exceeded 80 cm; the humus content was 3.0 ... 3.2%. The soil had a high level of carbonate content, mainly from the surface, the presence of caprolites and worm tunnels, poor development of white-eyed, diffuseness of carbonate formations.

The density of the soil of the humus horizon did not exceed 1.4, and in the arable layer it ranged from 1.0 ... 1.2 g / cm³. The arable layer had a completely satisfactory porosity of 50 ... 66% of the soil volume and provided high air capacity and gas exchange. The content in the arable layer of mobile phosphorus (P₂O₅) was average and exchangeable potassium (K₂O) was high (according to Machigin's method).

The average long-term amount of precipitation for the year was 582.4 mm, including 290... 300 mm for the growing season. Summer precipitation was predominantly stormy. At the same time, moisture falling on the soil surface quickly evaporated due to high temperatures, when the soil temperature reached 55 - 65°C. The hydrothermal coefficient varied within 0.7 - 0.8. According to climatic conditions, the territory belongs to the zone of insufficient and unstable moisture.

The seeds were treated with the studied biological products and growth regulators a day before sowing. The treatment of plants in the first experiment was carried out in the tillering and heading phase and in the second experiment they were treated in the period from tillering to stemming. Seeds and crops of winter wheat treated with water were used as control ones.

The seeding rate of soft winter wheat according to forecrop black fallow was 400 (experiment 1) and 450 (experiment 2), and for oil flax it was 500 germinating seeds per 1 m² (experiment 1).
The main cultivation and preparation of the soil, sowing and care measures were carried out in accordance with the Zonal systems of agriculture of Rostov region for the southern zone. Full schemes of field experiments are shown in the tables of research results.

3. Research results

During the years of research, the yield of winter wheat to a certain extent depended on the use of microbiological preparations, fertilizers and growth regulators and the effectiveness of their use was different depending on weather conditions.

The results of research of the 1st experiment indicate that in all the years of research, the highest grain yield was formed by Niva Stavropolya variety in crops after the black fallow, which is explained by the most favorable conditions, especially in terms of soil moisture supply.

In the context of the research years in the crops of black fallow, the variety of soft winter wheat Niva Stavropolya formed the maximum yield in 2017, the most favorable year, which, according to the experimental options, was 4.85 - 6.95 t / ha. In 2016, it was slightly lower - 4.05-5.70 t / ha and the lowest in 2018 - 3.46-4.18 t / ha. On average, over 3 years, the control yield was 4.12 t / ha. The application of mineral fertilizers in the form of a background P<sub>60</sub>K<sub>40</sub> before sowing and two nitrogen fertilizers according to N<sub>30</sub> contributed to the increase in yield up to 4.73 t / ha.

The use of the studied biological products on a fertilized background had a positive effect on the increase in yield in comparison with the control. Thus, the use of the biological product Extrasol only for seed treatment provided the increase in the yield of 1.01 t / ha, and two additional treatments with the same biological product in the tillering and heading phases contributed to the increase to 1.16 t / ha. Similar results were obtained during the research of the biological product Rostok. Thus, during the treatment of seeds with this preparation, the yield increase was 1.00 t / ha, and it was 1.19 t / ha with the use of additional fertilizers for the growing season of plants.

Table 1. Effect of biological products and water-soluble fertilizers on the yield of soft winter wheat (2016-2018)

