Implementation of the ecological principle of organic farming in the forest-steppe zone of the Middle Volga region

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Abstract. The researches of cultivation of winter wheat with application of the biologically active substance potassium humate and nitrogen fertilizers of different concentrations N_{20} and N_{40} and their interaction N_{20}+GK and N_{40}+GK showed that potassium humate, without being a mineral fertilizer, increased the crop capacity, nitrogen content in grain, mass proportion of grain protein, nitrogen content in grain protein, Grain nutrition and quantity of gluten were the same as nitrogen fertilizers in concentrations of N_{20} and N_{40}, and had comparable values for grain protein mass fraction, nitrogen removal with grain protein, grain nutrition and quantity of gluten; it also showed decrease for yield and nitrogen removal with grain of the crop up to 12% under simultaneous action of N_{20}+GK and N_{40}+GK. The application of potassium humate is ecologically and economically profitable from all the presented options, moreover the value of the crop yield is comparable with the applied nitrogen fertilizers in the concentrations of N_{20} and N_{40}. In view of economic component of agricultural production in conditions of forest-steppe zone of Middle Volga region at the present time intensive system of agriculture with elements of biologization is possible.

1 Introduction

Based on the principle of ecologization in organic farming, it is assumed that agricultural production should be carried out within the natural ecological system and natural life cycles. Agriculture should not radically transform the environment [1, 2]. Therefore, the agricultural producer should focus on the use of organic fertilizers, biological means of plant protection and medicines for animals. Currently, in agricultural production prevails integrated intensive farming system with elements of biologization [3-6]. This is due primarily to the fact that the transition to organic farming will lead to a decrease in crop yields by an average of one-third [7, 8], which is unacceptable, since the growth of the population of the planet. Therefore, it is important to choose this approach in obtaining crops to produce high yields and without loss of quality, using resource-saving technologies and justified-necessary fertilizers or substances for growth and development [9-11]. Also, organic farming can be more

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destructive to the environment than traditional agriculture, as it must be cultivated on a large area to produce the necessary volume of products [12, 13].

Therefore, in solving the above problems it is necessary to substantiate the optimal directions of development of agriculture and the agro-industrial complex as a whole, presenting them in the form of environmental and economic foundations of production [14, 15].

Winter wheat is one of the most valuable food crops. Its grain is characterized by high protein content and excellent baking qualities [16, 17].

The aim of the research is to study the effect of different concentrations of nitrogen fertilizers and potassium humate, as well as their combined action on the yield and quality of winter wheat grain to determine the ecological and economic cost-effective and profitable production.

2 Materials and methods

The studies were carried out in 2020-2022 in the experimental field of the laboratory "Agroecology" located on the land use of the former training farm of the Samara SAU, which is located in the central zone of the Samara region or the southern part of the forest-steppe zone of the Middle Volga region. Cultivation was carried out according to the technology generally accepted in the region. In the experiments, elite dressed seeds of released variety of winter wheat Volga 86 were sown [18].

In the tillering phase, Prima herbicide in a dose of 500 ml/ha was used against annual dicotyledonous weeds in all experimental variants. Harvesting was carried out with a TERRION plot harvester in the phase of full grain ripeness.

The experiment used the conventional technology of winter wheat cultivation, sowing was carried out in the second decade of August 2020-2021. The area of plots was 2 hectares. 5.0 million germinated seeds per 1 ha were sown. Experiment scheme is presented in table 1.

Calculation of fertilizer doses was carried out depending on the level of nitrogen content in the soil and for the planned yield. Ammonium nitrate fertilization was carried out by spreading. Potassium humate was applied in the phase of winter wheat plants emerging in the tube by spraying a tank mixture with herbicide Prima Forte, SE with a working solution of 200 l/ha.

Ammonium nitrate (NH_4NO_3) is a highly concentrated granular nitrogen fertilizer. It is produced by neutralizing nitric acid with ammonia gas and then granulating the product. It contains nitrogen in two forms: ammonium and nitrate, 17% each. Universal nitrogen fertilizer can be used as a pre-sowing fertilizer and as a top dressing. Especially effective for early spring fertilizing of winter crops.

