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The efficiency of humic growth stimulators in pre-sowing seed treatment and foliar additional fertilizing of sown areas of grain and industrial crops

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Abstract. The aim of the research was to establish the effectiveness of preparations, made on the basis of humic and fulvic acids on the yields of crops in case of different methods and amounts used. The experiments were held with varieties and hybrids of winter wheat, soya, corn, and sunflower. Based on the obtained results of investigation during the period of 2015–2017, the positive impact of foliar additional fertilizing with 4R Foliar Concentrate growth stimulator on the basis of humic and fulvic acids on the formation of productivity of the main crops sown areas was established.
Proceeding from the results of the research, the using of growth stimulators based on humic and fulvic acids, which contain high concentrations of these substances, can be recommended as an expedient and efficient measure of raising the productivity and improving qualitative indicators of corn, sunflower, soya, and winter wheat yields.

Key words: fertilizing, humic substances, plant development, seed treatment.

INTRODUCTION

Modern development of plant production output requires solution of the problem of stable increase of agricultural crops' yield with simultaneous preservation of soil resources. Application of growth stimulators has become very active today. They give an opportunity to open genetic potential of plants in a better way, to use fertilizers and means of plants protection more efficiently, that results in improving stability of agricultural crops' yield. Growth stimulators are highly important for increase of plant resistance to the stress situations such as moisture deficit, unfavourable temperature conditions, aftereffect of pesticides etc.

Preparations made on the basis of humic substances occupy the original place among a great number of plant growth stimulators. Favourable action of humic substances has been known for a long time. They activate nutrient uptake by plants, raise the coefficient of useful elements from mineral fertilizers, intensify soil micro-flora activity, activate synthesis of proteins, carbohydrates and vitamins in plants, increase plant resistance to radiation as well as to low and high temperatures. Humic substances decrease penetration of heavy metals and pesticides into plants, activate their growth, increase productivity, improve production quality and accelerate harvest ripening.

ANALYSIS OF THE LATEST PUBLICATIONS

Manure, composts, vermicomposts, and other organic substances are the source of humic acids for soil. They have the direct (raising the yield) and indirect impact (improving soil fertility). Thanks to organic substances the mineral composition of soil improves, its compaction decreases, and the amount of water increases. At the same time, humic substances stimulate growing root system and activate anti-stress plant systems (Garcia et al., 2014; Tahiri et al., 2014).

Considering rapid intensification and improving cultivation technologies, recently taking place in Ukraine, the reproduction of soil organic component becomes very important, because there is a real threat of losing the fertile potential of these lands. It is rather problematic to replenish the organic component in our conditions, as one of the main branches (livestock farming), which is the source of organic substances, is in a crisis condition because of considerably lower profitability of production comparing to plant growing (Minkova et al., 2016).

The preparations, received on the basis of humic and fulvic acids are one of the sources of replenishing soils with nutrients of organic origin. There are quite a lot of such substances on the market of growth stimulators in Ukraine, but their using on the farms of different size and level of production has certain specifics. First of all, they are mainly characterized as plant growth stimulators proper, which are recommended to be used for pre-sowing seed treatment and foliar fertilization.

On the other hand, the recommended amount, doses, and concentration of the substances, the compatibility and expediency of using in mixtures etc. are to be investigated. In generalized scientific reviews it is noted, that the market of growth stimulators is developing extremely dynamically, but many scholars consider these preparations not objectively and scientifically evaluated (Calvo et al., 2014).

The content of soil organic component is one of the most important indicators of its quality, potential, and suitability to growing crops, and, thus, it requires replenishment (Rosa et al., 2017). One of the solutions to this problem is using humic substances and preparations made on their basis. So, for example, humic substances, received from manure, are wonderful supplement to mineral fertilizers, which ensures effective using of nutrients and improves the development of plants (Baldotto et al., 2017). Nevertheless, the results of research presented in scientific literature, show different effectiveness of using such substances in cultivating crops depending on the origin of raw products, molecular structure of humic acids, soils or even the absence of influence or negative reaction of plants (Leventoglu & Erdal, 2014; Martinez-Balmori et al., 2014; Kalinichenko et al., 2014; Savy et al., 2016; Conselvanet al., 2017; Oliveira et al., 2017).

