

# Influence of mineral and modified fertilizers on oat yield

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**Abstract.** The paper presents the study of the influence of mineral and modified fertilizers on the formation of yield and quality of oat grain in the Middle Volga. The study was carried out in 2016-2018 on the experimental field of Ulyanovsk Research Institute of Agriculture. The meteorological conditions of vegetation periods during the study varied in temperature and moistening. Three-year studies made it possible to confirm that the administration of a half-dose biomodified azophoska ( $\frac{1}{2}N_{15}P_{15}K_{15m}$ ) increased grain yield in relation to the absolute control on all study backgrounds by 0.13-0.49 t/ha. The greatest effect of fertilizers was observed against the background of ammonium nitrate ( $NH_4NO_{3m}$ ) applied under presowing cultivation at a dose of 40 kg active ingredient/ha treated with microbiological preparation BisolbiFit. Yield enhancement was accompanied by a relative decrease of protein content of oat grains ranging from 11.3 to 12.4 %. There is a negative relation ( $r=-0.76$ ) between the mass of 1000 grains and the protein content.

## 1 Introduction

Due to continuous increase in the cost of mineral fertilizers and possible negative effects on product quality and the environment, it is important to find ways to reduce their doses without losing their efficiency. According to some scientists [1, 2], the use of biological preparations made on the basis of effective microbial strains is becoming ever more relevant. It is proposed to use them not only for pre-sowing seed treatment of seeds or vegetative plants, but directly applying them to mineral fertilizers during planting (biomodified fertilizers). According to the authors, the latter allows reducing the doses of fertilizers and increasing the utilization rates of their nutrients, as well as improving plant nutrition.

The above led to the purpose of the study, i.e. to study the impact of mineral and biomodified fertilizers on the formation of oat yield.

## 2 Materials and methods

The study was carried out on a stationary site of the experimental field of Ulyanovsk Agricultural Research Institute – Branch of Samara Federal Research Center of the Russian Academy of Sciences in 2016–2018 in grain crop rotation: complete fallow – winter wheat – spring wheat – barley – oat. The soil of the experimental field contains leached heavy loamy chernozem with humus content of 6.43–6.62 %, available phosphorus and potassium compounds (according to Chirikov) – 214–228 and 101–117 mg/kg of soil,  $pH_{KCl}$  – 6.3–6.8 units.

Research objects:

- azophoska – mineral fertilizer containing 15 % nitrogen, phosphorus and potassium (NPK);
- bisolbifit – microbiological preparation based on rhizospheric bacteria strain *Bacillus Subtilis Ch-13*. Bacteria can synthesize substances that inhibit the development of plant pathogenic fungi and bacteria, as well as substances that stimulate plant growth. Pre-sowing treatment of seeds with Bisolbifite biopreparation (dry form) was carried out 1 day prior to sowing at the rate of 400–600 g/t, consumption of working solution – 10 l/t;
- biomodified fertilizer ( $NPK_m \frac{1}{2}$  and  $NPK_m$ ). A dry form of BisolbiFit biopreparation was used to prepare a biomodified fertilizer at a rate of 4 kg per 1 ton of fertilizer. The biopreparation was applied to a mineral fertilizer on the day of its application to the soil.

**Table 1.** Scheme of the experiment

Option	background		
1. Control without fertilizers	Background 1 zero	Background 2 $NH_4NO_{3,m}$	Background 3 $NH_4NO_3$
2. Bisolbifite – pre-sowing seed treatment (400–600 g/t)			
3. NPK – azophoska at a dose of 15 kg active ingredient/ha			
4. $NPK_m$ – treatment of azophoska granules with biopreparation at a dose of 15 kg active ingredient/ha			
5. $\frac{1}{2} NPK_m$ – treatment of azophoska granules with biopreparation at a dose of 7.5 kg active ingredient/ha			

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The field experiment was carried out according to the developed scheme (Table 1). The efficiency of fertilizers was evaluated in 3 backgrounds. The first background remained as a control (zero, absolute control), the second included ammonia nitrate in a dose of 40 kg/ha treated with Bisolbifite biopreparation, the third – ammonia nitrate in a pure form in a dose of 40 kg active ingredient/ha introduced for pre-plant cultivation.

The accounting area made 100 m<sup>2</sup> (4\*25), triple application, random location. The organization of field experiments, selection of soil and plant samples, observations and laboratory analyses were carried out according to corresponding GOST standards.