Biologically active potassium humate is a source of humic compounds that make up the main share of soil humus which plays a crucial role in fertility. Potassium humate is produced by processing valuable organic raw materials – lowland peat. The composition of this potassium humate: humic acids – 70%, fulvic acids – 15%, potassium – up to 5 g/l, pH – 9-12. Potassium humate increases the germination of seeds and accelerates their development; increases plant resistance to stress caused by drought, salinity, pesticides and mineral fertilizers as well as activates the processes of restoration and preservation of soil fertility.

Field experiments were accompanied by accompanying observations, laboratory-field analyses and studies.

In agrochemical analysis of soil, easily hydrolyzable nitrogen was determined according to I.V. Tyurin and M.M. Kononova, mobile phosphorus and exchangeable potassium according to V.F. Chirikov in modification of CINAO [20]. Humus content was determined

by I.V. Tyurin's method at the Department of Agrochemistry, Soil Science and Agroecology, Samara State Agrarian University [19].

Grain yield accounting was done by direct harvestering with Vector harvester.

Determination of chemical and technological qualities of grain was carried out according to the method of state variety testing of crops (GOST 9353-2016) [20-22].

Calculation of bioenergy efficiency was carried out by the method of Rabochev G.I. (2005) [23].

Calculation of economic efficiency of research results was carried out by the method developed by the Department of Economic Theory and Economics of Agroindustrial Complex of Samara State Agrarian University [23, 24].

3 Results and discussion

The results of the research on winter wheat of Povolzhskaya 86 variety, yield, grain protein content, natural weight and gluten content, as well as the calculation of nitrogen removal with grain and protein are presented in Table 1.

Table 1. Yield, protein content, natural weight, gluten content and nitrogen export with protein and grain of winter wheat, on average for 2020-2022.

Schematic of experience	Yield, t/ha	Nitrogen removal with grain, kg/t	Mass fraction of protein, %	Nitrogen removal with protein, kg/ha	Natura, g/l	Gluten content, %
Without fertilizer	2.93	108.4	13.9	43.7	732	27.5
Ammonium nitrate N20	3.27	121.0	14.7	46.0	740	29.4
Ammonium nitrate N40	3.38	125.1	14.8	46.3	742	29.5
Fertilizer average	3.33	123.1	14.7	46.2	741	29.4
Potassium humate (PH)	3.32	123.8	14.7	46.2	738	29.3
Ammonium nitrate N20 + PH	3.67	135.8	14.9	46.6	743	29.7
Ammonium nitrate N40 + PH	3.76	139.1	15.0	46.9	745	30.0
Fertilizer average + PH	3.72	137.4	14.9	46.7	744	29.8
Coefficient of variation by experimental variants V, %	17	–	7	–	11	12

The yield of winter wheat in three years of research in the variant without fertilizers was 2.93 t/ha. Nitrogen fertilizers in concentrations of N_{20} and N_{40} increased the yield compared with the variant without fertilizers by 11.6% and 15.4%, respectively. On average, the application of nitrogen fertilizers, compared with unfertilized background, increased the yield by 13.7%. The treatment with biologically active potassium humate increased the yield by 13.3%, the combined effect of nitrogen fertilizers and potassium humate – by 27%, compared to the variant without fertilizers.

Thus, the highest yield capacity of winter wheat was noted in the variant with simultaneous application of nitrogen fertilizers N_{40} and potassium humate; the yield capacity was lower by 2.5% when ammonium nitrate N_{20} and potassium humate were used together, 5%, while using bioactive potassium humate, ammonium nitrate in the concentration of N_{20}, N_{40} and the variant without fertilizers yield capacity was lower by 13.6%, 11.2%, 15% and 28.3%, respectively.

Nitrogen removal with grain of winter wheat harvest obtained over the years of the study had the lowest value in the variant without fertilizers – 108.4 kg/t. Application of nitrogen fertilizers in concentration of N_{20}, N_{40} and potassium humate increased nitrogen removal with grain harvest by 14.2%; combined action of ammonium nitrate N_{20} and ammonium nitrate N_{40} increased by the highest value of removal, by 26.7%.