| №  | Option                                      | Forecrop                        | Black fallow | Oil flax |
|----|--------------------------------------------|---------------------------------|--------------|----------|
|    |                                            | Black fallow                   | Niva Stavropolya | Victoria 11 |
| 1  | Control                                    | 4.12                           | 2.97         |
| 2  | Background                                 | 4.73                           | 3.42         |
| 3  | Background + Extrasol 1 l / t ST           | 5.13                           | 3.57         |
|    | Background + Extrasol 1 l / t ST +         |                                |              |
| 4  | Extrasol 1 l / ha TT<sub>1</sub> +         | 5.28                           | 3.75         |
|    | Extrasol 1 l / ha TH<sub>2</sub>           |                                |              |
| 5  | Background + Rostok 0.5 l / t ST           | 5.12                           | 3.63         |
|    | Background + Rostok 0.5 l / t ST +         |                                |              |
| 6  | Rostok 0.5 l / ha TT<sub>1</sub> +         | 5.31                           | 3.79         |
|    | Rostok 0.5 l / ha TH<sub>2</sub>           |                                |              |
| 7  | Background + Aquamix 0.1 kg / t ST         | 5.29                           | 3.62         |
| 8  | Background + Aquamix 0.1 kg / t ST +       | 5.37                           | 3.80         |
|    | Aquarin 5.2 kg / ha TT<sub>1</sub>         |                                |              |
| 9  | Aquarin 5.2 kg / ha TT<sub>1</sub> +       | 5.50                           | 3.86         |
|    | Aquarin 5.2 kg / ha TH<sub>2</sub>         |                                |              |
| 10 | Aquarin 5.2 kg / ha TT<sub>1</sub> +       | 5.59                           | 3.97         |
|    | Aquarin 9.2 kg / ha TH<sub>2</sub>         |                                |              |
|    | HCP<sub>60</sub>                           | 0.14…0.19                     | 0.15…0.18    |

**Legend.** ST – seed treatment; TT<sub>1</sub> – treatment in tillering, TH<sub>2</sub> – treatment in heading.
It was found that among biological products for seed treatment, the best results were obtained by Aquamix, the increase in yield was 1.17 t / ha to the control group. The additional use of water-soluble chelated fertilizers such as Aquarin for the treatment of plants in combination with Aquamix contributed to a further increase in yield by 1.25; 1.38; 1.47 t / ha compared to the control group.

The highest yield of the variety Niva Stavropolya was obtained in the option Background + Aquamix 0.1 l / t (seed treatment) + Aquarin 5 - 2 kg / ha (tillering) + Aquarin 9 - 2 kg / ha (heading), which was 5.59 t / ha (table 1).

During all research years, in the forecrops of oil flax, the variety of soft winter wheat Victoria 11 formed a lower yield than Niva Stavropolya variety in the crops of black fallow forecrop. On average, over the research years, the grain yield in the control option was 2.97 t / ha. The introduction of mineral fertilizers in the form of a background (N60P60K40 before sowing + N30 for tillering + N30 for heading) provided the increase in yield by 0.45 t / ha. The use of biopreparations Extrasol, Rostok and Aquamix for pre-sowing seed treatment increased the yield by 0.60; 0.66 and 0.65 t / ha, respectively. Additional application of two treatments of plants for vegetation with the indicated biological products served to further increase of the yield by 0.78; 0.82 and 0.89 t / ha.

Table 2. Effect of biological products and water-soluble fertilizers on protein and gluten content in grains of soft winter wheat (2016 - 2018)

| №  | Option                                      | Niva Stavropolya | Victoria 11 |
|----|---------------------------------------------|------------------|-------------|
|    |                                             | protein content, %| gluten      | protein content, %| gluten      |
|    |                                             | 12.1             | 20.4        | 11.5             | 18.0        |
| 1  | Control                                     | 12.7             | 21.6        | 11.9             | 18.8        |
| 2  | Background                                  | 12.9             | 22.1        | 12.1             | 18.8        |
| 3  | Background + Extrasol 11 / t ST             | 13.2             | 22.9        | 12.1             | 20.2        |
| 4  | Background + Extrasol 11 / t ST + Extrasol 11 / t TT + Extrasol 11 / t TH2 | 12.8             | 22.2        | 12.2             | 20.3        |
| 5  | Background + Rostok 0.5 l / t ST            | 13.1             | 23.4        | 12.3             | 20.6        |
| 6  | Background + Rostok 0.5 l / t ST + Rostok 0.5 l/ha TT1+ Rostok 0.5 l/ha TH2 | 12.8             | 22.5        | 12.1             | 20.7        |
| 7  | Background + Aquamix 0.1 kg / t ST          | 13.0             | 23.0        | 12.4             | 21.1        |
| 8  | Background + Aquamix 0.1 kg / t ST + Aquarin 5 2 kg / ha TT1 | 13.3             | 23.5        | 12.7             | 20.9        |
| 9  | Background + Aquamix 0.1 kg / t ST + Aquarin 5 2 kg / ha TH2 | 13.4             | 23.8        | 12.8             | 21.2        |

The highest yield of the variety of soft winter wheat Victoria 11 in crops of the forecrop of oil flax 3.97 t / ha and the largest increase to the control 1.0 t / ha were obtained in the option including the complex application of mineral fertilizers and biological products Background + Aquamix 0.1 kg / t (seed treatment) + Aquarin 5 - 2 kg / ha (in tillering) + Aquarin 9 ... 2 kg / ha (in heading).

