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# Humic preparation and plant activity

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**Abstract:** The purpose of this study was to investigate the effect of a biological humic preparation – "HUMIN PLUS", made from natural raw materials – environmentally friendly lake sapropel on the biological development of agricultural crops. The study consisted in obtaining information and assessing the effect of a biological product on the dynamics of seedlings development, planting density, as well as crop productivity. To assess the preparation, as well as to identify the effect on the stages of plant ontogenesis, the physicochemical parameters were studied, including the content of humates, and trace elements in the sapropel extract. To interpret the effect of the growth regulator on the seed germination energy, an adaptive-neural inference system was used. To establish the nature of the action of preparation on the development biology of plant, in the conditions of Kazakhstan, a series of experiments were carried out at different stages of ontogenesis of agricultural crops. It was found that the action of the "HUMIN PLUS" preparation significantly increases the content of essential and nonessential amino acids. The findings have established that the sapropel extract "HUMIN PLUS" affects the biological activity of plants, accelerating the seed germination and increasing the productivity of agricultural crops in Kazakhstan.

**Keywords:** alkaloid stimulants, amino acids, fulvic acids, humic acids, lake sapropel, lignohumates, thermochemical technology, vortex reactors

## INTRODUCTION

It is known that the absorption of nitrogen from fertilisers does not exceed 50%, phosphorus – 20%, potassium – 25–60%, depending on the type of soil. The rest is washed out with rain and gets into water bodies, contaminates products with nitrates when using mineral nitrogen or is fixed in the soil when using phosphorus fertilisers. If the ecological inexpediency of using such mineral fertilisers in crop growing is ignored, this may result in economic cost. Therefore, the main factor in increasing the efficiency of fertilisers is the use of complex preparations made on natural raw materials enriched with agronomic beneficial microflora, which allows stimulating the development of the root system and thereby increasing their adsorbing function, as a result of which the assimilation of nutrients is activated [Yakovenko 2021]. In addition, the use of such preparations regulates the vital activity of soil microflora by increasing the useful species of microorganisms and optimising their interaction with plants in the agricultural ecosystem [Ahammed *et al.* 2019; Gumentyk *et al.* 2020; Kireicheva, Khokhlova 2004]. One of such preparations is organic-mineral universal humic micronutrient fertiliser "HUMIN PLUS".

Organic preparations based on sapropel extract do not cause resistance of harmful organisms and have no negative impact on the environment [García *et al.* 2019; Ladonin 2002; Paz *et al.* 2019]. Lake sapropel is an ideal raw material for the production of fertilisers, growth stimulants, plant protection agents, and biological preparations. It successfully combines macro- and microelements, vitamins, humic and fulvic acids, biostimulants and other physiologically active components. Along with this, it includes beneficial soil microorganisms and protective bacteria [Kireicheva, Khokhlova 2004; Zandonadi *et al.* 2019]. "HUMIN PLUS" refers to organomineral humic preparations obtained on the basis of pure natural raw materials, e.g. lake sapropel, which meets sanitary and epidemiological standards.

The study of the influence of humic fertilisers on plant yield revealed new interesting patterns. Previously, it was believed that the yield of plants is largely determined only by the intensity of photosynthesis. A number of scientists (Popov [2004], Zherebtsov *et al.* [2020]) made significant additions. The size of the crop mass yield also depends on the speed of deployment of the working leaf surface, which is achieved by treating plants with humic fertilisers. A certain amount of sulphur, nitrogen, boron and other substances enter plants through their leaves. The faster the working leaf surface unfolds, and the larger the area it will occupy, the more effective the plant nutrition with air will be and the greater the amount of the above nutrients will be assimilated by the plant. This, in turn, leads to an increase in grain yield.

Thanks to the use of organic humic preparations, the acceleration of the passage of phenological phases in wheat, maize, alfalfa from 2 to 7 days was noted. The same was noted in other cultivated plants. This is especially important in risk farming areas, where persistent cold weather often sets in before harvesting. Intensive use of humic preparations is necessary for plants, which in their "biology" have a short growing season, and, accordingly, a limited time for feeding and forming a crop. In addition, the study of the proposed technology in crop production showed that the treatment of plants with the activated substrate "HUMIN PLUS" and its introduction into the soil in very small quantities, from 0.2 to 0.3 cubic centimetres of concentrate per hectare, gives an effect equivalent to the application of chemical fertilisers in hundreds of kilograms per hectare and tens of tonnes of organic matter per hectare at a significantly lower cost [Galaktionova *et al.* 2019; Perminova *et al.* 2003].