### 3 Results and discussion

The change of the crop yield structure makes it possible to identify those elements that prevail in the formation of yields in specific soil-climatic conditions [3–5]. At the same time, it is necessary to analyze the dynamics of each element of crop productivity, which participates in yield formation. Table 2 shows the oat yield structure in experiments.

The main basic component of yield formation is the optimal number of productive stems per unit area [6, 7]. The correlation dependence of oat grain yield with this indicator made 0.76. Depending on the dose and type of fertilizer, the number of productive stems varied within 273–311 pcs/m<sup>2</sup> in the control option, 297–315 pcs/m<sup>2</sup> in the option with BisolbiFit (pre-sowing seed treatment), 300–320 pcs/m<sup>2</sup> in the option with Azophoska in its pure form (N<sub>15</sub>P<sub>15</sub>K<sub>15</sub>), 312–157 pcs/m<sup>2</sup> in the option N<sub>15</sub>P<sub>15</sub>K<sub>15m</sub> and 314–317 pcs/m<sup>2</sup> in the option ½N<sub>15</sub>P<sub>15</sub>K<sub>15m</sub>. The highest number of productive stems per 1 m<sup>2</sup> was observed for N<sub>15</sub>P<sub>15</sub>K<sub>15m</sub> and N<sub>15</sub>P<sub>15</sub>K<sub>15</sub> in background 2 – NH<sub>4</sub>NO<sub>3m</sub> (Table 2).

**Table 2.** Oat yield structure depending on fertilizer and biopreparation (2016-2018)

Background	Option	Number of productive stems per 1 m <sup>2</sup> , pcs	Grain weight in a panicle, g	Number of grains in a panicle, pcs	Weight of 1000 grains, g
Zero	1. Control	273	0.85	23.9	35.6
	2. BisolbiFit	297	0.89	24.3	36.6
	3. N <sub>15</sub> P <sub>15</sub> K <sub>15</sub>	300	0.90	24.3	37.0
	4. N <sub>15</sub> P <sub>15</sub> K <sub>15m</sub>	312	0.90	24.2	37.2
	5. ½N <sub>15</sub> P <sub>15</sub> K <sub>15m</sub>	314	0.89	24.0	37.0
NH <sub>4</sub> NO <sub>3m</sub>	1. Control	311	0.90	24.2	37.2
	2. BisolbiFit	315	0.95	25.4	37.4
	3. N <sub>15</sub> P <sub>15</sub> K <sub>15</sub>	320	1.07	27.8	38.4
	4. N <sub>15</sub> P <sub>15</sub> K <sub>15m</sub>	327	1.08	27.8	38.8
	5. ½N <sub>15</sub> P <sub>15</sub> K <sub>15m</sub>	317	0.97	25.7	37.7
NH <sub>4</sub> NO <sub>3</sub>	1. Control	308	0.89	24.1	37.0
	2. BisolbiFit	313	0.90	24.1	37.3
	3. N <sub>15</sub> P <sub>15</sub> K <sub>15</sub>	317	1.0	26.5	37.8
	4. N <sub>15</sub> P <sub>15</sub> K <sub>15m</sub>	320	1.0	26.3	38.0
	5. ½N <sub>15</sub> P <sub>15</sub> K <sub>15m</sub>	318	0.98	26.5	37.0

The structural indicator “number of grains in a panicle” plays a certain role in yield formation. On average over 3 years of study, the minimum number was

noted in control options of all studied backgrounds, respectively: 23.9 pieces; 24.2 pieces; 24.1 pieces. In all options that used mineral and modified fertilizers were characterized by the largest amount of grains. In the option with biopreparation, the number of grains in a panicle varied from 24.3 to 25.4 pieces.

A direct bond (r=0.97) was noted in the analysis of such indicators as the “number of grains in a panicle” and the “weight of grains in a panicle”. Consequently, these grain quality indicators have similar changes depending on the type of fertilizer.

The weight of 1000 grains characterizes the degree of grain ripeness, density of its tissues and the amount of endosperm in a grain, which impacts sowing and commercial qualities of grain [3, 5]. Over the years of study, the weight of 1000 grains fluctuated in the range of 35.6–38.8 g. Without the use of mineral fertilizers and biopreparation in a zero background it amounted to 35.6 g; 37.2 g in NH<sub>4</sub>NO<sub>3m</sub> and 37.0 g in pure ammonium nitrate. The application of fertilizers positively affected the studied indicator thus increasing its value by 0.8–1.6 g. Compared to the zero background, the weight of 1000 grains after the application of mineral, biomineral fertilizers and biopreparation increased in NH<sub>4</sub>NO<sub>3m</sub> background from 37.2 to 38.8 g and from 37.0 to 38.0 g in NH<sub>4</sub>NO<sub>3</sub> background.