The mass fraction of white of winter wheat grain obtained during the study years had the lowest value in the variant without fertilizers – 13.9%; the application of nitrogen fertilizers in concentration of N_{20}, N_{40} and potassium humate increased the content of protein by 5.4%; the joint action of ammonium nitrate N_{20}+kali humate and ammonium nitrate N_{40}+kali humate increased the content of protein by the greatest value – 6.7%.

Thus, compared with the variant without fertilizers options with the use of nitrogen fertilizers N_{20}, N_{40} and potassium humate protein content had comparable values. The combined application of the nitrogen fertilizers N_{40} + potassium humate and N_{20} + potassium humate had the greatest positive effect on this indicator, increasing its value by 6.7%, compared with the nitrogen fertilizer in the concentration of N_{20}, N_{40} and potassium humate.

Nitrogen removal with grain protein obtained in three years of research had the lowest value in the variant without fertilizers – 43.7 kg/t, the use of nitrogen fertilizers in the concentration of N_{20}, N_{40} and potassium humate increased nitrogen removal with grain harvest by 5.7%, the combined effect of ammonium nitrate N_{20} + potassium humate and ammonium nitrate N_{40} + potassium humate by the highest value – 6.9%.

Grain natura or natura weight is its mass in a certain volume. One of the most common indicators of the quality of wheat, associated with a number of characteristics - the performance, density, coarseness and shape of the grain. Flour yield depends on this indicator, but it is also affected by impurities and moisture [18]. Natural grain weight determined depending on different fertilizers had close values, changing insignificantly.

Amount of gluten was the lowest in the variant without fertilizers 27.5%, the use of nitrogen fertilizers in concentration of N_{20}, N_{40} and potassium humate increased the amount of gluten by 5.5%, the combined effect of ammonium nitrate N_{20} + potassium humate and ammonium nitrate N_{40} + potassium humate was the greatest amount - 8.4%.

The influence of potassium humate was comparable with the effect of nitrogen fertilizers in concentrations of N_{20} and N_{40} on the studied indicators. The combined application of the nitrogen fertilizers N_{40}+potassium humate and N_{20}+potassium humate had a greater positive effect on the crop yield, nitrogen removal with grain yield, mass fraction of grain protein, nitrogen removal with grain protein, Grain sodicity and quantity of gluten, increasing their value as compared with the influence of potassium humate by 12%, 11%, 1.4%, 1.1%, 0.4%, 1.7%, respectively, showing a significant difference by the indices of crop capacity and nitrogen absorption with grain of the crop.

Thus, potassium humate, without being a mineral fertilizer, increased the crop capacity, nitrogen absorption with grain, mass fraction of grain protein, nitrogen absorption with grain protein, body of grain and gluten quantity by the same value as nitrogen fertilizers in concentrations of N_{20} and N_{40}, and had comparable values for indices of grain protein mass fraction, nitrogen removal with grain protein, grain nature and quantity of gluten, showed considerable difference for indices of yield and nitrogen removal with grain yield up to 12% with the joint action of N_{20}+potassium humate and N_{40}+potassium humate.

According to the represented characteristics, biologically active potassium humate having minimal influence on the nature had the same effect as the used fertilizers but yield and nitrogen removal with grain of the crop up to 12% lower than N_{20}+potassium humate and N_{40}+potassium humate.

Table 2 presents the results of ecological and economic evaluation of effectiveness of ammonium nitrate and potassium humate application on winter wheat crops during the study period.

Table 2. Ecological and economic evaluation of the effectiveness of ammonium nitrate and potassium humate application to winter wheat crops, on average for three years of research.