One of the first technological methods of growing crops is pre-sowing seed treatment and using preparations made on the basis of humic acids complex, which can be a considerable prerequisite of managing harvest from the initial stages of plant development. The treatment of corn seeds with the humic preparation Volume Humykos (18% of humic acid content) in the experiments of Brazilian scholars positively affected the germination rate, growth intensity, the length of sprouts and roots, while plant dry weight also increased considerably (Rodrigues et al., 2017). Though, as some authors note, raw products, from which humic acids were obtained, and also their concentrations and the type of soil are important for seed treatment (Melo et al., 2015).

In laboratory experiments, adding humic acids in the nutrient substrate for corn sprouts resulted in doubling the number of leaves and the length of roots (Sun et al., 2016).

In scientific publications of Russian scholars it is noted, that ultra-disperse using of humic acids in vitro resulted in better seed germination by 3.4%, and in field experiment, the difference was 10.2% as compared with the control group. Moreover, the plant weight increased by 11.5%, the leaf area increased by 5.1% and photosynthesis pure productivity – by 13.4% in comparison with the control group (Churilov et al., 2015). In other laboratory experiments, the treatment of 11-day plants with humic substances, received from different leonardites, resulted in positive effect: nitrogen metabolism accelerated, and as a result, plant growth improved (Oliveira et al., 2017).

Using humic acids favors better formation of corn yield under the conditions of water or nutrient stress or in case of soil pollution with heavy metals (Santos et al., 2014; Zhang et al., 2014; Moghadam et al., 2016).

The pre-sowing treatment of soya seeds with preparations, containing the complex of humic and fulvic acids (ligno-humate, lexin and adding them to treatment mixtures) favors not only yield increasing, but also improving the product quality, in particular, oil output (Prochazka et al., 2016). On poor sandy soils the reaction of soya on organic-mineral fertilizers, containing humic substances, was noticed concerning plant height, dry weight of root system, and, as a result, the yield. Almost the same positive effect of humic preparations was noticed under the conditions of salt and water stress (Muhammad et al., 2013; Dinler et al., 2016; Prado et al., 2016a; Prado et al., 2016b; Tuncturk et al., 2016; Matuszak-Slamani et al., 2017; Rosa et al., 2017).

Some scholars note, that although humates are distinguished by their compactness and convenience in using, their effect is inferior to the impact of organic fertilizers, in particular, manure (Daur, 2013), but combining pre-sowing seed treatment with foliar fertilizing leads to increasing soya yields by 8% (Lingaraju et al., 2016).

Using humic acids on poor soils is also effective on the sown areas of sunflower. Besides increasing biometric indices of plants, soil properties also improve and yield stability grows (Sadiq et al., 2014; Baldotto et al., 2015). In Romania using organic-mineral fertilizer, combining nitrogen, phosphorus, microelements (Fe, Cu, Zn, Mg, Mn, B), and potassium humate enabled to raise the yield by 14.4% (Parvan et al., 2013).

It is assumed, that anti-stress action of humic acids may be noticed in their participation in creating plant waxes, which explains softening effect of humic substances in stress conditions (Kulikova et al., 2014).

The experience of using humic acids on wheat in the amount of 2 kg ha^{-1} with microfertilizers containing Cu and Zn enabled to raise the yield of grain by 20.2%, and the output of general biomass grew by 17.1%. Using these substances separately increased wheat yield only by 6.52–7.52% (Manzoor et al., 2014). Under the conditions of salt stress, humic acids considerably decrease the entry of harmful amounts of elements in plants, in particular, sodium, leaving unchangeable the assimilation of other nutrients (Asik et al., 2009; Jamal et al., 2011; Jarosova et al., 2016). Such properties of humic acids make their using promising in organic cultivation of wheat (Muhammad et al., 2013).