The aim of the article is to show the study of the effect of a biological humic preparation – "HUMIN PLUS", made from natural raw materials – environmentally friendly lake sapropel on the biological development of agricultural crops.

## MATERIALS AND METHODS

Among the modern technologies that ensure the production of humic products at a high level is the method of mechanochemical activation. The essence of the method lies in a powerful pulsewise mechanical action on the humic raw materials, oxidised brown coal, peat, with a minimum use of chemical reagents. The most effective method, which is gaining more and more popularity, is to carry out standard physicochemical processes in the liquid phase while organising a developed cavitation zone in it. Cavitation is the process of collapse of vapour-gas bubbles that arise in a liquid when it is sharply stretched. In a vortex, ultrasonic or magnetic resonator reactor, the dispersion, extraction, dissolution, disintegration of cellular structures, and destruction of cellulose occur simultaneously. The physiological activity of humic preparations with disordered polymer structures of humates, obtained using a resonator reactor, is increasing. Since the finer the disordered polymer structure of such substances, the more efficiently they are absorbed by the membranes of the plant cell structure. The end product at the outlet of the reactor is organomineral fertiliser of increased biological activity, a high yield of water-soluble organic substances with an accelerated course of hydrothermal synthesis reactions [Gökçe 2021].

The raw material for the production of "HUMIN PLUS" is ecologically clean lake sapropel, or deposits in freshwater reservoirs consisting of organic and mineral substances. These substances arise during the biological humification of plant and animal residues (plankton, pollen, animal and plant organisms). The cheapness of raw materials predetermined its choice for many manufacturers. The fundamental difference between humic substances from peat or lignins and those obtained from sapropel is that the nature of the former is determined, first of all, by cellulose and lignins. Because of this, their molecules contain in significant quantities components with aromatic nuclear structures, characterised by hydrophobic properties. A special type of humic substances originating from plankton, plant and animal organisms are formed in sapropel. Their origin is determined by carbons and proteins. The share of amic acids in humic and fulvic acids originating from sapropel is from two to three times higher than in the corresponding acids formed on land. In this way, they differ in principle from humic substances obtained from peat, coal or lignins. The molecules of humic substances from sapropel contain very few aromatic (benzoic) nuclear structures.

It is the aliphatic components that are mainly consumed in the agricultural use of soils as a result of the vital activity of plants and microflora. As a result of which there is a decrease in the proportion of the labile organic part of humus and a relative increase in its inert part, and as a consequence, a decrease in soil fertility. Therefore, the replenishment of reserves of active organic matter in soils should be carried out at the expense of sources containing the corresponding components. Such sources include sapropel humic substances, in the molecules of which the aliphatic part of the carbohydrate-lipid-protein nature predominates [Kozhakhmetov, Ostrovsky 2014; Lebedev *et al.* 2019]. Based on the study of technology, patent No. 4213 "Method of pre-sowing seed treatment" [Kozhakhmetov 2019], the results of research and development were registered in 2018 at the National Centre for State Scientific and Technical Expertise No. 0118RK0116 [Kozhakhmetov 2018].

## RESULTS AND DISCUSSION

Chemical and microbiological analyses showed that a concentrated sapropel extract ("HUMIN PLUS") contains a complex of biologically active substances (humic and fulvic acids, amino acids – lysine, methionine, cystine, threonine, vitamins, carbohydrates) and microorganisms in an unchanged state. Calcium, magnesium, iron, selenium, nickel, vanadium, lithium, bromine, and iodine are contained in the preparation in amounts of the natural background of sapropel (Tab. 1).

At high wet weight of the maize, as well as the dry weight of the aerial part, were noted in the variant with the use of the preparation and amounted to 121–116 kg·m$^{-2}$, respectively. The excess to the control in this case was 4–9 kg·m$^{-2}$, or 3.5–7.5%, respectively [Kireicheva, Khokhlova 2004; Zandonadi *et al.* 2019] – Figure 1.