In the conditions of Rostov region, the main purpose of soft winter wheat grain is food. Therefore, the production of good quality grain remains one of the important tasks in crop production industry.
The most important ones of the whole variety of indicators are the content of protein and raw gluten, which determine the food value of wheat grain and its baking value.

In the experiment, a better quality grain was formed by Niva Stavropolya variety in crops according to the forecrop of black fallow, where it corresponded to the requirements of GOST 9353–2016 for food wheat of the 3rd and 4th class. In the crops of the forecrop of oil flax, the seed of Victoria 11 variety met the requirements of the 4th class (table 2).

The highest protein and gluten content in the studied varieties of soft winter wheat was noted in the option Background + Aquamix 0.1 kg / t (seed treatment) + Aquarin 5 - 2 kg / ha (tillering) + Aquarin 9 - 2 kg / ha (heading), where the highest grain yield was obtained.

In the 2nd experiment, where the varieties of soft winter wheat Grom and Yuka were studied in crops according to the forecrop black fallow, the maximum yield was obtained in a favorable 2017, which varied from 10.45 to 11.19 t / ha. Average yield was in 2018 7.82 ... 8.86 t / ha and the lowest was in 2016 6.86 ... 8.40 t / ha.

Analyzing the average yield over three years, it is necessary to note that the high productivity of the varieties and weak, but positive, effect of the studied preparations. In terms of varieties, Grom variety was more productive due to the high yield in 2016 compared to Yuka variety. Thus, the average yield for all variants of the experiment for Yuka variety was 8.89 t / ha, and for Grom variety it was 9.12 t / ha.

As for the relatively low effect on the yield of preparations, possibly this was due to favorable conditions in terms of moisture supply and a high agricultural background for the forecrop of black fallow, when the potential productivity of the variety is realized to a greater extent.

On average, over the research years, the highest yield for Yuka variety was obtained in the option with Humate - 9.03 t / ha and it was almost the same in the option with Rostock preparation - 9.02 t / ha. For Grom variety, the maximum yield was formed in the option with the use of Emistim - 9.24 t / ha, including the addition to the control crop, respectively, for the varieties 0.38 ... 0.37 and 0.32 t / ha (Table 3).

| №  | Option     | Variety           | yield, t/ha | ± to control | yield, t/ha | ± to control |
|----|------------|-------------------|-------------|--------------|-------------|--------------|
| 1  | Control    | Yuka              | 8.65        | –            | 8.92        | –            |
| 2  | Scarlet    |                   | 8.75        | 0.10         | 9.09        | 0.17         |
| 3  | Rostok     |                   | 9.02        | 0.37         | 9.21        | 0.29         |
| 4  | Emistim    |                   | 8.96        | 0.31         | 9.24        | 0.32         |
| 5  | Humate     |                   | 9.03        | 0.38         | 9.21        | 0.29         |
| 6  | Rhizoagrin |                   | 8.90        | 0.25         | 9.18        | 0.26         |
| 7  | Flavobacterin |             | 8.92        | 0.27         | 9.12        | 0.20         |
| 8  | Extrasol   |                   | 8.88        | 0.23         | 9.02        | 0.10         |
|    | Average by variety |          | 8.89        | –            | 9.12        | –            |
|    | LSD        |                   | 0.27        | –            | 0.39        | –            |