The aim of the research was to establish the effectiveness of preparations, made on the basis of leonardite, on the yields of crops in case of different methods and amounts of using. 4R Foliar Concentrate has humic acids content of 90.06%. Nitrogen content is 1.14%; phosphorus content is 0.02%, P_2O_5 – 0.05%; potassium content is 0.02%; calcium content is 0.62%; sulphur content is 0.42%; sodium content is 0.07%; magnesium content is 0.17%. Besides, the preparation consists of nearly sixty microelements, including rare-earth ones, so the total content of microelements is about 5%.

MATERIALS AND CONDITIONS OF RESEARCH

Research was conducted during 2015–2017 on the experimental field of Poltava M.I. Vavilova State Agricultural Experimental Station of the Institute of Pig-Breeding and Agro-Industrial Production of the National Academy of Agrarian Sciences of Ukraine in the village of Stepne of Poltava district. This is the central part of the Eastern Forest-Steppe of Ukraine, almost on the conventional border with the Northern Steppe and Southern Forest-Steppe – the zone of insufficient moistening.

The soil is typical black, low-humic, heavy loamy clay (AU-BCA-Cca), the arable layer of which is characterized by the following agrochemical and agro-physical indices: humus content – 4.9–5.2%; easily hydrolyzed nitrogen (according to Turin and Kononova) – 119.1–127.1 mg; P_2O_5 in acetic acid extract (according to Chirikov) – 100.0–131.0 mg; exchangeable potassium (according to Maslova) – 171.0–200.0 mg per 1 kg of soil. Soil density is 1.05–1.17 g cm^{-3}. General layering is 55.5–59.8%. The least soil moisture is about 29.7–31.5%. The full soil moisture is about 39%. The range of active moisture is about 25 mm. The moisture of capillary connection disruption is 20–22%. According to the mechanical composition typical black soil with low humus content is heavy loam. Content of dust-like particles with size less than 0.25 mm is 9.4%, content of agronomic valuable aggregates (particle size is 0.25–10 mm) is 74.6%, content of lumpy ones (aggregates > 10 mm) is 16.0% in the soil layer of 0–30 cm. (Stolbovoy & Sheremet, 2000; World Reference base for Soil Resources, 2014)

Under such agrochemical and physical indicators, such type of soil is considered to be one of the best as to the level of fertility in Ukraine (Patyka et al., 2014).

The description of the weather conditions is given in the Table 1.

Table 1. Average weather data during the 2015–2017 crop year

Indicators	September	October	November	December	January	February	March	April	May	June	July	August	Total per year
	Air temperature, °C												
Average monthly	19.9	6.4	4.7	0.6	-7.1	0.9	4.3	13.2	16.6	21.1	23.5	22.4	10.5
Average annual	14.5	7.6	1.7	-3.4	-5.6	-4.9	0.7	9.3	15.7	19.4	21.2	20.1	8.0
± to average annual	5.4	-1.3	3.0	2.8	-1.5	4.0	3.6	3.9	0.9	1.7	2.3	2.3	2.5
	Precipitation, mm												
Monthly	3.3	1.2	54.6	40.1	85.9	31.5	74.5	45.6	115.0	26.1	30.1	200.2	708.1
Average annual	45.9	41.3	40.4	42.0	40.5	32.8	30.7	31.2	45.5	65.2	61.1	42.7	519.3
± to average annual	-42.6	-40.1	14.2	-1.9	45.4	-1.3	43.8	14.4	69.5	-39.1	-31.0	157.5	188.8

The weather conditions of vegetation period in 2015 (not uniform distribution of precipitation and active temperatures) to some extent negatively influenced plant growth, development, and grain yield formation. Arid summer and particularly July, August, and the first two autumn months were not favorable for moisture accumulation in the soil. In September and October the precipitation level was correspondingly 7.2 and 2.9% of the average index during many previous years, and the average air temperature in September was 5.4 °C higher than usually, and in October, on the contrary, it was 1.2 °C lower.