Indicators	Variants					
	Without fertilizer	**Ammonium nitrate N_{20}**	**Ammonium nitrate N_{40}**	**Potassium humate (PH)**	**Ammonium nitrate N_{20} + PH**	**Ammonium nitrate N_{40} + PH**
Yield, t/ha	2.93	3.27	3.38	3.32	3.67	3.76
Sales price, t/rub.	9000					
Cost of output, rub./ha	27180	30240	31320	29790	34110	35190
Cost equivalent of reduced soil fertility, rub./ha	8120	6400	6486	7200	5600	6020
Cost of production, including the cost of restoring soil fertility, rubles/ha	18791	20475	21596	19453	21677	22798
Cost per ton, rub.	5720	5831	6094	5877	6206	6222
Profit, rub/ha	8389	9724	9762	10337	12433	12392
Profitability level,%	57.4	53.1	47.7	54.4	46.7	44.6

Variants without fertilizers and the application of potassium humate, compared with all other variants, had the same selling price, the lowest values on the indicators presented in Table 2, and the level of profitability was the highest. These variants are the most ecologically and economically profitable of all presented variants, although the variant without fertilizers had the lowest yield, and at application of potassium humate the value of the yield was comparable with the application of nitrogen fertilizers in the concentration of N_{20} and N_{40}.

4 Conclusion

When comparing all variants of fertilizers' application the variants of combined action of nitrogen fertilizers N_{40}+ PH and N_{20}+ PH had positive effect to get the increased yield, differing in values by 2.5%. The variants with the application of the nitrogen fertilizers N_{20}, N_{40} and potassium humate showed the lower yield values than combined application of fertilizers and potassium humate by 13.6%, 11.2% and 15%; they were slightly different and had comparable values.

Application of nitrogen fertilizers N_{20}, N_{40} and potassium humate by values of protein content had comparable values. The combined application of the nitrogen fertilizer N_{40} + PH and N_{20} + PH had the greatest positive effect on this indicator, increasing its value by 6.7%, compared with the nitrogen fertilizer in the concentration of N_{20}, N_{40} and potassium humate.

The influence of potassium humate was comparable with the effect of nitrogen fertilizers in concentrations of N_{20} and N_{40} on the studied indicators. The combined application of the nitrogen fertilizers N_{40}+potassium humate and N_{20}+potassium humate had a greater positive effect on the crop yield, nitrogen removal with grain – by 12%, 11%, and on the grain protein mass fraction, nitrogen removal with grain protein, grain natures and the amount of glue - by 1.4%, 1.1%, 0.4%, 1.7%, respectively, showing a slight difference in the indicators compared to the effect of potassium humate.

The biologically active substance potassium humate having minimal influence on the nature promoted the same effect by the studied parameters as the used fertilizers and yield and removal of nitrogen with grain yield up to 12% in comparison with joint action of N_{20}+ PH and N_{40}+ PH.

According to the presented indicators, variants without fertilizers and application of potassium humate, in comparison with all other variants, had the same selling price, the lowest values on other indicators, and the level of rentability was the highest. These variants are the most ecologically and economically profitable of all presented variants, although the variant without fertilizers had the lowest yield, and at application of potassium humate the value of the yield was comparable with the use of nitrogen fertilizers in the concentration of N_{20} and N_{40}.

Principles of organic farming, in particular organic, currently in the forest-steppe of the Volga region, cannot be fully implemented on the economic component, only partial implementation, approximation and aspiration for their implementation is possible.

The researches on application of biologically active potassium humate, different concentrations of nitrogen fertilizers and their joint action showed that potassium humate, not being a mineral fertilizer, increased the crop capacity, nitrogen removal with grain of the crop, mass fraction of grain protein, nitrogen removal with grain protein, Grain nutrition and quantity of gluten were the same as nitrogen fertilizers in concentrations of N_{20} and N_{40}; they also had comparable values according to such indices as grain protein mass fraction, nitrogen removal with grain protein, grain nutrition and quantity of gluten; it showed decrease in crop capacity and nitrogen removal with grain of the crop up to 12% due to combined action of N_{20}+kali and N_{40}+kali nutrient.

The use of biological preparations in the recommended amounts at negligible cost leads to higher yields with good quality and is a promising alternative to replace mineral fertilizers.

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