The correlation analysis made it possible to establish the dependence of yield on the main elements of oat yield structure. Such indicators as the “number of productive stems – yield”, “weight of grains in a panicle – yield”, “weight of 1000 grains – yield” and the “number of grains in a panicle – yield” are marked by direct correlation, which coefficients made 0.76, 0.86, 0.88 and 0.81 respectively (Fig. 1).

Grain yield is the main indicator in the evaluation of studied plant cultivation techniques. Its formation largely depends on plant growing conditions. In the process of growth and development, certain requirements are placed on external environmental conditions, which are related to the nature and intensity of physical and biochemical processes. One of the most effective and fast-acting factors improving plant nutrition and increasing oat yield is the use of mineral fertilizers. In recent decades, microbiological preparations, which due to their additional involvement in agrocenosis of the main elements of mineral nutrition, also contribute to the increase of grain productivity of the culture, is considered a promising direction [3, 8].

As a result of our studies over 2016-2018, there was a positive effect of mineral and biomodified fertilizers, as well as biopreparations on the oat yield. On average over 3 years the yield of oats grain (Table 3) varied from 2.15 to 2.71 t/ha, without fertilizers it made 2.24 t/ha, with NH<sub>4</sub>NO<sub>3m</sub> – 2.57 t/ha and NH<sub>4</sub>NO<sub>3</sub> – 2.38 t/ha.

Without the use of mineral fertilizers and biopreparations the grain yield reached 2.15 t/ha, in the background of NH<sub>4</sub>NO<sub>3m</sub> – 2.43 t/ha and in the background of ammonium nitrate in pure form – 2.25 t/ha (Table 3). The use of azophoska increased yields in all studied backgrounds by 0.13, 0.18 and 0.15 t/ha,

respectively. Biomodification of mineral fertilizer ( $N_{15}P_{15}K_{15m}$ ) contributed to further increase of oat yield.

The use of a half-dose biomodified azophoska ( $\frac{1}{2}N_{15}P_{15}K_{15m}$ ) increased grain yields relative to the

absolute control by 0.13 t/ha (background 1), 0.49 t/ha (background 2) and 0.24 t/ha (background 3).

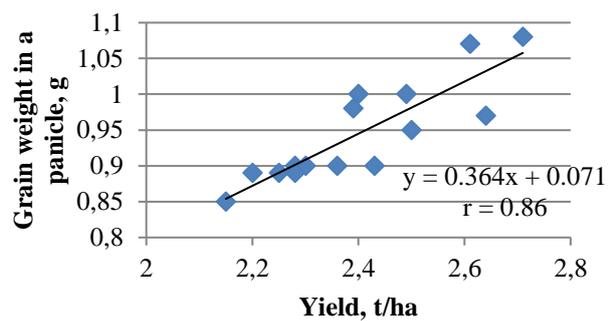
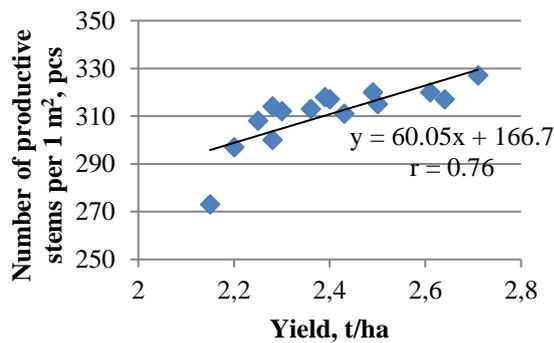
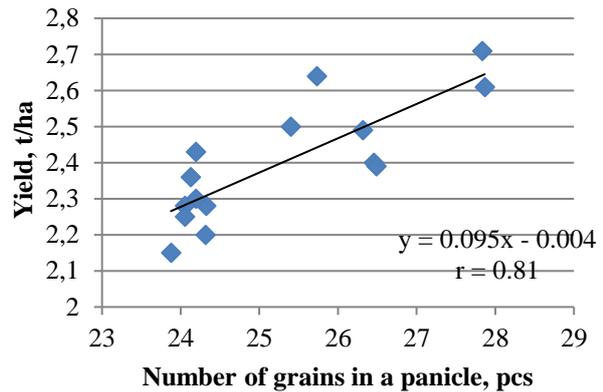
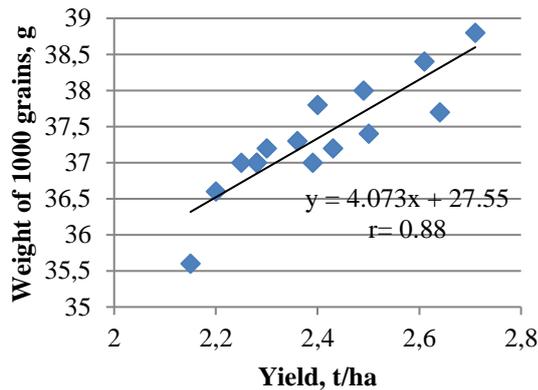