During the winter the average temperature of air was 1.9°C below zero or it was 2.7 °C higher than usually.

During the spring period of 2016, the actual average daily air temperature in March, April, and May was higher than usually on 3.6, 3.9, and 0.9 °C correspondingly. In June and July, the actual precipitation levels were 26.1 and 30.1, which are 2.5 and 2.0 times less, than the indices during many previous years.

Intensive rains at the end of summer, particularly in August and rainless, warm weather in September enabled to conduct autumn field work in optimal terms, including the sowing of winter crops, the vegetation of which continued practically to the end of October. However, at the same time, the autumn was somewhat colder, than usually for many years, especially it concerns October and November.

The precipitation during this period was also not regular. In particular, in September it was only 4.9 mm or 40.9 mm less, than usually, and in October and November – 1.4 and 55.7 mm correspondingly more.

The temperature rate during December 2016 and January 2017 was higher in comparison with average indices for the previous many years on 0.3 and 0.9 °C correspondingly, and in February it grew on 1.6 °C. During the spring period the precipitation was 21.6 mm less than usually. The total amount of precipitation during the summer months was 58.3 mm, while usually it was 169.0 mm, which is on 110.7 mm less. On the whole during the agricultural year the average temperature of air was on 1.1 °C higher, and the precipitation was on 103.0 mm less. Thus, the experiments were conducted in difficult weather conditions, which enabled to establish the effectiveness of the preparations and investigate their anti-stress action.

METHODS OF RESEARCH

The experiment was conducted during the period of 2015–2017. The experiments were held with varieties and hybrids of winter wheat, soya, corn, and sunflower. The number of experiment replication – three times. The distribution of variants was random. The results of investigating the variants of the experiment block, in which foliar application of 4R Foliar Concentrate stimulator was used, are presented in this article. Ammonium nitrate was applied by broadcasting over frozen-melted soil, and growth stimulator – by foliar additional fertilizing of the sown areas with a sprayer.

The variants of the experiment:

- for ***winter wheat:*** 1 – control group (without treatment of seeds by growth stimulators only by complex against pests and diseases); 2 – root additional fertilizing with ammonium nitrate (150 kg ha^{-1}); 3 – root additional fertilizing with ammonium nitrate (100 kg ha^{-1}); 4 – root additional fertilizing with ammonium nitrate (100 kg ha^{-1})+ foliar additional fertilizing of the sown area with 4R Foliar Concentrate in the phase of spring tillering (2 kg ha^{-1}); 5 – foliar additional fertilizing of the sown area with 4R Foliar Concentrate in the phase of spring tillering (1 kg ha^{-1}); 6 – foliar additional fertilizing of the sown area with 4R Foliar Concentrate in the phase of spring tillering (2 kg ha^{-1}); 7 – foliar additional fertilizing of the sown area with 4R Foliar Concentrate (1 kg ha^{-1}) in the phase of spring tillering and repeated foliar additional fertilizing of the sown areas with 4R Foliar Concentrate in the phase of spike formation beginning (1 kg ha^{-1}) (the variety of winter wheat – Vatazhok; the proceeding crop – soya; the sown area of the experimental plot – 0.15 ha, the record plot – 100 m^2);
- for ***corn: the main fertilization*** $\mathbf{N_{40}P_{40}K_{40}}$ 1 – control group (without using the preparation); 2 – foliar additional fertilizing of the sown area in the phase of 3–5 leaves with 4R Foliar Concentrate (1 kg ha^{-1}); 3 – foliar additional fertilizing of the sown area in the phase of 3–5 leaves with 4R Foliar Concentrate (2 kg ha^{-1}); 4 – foliar additional fertilizing of the sown area in the phase of 3–5 leaves with 4R Foliar Concentrate (1 kg ha^{-1}) and repeated foliar additional fertilizing of the sown area in the phase of 10 leaves with 4R Foliar Concentrate (1 kg ha^{-1})(corn hybrid Marsel; the proceeding crop – soya; the sown area of the experimental plot – 0.18 ha, the record plot – 35 m^2);
- for ***soya: the main fertilization*** $\mathbf{N_{15}P_{15}K_{15}}$ 1 – control group (without using the preparation); 2 – foliar additional fertilizing of the sown area with 4R Foliar Concentrate (1 kg ha^{-1}) in the phase of 2–3 ternate leaves; 3 – foliar additional fertilizing of the sown area with 4R Foliar Concentrate (2 kg ha^{-1}) in the phase of 2–3 ternate leaves; 4 – foliar additional fertilizing of the sown area with 4R Foliar Concentrate (1 kg ha^{-1}) in the phase of 2–3 ternate leaves and repeated foliar additional fertilizing of the sown area with 4R Foliar Concentrate (1 kg ha^{-1}) in the phase of budding – beginning of blossoming(soya variety –Bilosnizhka; the proceeding crop – winter wheat; the sown area of the experimental plot – 0.17 ha, the record plot – 100 m^2);