The research results indicate that practically all experimental variants provided the formation of high-quality grain. However, the studied microbiological preparations and growth regulators did not have a significant effect on the quality indicators of soft winter wheat in relation to the control group. In terms of protein and gluten content, the grain of the studied varieties in all options of the experiment corresponded to the 1st and 2nd class for food wheat according to GOST 9353-2016 (Table 4).
Table 4. Effect of microbiological preparations and growth regulators on grain quality (2016 ... 2018)

| №  | Option          | Yuka  | Grom  |
|----|-----------------|-------|-------|
|    |                 | protein |        | protein |        |
|    |                 | content, % |     | content, % |     |
| 1  | Control         | 14.3   |       | 14.8    |       |
| 2  | Scarlet         | 14.4   |       | 14.9    |       |
| 3  | Rostok          | 14.3   |       | 14.6    |       |
| 4  | Emistim         | 14.4   |       | 14.8    |       |
| 5  | Humate          | 14.4   |       | 14.7    |       |
| 6  | Rhizoagrin      | 14.7   |       | 14.5    |       |
| 7  | Flavobacterin   | 14.4   |       | 14.6    |       |
| 8  | Extrasol        | 14.6   |       | 15.0    |       |

For the economic assessment of the studied biological products and fertilizers, a system of indicators was used, the main of which were the cost of 1 ton of products, profit and profitability.

In the 1st experiment, the highest indicators of economic efficiency were obtained for the variety of soft winter wheat Niva Stavropolya in crops according to forecrop of black fallow, which was explained by a higher grain yield (table 5).

Table 5. Economic efficiency of cultivation of soft winter wheat varieties depending on the use of biological products and fertilizers (2016- 2018)

| №  | Option                                      | Niva Stavropolya | Victoria 11 |
|----|---------------------------------------------|------------------|-------------|
|    |                                             | 1   | 2   | 3   | 1   | 2   | 3   |
| 1  | Control                                     | 5339 | 19202 | 87 | 7003 | 8902 | 43 |
| 2  | Background                                  | 5697 | 20352 | 76 | 7152 | 9741 | 40 |
| 3  | Background + Extrasol 1 l/t ST              | 5378 | 23712 | 86 | 6998 | 10716 | 43 |
|    | Background + Extrasol 1 l/t ST +            |      |       |    |      |      |    |
|    | Extrasol 1 l/ha TT + Extrasol 1 l/ha TH₂    |      |       |    |      |      |    |
| 4  | Background + Rostok 0.5 l/t ST              | 5339 | 24192 | 87 | 6914 | 11201 | 45 |
|    | Background + Rostok 0.5 l/t ST +            |      |       |    |      |      |    |
|    | Rostok 0.5 l/ha TT + Rostok 0.5 l/ha TH₂    |      |       |    |      |      |    |
| 5  | Background + Aquamix 0.1 kg/t ST            | 5314 | 24462 | 88 | 6952 | 11035 | 44 |
|    | Background + Aquamix 0.1 kg/t ST +          |      |       |    |      |      |    |
|    | Aquarin 5 kg/t TT₁ + Aquarin 5 kg/t TH₂     |      |       |    |      |      |    |
| 6  | Background + Aquamix 0.1 kg/t ST +          | 5182 | 25826 | 93 | 6675 | 12635 | 50 |
|    | Aquarin 5 kg/t TT₁ + Aquarin 5 kg/t TH₂     |      |       |    |      |      |    |
| 7  | Background + Aquamix 0.1 kg/t ST +          | 5116 | 26862 | 95 | 6647 | 12941 | 57 |
|    | Aquarin 5 kg/ha TT₁ + Aquarin 9 kg/ha TH₂   |      |       |    |      |      |    |

Legend. 1 – production cost, rubles / t; 2 – profit, rubles / ha; 3 – profitability level, %.
The most cost-effective option for the cultivation of Niva Stavropolya variety was the use of the option Background + Aquamix 0.1 kg / t (seed treatment) + Aquarin 5 - 2 kg / ha (tillering) + Aquarin 9 - 2 kg / ha (heading), where the cost of production was the lowest - 5028 t / ha, while the profit and profitability were the highest - 27,792 rubles / ha and 99%, respectively.

The level of all economic indicators for Victoria 11 variety was lower compared to Niva Stavropolya variety, which is explained by the lower grain yield obtained in the crops according to oil flax forecrop. Nevertheless, the highest indicators were also noted in this option of the experiment: the production cost was 6388 rubles / ton, the profit was 14341 rubles / ha and the profitability was 57%.

In the 2nd experiment, the indicators of economic efficiency were much higher, due to the high yield of the studied varieties of soft winter wheat (Table 6).