Fig. 1. Dependence of oat yield on yield structure elements, 2016–2018

Table 3. Oat yield depending on fertilizers and biopreparation, 2016–2018

Background	Option	Yield, t/ha	Addition to the control	
			t/ha	%
Zero	1. Control	2.15	–	–
	2. BisolbiFit	2.20	0.05	2.3
	3. $N_{15}P_{15}K_{15}$	2.28	0.13	6.0
	4. $N_{15}P_{15}K_{15m}$	2.30	0.15	7.0
	5. $\frac{1}{2}N_{15}P_{15}K_{15m}$	2.28	0.13	6.0
<b>Average for background</b>		<b>2.24</b>		
$NH_4NO_{3m}$	1. Control	2.43	–	–
	2. BisolbiFit	2.50	0.07	3.0
	3. $N_{15}P_{15}K_{15}$	2.61	0.18	7
	4. $N_{15}P_{15}K_{15m}$	2.71	0.28	12
	5. $\frac{1}{2}N_{15}P_{15}K_{15m}$	2.64	0.21	9
<b>Average for background</b>		<b>2.57</b>		
$NH_4NO_3$	1. Control	2.25	–	–
	2. BisolbiFit	2.36	0.11	5
	3. $N_{15}P_{15}K_{15}$	2.40	0.15	7
	4. $N_{15}P_{15}K_{15m}$	2.49	0.24	11
	5. $\frac{1}{2}N_{15}P_{15}K_{15m}$	2.39	0.05	6
<b>Average for background</b>		<b>2.38</b>		
<b>LSD<sub>05</sub></b> Factor A – 0.05; Factor B – 0.06; Factor AB – 0.12				

It was also found that a higher yield was formed in the background with ammonium nitrate ( $NH_4NO_{3m}$ ) at a dose of 40 kg active ingredient/ha treated with microbiological preparation BisolbiFit.

The efficiency of any crop cultivation approach is characterized not only by yield, but also by the quality of its products. Table 4 shows the assessment of oat quality caused by grain biochemical composition.

Table 4. Oat grain quality over 2016–2018

Option	Weight of 1000 grains, g	Protein, %	Grain-unit, g/l	Hoodness, %
<b>Background 1 – zero</b>				
1. Control	35.6	12.4	470	33.1
2. BisolbiFit	36.6	12.1	472	33.0
3. $N_{15}P_{15}K_{15}$	37.0	11.8	480	29.6
4. $N_{15}P_{15}K_{15m}$	37.2	11.5	478	27.3
5. $\frac{1}{2}N_{15}P_{15}K_{15m}$	37.0	11.6	474	30.0
<b>Background 2 – <math>NH_4NO_{3m}</math></b>				
1. Control	37.2	12.0	478	30.0
2. BisolbiFit	37.4	12.0	482	29.5
3. $N_{15}P_{15}K_{15}$	38.4	11.6	488	27.0
4. $N_{15}P_{15}K_{15m}$	38.8	11.3	490	25.8
5. $\frac{1}{2}N_{15}P_{15}K_{15m}$	37.7	11.3	488	27.2
<b>Background 3 – <math>NH_4NO_3</math></b>				
1. Control	37.0	12.1	474	31.5
2. BisolbiFit	37.3	12.0	478	29.0
3. $N_{15}P_{15}K_{15}$	37.8	11.6	488	27.6
4. $N_{15}P_{15}K_{15m}$	38.0	11.5	486	27.0
5. $\frac{1}{2}N_{15}P_{15}K_{15m}$	37.0	11.6	484	28.0

In the control option the protein content in 3 studied backgrounds made respectively: 12.4, 12.0, 12.1 %. The studies showed that the increased yields led to a certain decrease of protein content in oat grains, which ranged from 11.3 to 12.4 % and on average made 11.8 %. At the same time the lowest values of protein content in grain were observed in 2016 (10.9–11.6 %), which is caused by established conditions of culture vegetation. In 2018, the amount of it in the grain was maximum and varied from 12.4 to 13.2 %.