- for ***sunflower: the main fertilization*** $\mathbf{N_{30}P_{30}K_{30}}$ 1 – control (without using the preparation); 2 – foliar additional fertilizing of the sown area in the phase of 2–3 pairs of leaves with 4R Foliar Concentrate (1 kg ha^{-1}); 3 – foliar additional fertilizing of the sown area in the phase of 2–3 pairs of leaves with 4R Foliar Concentrate (2 kg ha^{-1}); 4 – foliar additional fertilizing of the sown area in the phase of 2–3 pairs of leaves with 4R Foliar Concentrate (1 kg ha^{-1}) and repeated foliar additional fertilizing of the sown area in the phase of budding with 4R Foliar Concentrate (1 kg ha^{-1}) (sunflower hybrid KC-108; the proceeding crop – winter wheat; the sown area of the experimental plot – 0.18 ha, the record plot – 35 m^2).

Variant placing in the experiments was random; repetition was three times. The farming system is conventional. The results of the research were processed using the method of multivariate disperse analysis.

RESULTS AND DISCUSSION

The analysis of the above presented theoretical material testifies about certain debatable problems. The distributors of the preparations categorically support the expediency of using humates, but lately, this method has been criticized in publications of practical character, as stated in the Ukrainian production journals. The main argument of the criticism is the unnatural method of using humic preparations for vegetative surfaces, as they must be in contact with the underground part of the plant.

Indeed, from the view point of the formation and functioning of humic acids this approach would be undisputable, but in such case physical-chemical properties of humates are ignored, in particular, considerable decreasing the solution surface tension force. As foliar additional fertilizing of plants has already been scientifically substantiated and confirmed in practice, it would be logical to foresee better availability of nutritious elements in case of using this group of preparations in mixtures with fertilizers. It should also be added, that the property of humic acids to transform nutritious macro- and microelements in the forms accessible to plants, is the peculiarity of these substances.

Humates are also surface active substances, which decrease the surface tension force, creating uniform distribution of solutions on the leaf surface and, thus, assisting in better assimilation of other substances. If humic preparations contain micro-elements, in such case there is no need to use micro-fertilizers, which is one of the sources of economizing.

As to the influence on the yield of winter wheat, foliar additional fertilizing of the sown area with 4R Foliar Concentrate in the concentration of 1 kg ha^{-1}in the phase of spring tillering was at the same level comparing to root additional fertilizing with ammonium nitrate in the amount of 100 kg ha^{-1}. Increasing the dose of 4R Foliar Concentrate preparation from 1 to 2 kg ha^{-1} ensured increasing grain yield on 0.13 t ha^{-1} or by 3.4% comparing to the option №5 and by 15.7% comparing to the control variant. The maximal crop grain yield was obtained in case of double foliar additional fertilizing of the sown area with 4R Foliar Concentrate in the phase of spring tillering (2 kg ha^{-1}) and in the phase of beginning spike formation (2 kg ha^{-1}) (Table 2).