The mode of action of humic substances is to stimulate all biochemical processes in the plant organism, not only at the initial stage of seed germination and the formation of the root system, but also the further growth and development of the plant [Borisenko *et al.* 2015; Kharytonov *et al.* 2019; Plutakhin 2013]. It was found that the action of the "HUMIN PLUS" preparation contributes not only to better use of active substances by plants, but also significantly increases the content of essential and nonessential amino acids (Fig. 2).

**Table 1.** Chemical and microbiological analysis of sapropel extract

| Indicator name | Value/feature |
|---|---|
| Appearance, colour | dark brown liquid |
| Acidity: (pH), max. | 10.0 |
| **Mass fraction of some organic and mineral components** | |
| Dry residue, max. (%) | 5.0 |
| Humates, min. ($g \cdot cm^{-3}$) | 20.0 |
| Calcium (CaO) ($g \cdot cm^{-3}$) | 2.0 |
| Magnesium (MgO) ($g \cdot cm^{-3}$) | 0.5 |
| Sulphur ($SO_3$), min. ($g \cdot cm^{-3}$) | 5.0 |
| Total nitrogen (N), min. ($g \cdot cm^{-3}$) | 2.0 |
| Total phosphorus ($P_2O_5$), min. ($g \cdot cm^{-3}$) | 2.0 |
| Total potassium ($K_2O$), min. ($g \cdot cm^{-3}$) | 3.5 |
| Total silicon (SiO), min. ($g \cdot cm^{-3}$) | 2.0 |
| **Mass fraction of microelements, min. ($mg \cdot cm^{-3}$)** | |
| Boron | 95.0 |
| Molybdenum | 10.0 |
| Manganese | 84.0 |
| Zinc | 45.0 |
| Copper | 53.0 |
| Cobalt | 8.0 |
| Iron | 50.0 |
| Iodine | 0.5 |
| Selenium | 0.4 |
| Chromium | 0.2 |
| **Mass fraction of some organic compounds** | |
| Crude protein ($g \cdot cm^{-3}$) | 0.5 |
| Crude fibre ($g \cdot cm^{-3}$) | 0.4 |
| Fat ($g \cdot cm^{-3}$) | 0.2 |
| Amino acids ($mg \cdot cm^{-3}$) | 235.0 |
| Vitamins (B1, B2, B12, C, E, D) ($mg \cdot cm^{-3}$) | 17.0 |
| **The number of the main physiological groups of microorganisms ($CFU \cdot cm^{-3}$)** | |
| Ammonifying | $9 \cdot 10^6$ |
| Amylolytic | $8 \cdot 10^5$ |
| Pedotrophs | $3 \cdot 10^5$ |
| Urobacterium | $30 \cdot 10^5$ |

Source: own study.

An adaptive-neural inference system was used to interpret the effect of the growth regulator on the germination energy of wheat seeds. The adaptive neural inference system belongs to hybrid systems. Hybrid systems provide an opportunity to take into account the experience of experts, as well as extract knowledge from data from field experiments.