The correlation analysis showed that the weight of 1000 grains is in positive relation with yield and revealed a negative relation between yield and protein content in oat grain ( $r=-0.76$ ) (Figure 2).

Besides, the assessment of the quality of oat grain shall consider such characteristics as grain-unit and

hoodness. The mineral nutrition of plants also influenced the grain-unit: on average over the years of study it varied from 466 to 490 g/l. In the control option it made 470–478 g/l, in the option with BisolbiFit biopreparation (pre-sowing seed treatment) – 472–482 g/l, in the option with azophoska ( $N_{15}P_{15}K_{15}$ ) – 480–488 g/l, in  $N_{15}P_{15}K_{15m}$  – 478–490 g/l, and in the option  $\frac{1}{2}N_{15}P_{15}K_{15m}$  – 474–488 g/l. In the 2 background with modified ammonium nitrate under pre-sowing cultivation, the largest amount of grain-unit was in option No. 4 ( $N_{15}P_{15}K_{15m}$ ) – the grain was more filled and coarse with a minimum percentage of hoodness compared to other options. It seems that not only films themselves, but also the magnitude of the air voids between them, as well as between shells and seed kernel, are important.

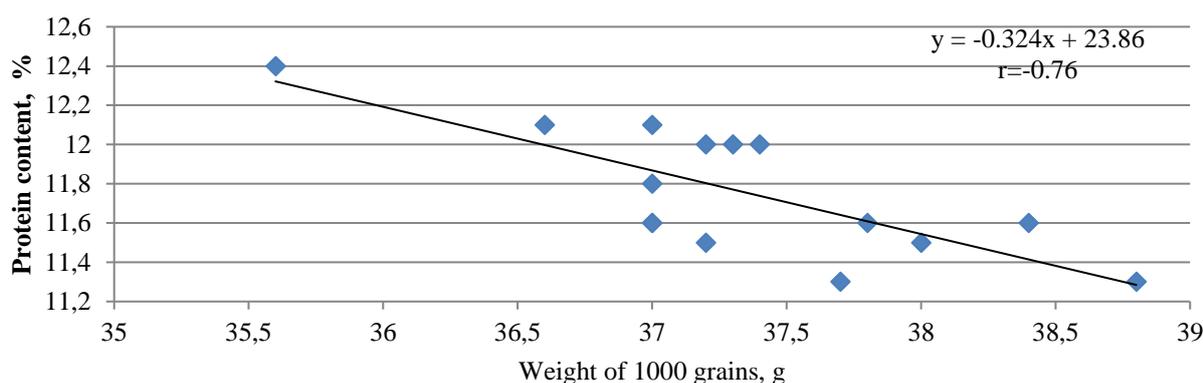


Fig. 2. Dependence of grain protein content on the weight of 1000 grains

Besides, oat availability depends on hoodness. Under different nutritional conditions of a plant this value decreased, its decrease to 27.3 % was observed for option  $N_{15}P_{15}K_{15m}$ . The use of mineral fertilizers and biopreparation influenced grain hoodness, the lowest percentage of hoodness was observed for the option  $N_{15}P_{15}K_{15m}$  in all studied backgrounds and made 27.3 %, 25.8 %, 27.0 %, which is 4–5 % lower than the control. Pre-sowing seed treatment did not have a significant impact on this indicator. The maximum value of grain hoodness was observed in the control option: 33, 30, 31 %.

## 4 Conclusion

1. The use of biomodified Azophoska significantly increased oat grain yield in zero background by 6–7 %, in the background with biomodified ammonium nitrate under pre-plant cultivation by 9–12 % and in the background with ammonium nitrate in pure form – by 6–11 % compared to traditional fertilizers.

2. The correlation analysis made it possible to establish the dependence of yield on the main elements of the oat yield structure. Such indicators as the “number of productive stems – yield”, “weight of grains in a panicle – yield”, “weight of 1000 grains – yield” and the “number of grains in a panicle – yield” are marked by direct correlation, which coefficients made 0.76, 0.86, 0.88 and 0.81 respectively.

3. The mineral nutrition of plants influenced the grain-unit: on average over the years of study it varied from 466 to 490 g/l. The lowest percentage of hoodness was observed for the option  $N_{15}P_{15}K_{15m}$  in all studied backgrounds and made 27.3, 25.8, 27.0 %, which is 4–5 % lower than the control.

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