### Table 6. Economic efficiency of cultivation of soft winter wheat varieties depending on the use of microbiological preparations and growth regulators (2016-2018)

| №  | Option    | Variety     | Yuka 1 | Yuka 2 | Yuka 3 | Grom 1 | Grom 2 | Grom 3 |
|----|-----------|-------------|--------|--------|--------|--------|--------|--------|
| 1  | Control   | Yuka        | 4318   | 31850  | 85     | 4187   | 34015  | 91     |
| 2  | Scarlet   | Yuka        | 4273   | 32610  | 87     | 4126   | 35215  | 94     |
| 3  | Rostok    | Yuka        | 4126   | 34940  | 94     | 4061   | 36275  | 97     |
| 4  | Emistim   | Yuka        | 4165   | 34365  | 92     | 4048   | 36520  | 98     |
| 5  | Humate    | Yuka        | 4125   | 34989  | 94     | 4054   | 36339  | 97     |
| 6  | Rhizoagrin| Yuka        | 4198   | 33835  | 90     | 4085   | 35935  | 96     |
| 7  | Flavobacterin| Yuka    | 4188   | 34005  | 91     | 4112   | 35455  | 95     |
| 8  | Extrsol   | Yuka        | 4201   | 33735  | 90     | 4148   | 34745  | 93     |

Legend. 1 - production cost, rubles / t; 2 – profit, rubles / ha; 3 – profitability level,%.

The maximum economic efficiency indicators for Yuka variety were obtained in the option with the use of Humate, where the profit from sales amounted to 34,989 rubles / ha with a profitability level of 94%. The indicators of the economic efficiency of cultivation of Yuka variety, which were similar in value, were obtained in the option with the use of Rostok preparation, where the profit amounted to 34,940 rubles / ha with 94% profitability level.

The most effective option of Grom variety was the treatment of seeds and crops with Emistim, where the unit cost was 4048 rubles / ton, the profit was 36,520 rubles / ha and the level of profitability was 98%.

High indicators of economic efficiency of Grom variety were also obtained during the use of Humate preparation, where the unit cost was 4054 rubles / ton, the profit was 36,339 rubles / ha and the profitability was 97%. The same level of profitability was observed in the option with Rostok.

### 4. Conclusion

In the conditions of the southern zone of Rostov region, the use of microbiological preparations, water-soluble fertilizers and growth regulators had a positive effect on the yield and grain quality of soft winter wheat varieties.

The maximum grain yield of Niva Stavropolya according to forecrop of black fallow was 5.59 t / ha and the maximum yield of Victoria 11 according to forecrop of oil flax was 3.97 t / ha. These indicators were obtained with the combined use of fertilizers and biological products in the following combination:

- before sowing P<sub>60</sub>K<sub>40</sub> by the forecrop of fallow and N<sub>60</sub>P<sub>60</sub>K<sub>40</sub> by the forecrop of oil flax + N<sub>30</sub> for tillering + N<sub>30</sub> for heading + Aquamix (0.1 l / t for seed treatment) + Aquarin 5 (2 kg / ha for tillering) + Aquarin 9 (2 kg / ha heading). This option of the experience provided the varieties with both the highest grain quality and economic efficiency. The highest economic effect was obtained during the
cultivation of Niva Stavropolya variety by the forecrop of black fallow, where the profit from the sale of products amounted to 27,792 rubles / ha.

In the crops of winter wheat according to the forecrop of black fallow, the high yield of grain of Yuka variety was provided by the microbiological preparation Humate - 9.03 t / ha. The highest grain yield in Grom variety was provided by the microbiological preparation Emistim / biostim - 9.24 t / ha.

The highest protein content of 14.7% and gluten content of 24.8% in Yuka variety was provided by Rizoagrin preparation and the highest protein content of 15.0 % and gluten content of 25.5% in Grom variety was provided by Extrasol preparation.

In the 2nd experiment the most effective option for the cultivation of Yuka variety was the use of Humate, where the profit from the sale of this variety as a food grain was 34,989 rubles / ha. The maximum indicators of economic efficiency for Grom variety in the same experiment were obtained during the treatment of seeds and crops with Emistim, which provided a profit of 36,520 rubles / ha and a profitability level of 98%.

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