The economic calculations confirmed a high effectiveness of additional fertilizing the sown area of winter wheat both with ammonium nitrate and 4R Foliar Concentrate growth regulator on the basis of humic and fulvic acids. Thus, the highest profitability of this element of the technology – 310% and 282% was in case of foliar additional fertilizing of the sown areas with 4R Foliar Concentrate (1.0 kg ha^{-1}) in the phase of spring tillering and 2 kg ha^{-1} of 4R Foliar Concentrate in the phase of spring tillering and 2 kg ha^{-1} in the phase of spike formation beginning. The profitability of root additional fertilizing with ammonium nitrate in the amount of 100 and 150 kg ha^{-1} was equal to 111% and 155% correspondingly. Changing a part of nitrogen in mineral fertilizers (33%) by foliar additional fertilizing with 4R Foliar Concentrate in the phase of spring tillering (2 kg ha^{-1}) was also economically effective, the profitability was 135%.

Table 2. Grain yield of winter wheat with different technologies of additional fertilizing of the sown areas

Variant	Coefficient of tillering, stems per one plant, piece	Number of grains per one plant, piece	Weight of grain per one plant, g	Plant height, cm	Yield, tha^{-1}	± comparing with the control	
						t ha^{-1}	%
1.	1.7	56.3	2.6	82.4	3.38	–	–
2.	2.3	75.2	3.5	97.3	4.05	0.67	19.8
3.	2.1	69.3	3.3	94.3	3.75	0.37	10.9
4.	2.3	75.9	3.6	97.5	4.25	0.87	25.7
5.	2.1	68.3	3.2	92.8	3.78	0.40	11.8
6.	2.1	69.5	3.3	93.9	3.91	0.53	15.7
7.	2.3	77.2	3.7	97.1	4.87	1.49	44.1
$LSD_{0.95}$					0.34	–	–

The difference between the experimental variants of foliar additional fertilizing the sown areas with 4R Foliar Concentrate as to the influence on the main structural elements forming the yield of soft winter wheat is noticeable. For example, plants were 5.5 cm higher as compared to the control, the number of grains was 10.1 pieces or by 15.5% more, grain weight was 0.5 g by 16.7% more. On the whole, spraying the sown areas positively affected the crop productivity.

Using 4R Foliar Concentrate stimulator for foliar additional fertilizing of the sownareas of corn positively influenced the realization of productivity genetic potential by the plants of this crop (Table 3). Thus, on the whole, the increase of corn grain yield was 0.87–1.25 t ha^{-1} or 12.1–17.3% as compared with the control group. Nevertheless, the most effective was foliar additional fertilizing of the sown areas with 4R Foliar Concentrate (1.0 kg ha^{-1}) in the phase of 3–5 leaves and repeated additional fertilizing with the same dose of the preparation in the phase of 10 leaves. Corn grain yield at such additional fertilizing was 8.46 t ha^{-1} or was 1.25 t ha^{-1}higher in comparison with the control.

Table 3. The crop yields in case of foliar additional fertilizing of the sown areas with 4R Foliar Concentrate preparation, t ha^{-1} (the average during 2015–2017)

Variant	Corn	Soya	Sunflower
1.	7.21	2.07	2.84
2.	8.08	2.45	3.22
3.	8.43	2.57	3.40
4.	8.46	2.74	3.50
$LSD_{0.95}$	0.51	0.18	0.23

The preparations also positively influenced the number of grains in corn ear and the weight of 1,000 grains. On the average, there were on 64 grains or by 13.1% more and the weight of 1,000 thousand of seeds – on 8.2 g or by 3.3% more. The economic analysis of the experiment results shows a high effectiveness of foliar additional fertilizing of corn sown areas with 4R Foliar Concentrate growth regulator on the basis of humic and fulvic acids. So, the highest profitability of this element of corn cultivation – 804% and 549% was in case of foliar additional fertilizing of the sown areas with 4R Foliar Concentrate (1.0 kg ha^{-1}) in the phase of 3–5 leaves and repeatedly in the phase of 10 leaves. According to economic indices, the variant of foliar additional fertilizing of the sown areas with 4R Foliar Concentrate (2 kg ha^{-1}) in the phase of 3–5 leaves was intermediate.

Foliar additional fertilizing of the sown areas under soya with 4R Foliar Concentrate growth regulator on the basis of humic acids positively influenced the crop productivity. In the variant, where the growth stimulator was used for seed treatment and foliar additional fertilizing, the height of soya plants increased on 24.0 cm, the number of beans on one plant – on 3 pieces, the number of grains on one plant – on 7.3 pieces or by 29.9%, the weight of 1,000 grains – on 7.2 g or 5.3% as compared with the control variant.

The increase of soya grain yield, as compared with the control, was 0.38–0.64 t ha^{-1} by 18.4–32.4% (Table 3). From agronomic viewpoint, foliar additional fertilizing of the sown areas with 4R Foliar Concentrate (1.0 kg ha^{-1}) in the phase of 2–3 ternate leaves and repeated foliar additional fertilizing of the sown area with the same amount of the preparation in the phase of budding-beginning of blossoming was the most effective. The soya grain yield in this case was 2.74 t ha^{-1} or was 0.64 t ha^{-1} higher as compared with the control, and also 0.14 t ha^{-1} more than when 2 kg ha^{-1} of 4R Foliar Concentrate was applied in the phase of 2–3 ternate leaves.

The increase of sunflower yield at foliar additional fertilizing of the sown areas with 4R Foliar Concentrate stimulator was 0.38–0.66 t ha^{-1} or 13.4–23.2%. The preparation also increased the area of leaf surface by 10.5%, the diameter of the head – by 7.1%, the weight of 1,000 seeds – on 0.8 g or by 1.6%. As in the previous experiments, foliar additional fertilizing of the sown area with 4R Foliar Concentrate in the phase of budding with the same amount of the preparation was the most effective. The yield of sunflower seeds in this case was 3.50 t ha^{-1}, or it was 0.66 t ha^{-1} higher as compared with the control and 0.1 t ha^{-1} higher in comparison with applying 2 kg ha^{-1} of 4R Foliar Concentrate in the phase of 2–3 pairs of leaves.

Foliar additional fertilizing in the experiment of growth regulator based on humic and fulvic acids did not affect the content and dynamics of humic and fulvic acids in the soil during the time of conducting experiments on black soils.

CONCLUSIONS

Based on the obtained test results during the period of 2015–2017, the positive impact of foliar additional fertilizing with 4R Foliar Concentrate growth stimulator on the basis of humic and fulvic acids on the formation of productivity of the sown areas of the main crops was established.

This agro-technical measure ensured the increase of winter wheat grain yield on 0.4–1.49 t ha^{-1} or by 11.8–44.1%, corn – on 0.87–1.25 t ha^{-1} or by 12.1–17.3%, soya – on 0.38–0.67 t ha^{-1}or by 18.4–32.4%, sunflower seeds – on 0.38–0.66 t ha^{-1} or 13.4–23.2%. It was found, that the best economic effect is achieved in case of double foliar additional fertilizing of the sown areas of the main field crops with 4R Foliar Concentrate preparation in phases of growth and development (1 kg ha^{-1} in both cases).

The results of the experiments show, that the conducted foliar additional fertilizing of the sown areas of the crops with the growth stimulator leads to improving the conditions of plant nutrition and raising the efficiency of applying mineral fertilizers.

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