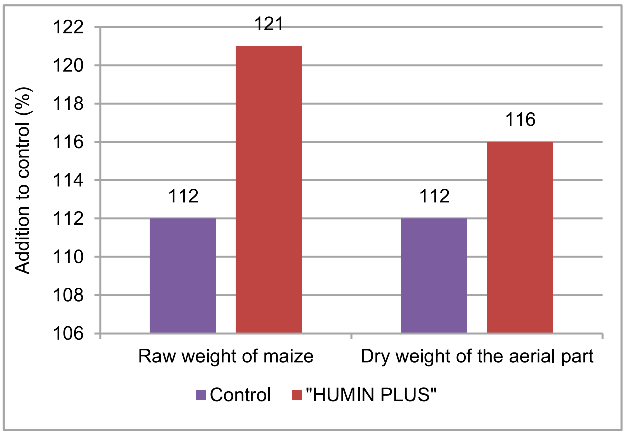


**Fig. 1.** Wet and dry weight ($kg \cdot m^{-2}$) of maize; source: study

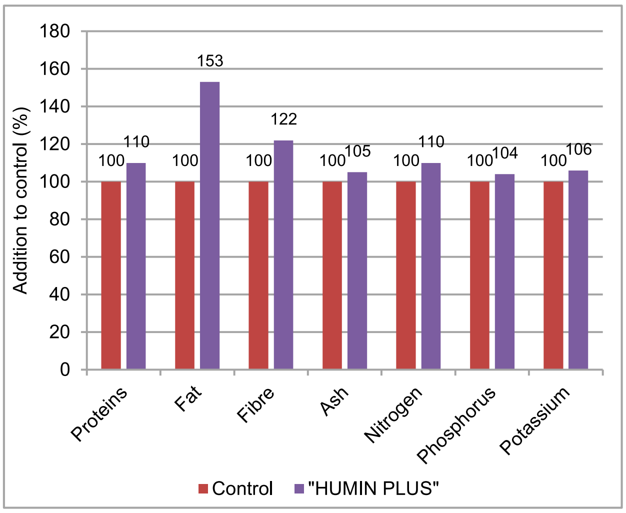


**Fig. 2.** Influence of the "HUMIN PLUS" on the quality of maize grain; source: own study

Humic acids are used as growth stimulants for spraying seeds, crops, soaking tubers and sprigs [DYMYTROV *et al.* 2021]. In experiments on rapeseed cultivars 'Posevnoy', the drug had a stimulating effect on the germination energy and germinating ability of seeds (Tab. 2). The effect of technology based on the "HUMIN PLUS" preparation on the germination energy of barley seeds was studied in laboratory conditions (Tab. 3). Studies have also shown that the preparation increases the resistance of winter beetroots to the effects of negative temperatures in winter (Tab. 4).

**Table 2.** Growth rates of rapeseed at the initial stages of development

| Group | Seed germination (%) | Dry weight of the plant (mg) | Volume of the root system ($cm^3$) |
|---|---|---|---|
| | averages ±*SD* | | |
| Control – no treatment | 48.5 ±4.3 | 150.0 ±5.5 | 105.0 ±5.8 |
| Treatment with "HUMIN PLUS" | 65.0 ±3.2 | 202.0 ±6.7 | 101.0 ±8.7 |

Source: own study.

**Table 3.** Influence of "HUMIN PLUS" on the germination of barley seeds

| Group | Sprouted seeds (%) after | | | |
|---|---|---|---|---|
| | 5 days | 10 days | 15 days | 20 days |
| Control – no treatment | 2.3 | 1.8 | 2.5 | 3.6 |
| Treatment with "HUMIN PLUS" | 7.5 | 9.8 | 12.5 | 18.3 |

Source: own study.

**Table 4.** Planting density (pcs. per 1 running meter) of non-planting seed plants

| Group | Planting density | | | | Viability (%) |
|---|---|---|---|---|---|
| | full germination | before overwintering | after overwintering | before harvesting | |
| Control – no treatment | 15 | 12 | 8 | 6 | 80 |
| Treatment with "HUMIN PLUS" | 23 | 20 | 15 | 13 | 87 |

Source: own study.

**Table 5.** Maize productivity (cultivar 'Altyn 739')

| Group | Seed yield (Mg·ha$^{-1}$) | Yield increase | |
|---|---|---|---|
| | | Mg·ha$^{-1}$ | % |
| Control – no treatment | 29.7 | – | – |
| Treatment with "HUMIN PLUS" | 35.2 | 5.5 | 16.2 |

Source: own study.

So, when pre-sowing seed treatment with the preparation, the planting density was 506 thous. pcs.·ha$^{-1}$, and the control was 330 thous. pcs.·ha$^{-1}$. In the autumn growing season, the loss of plants during the treatment of seeds with the preparation was 13% in the experiment, and 20% in the control, i.e., was large compared to the control. Similar changes were observed after overwintering. A test of agricultural technology in combination with "HUMIN PLUS" on maize showed that the highest yield (35.2 Mg·ha$^{-1}$) was observed when the preparation was used (Tab. 5). The addition to the control in this case was 5.5 Mg·ha$^{-1}$, or 16.2%.

## CONCLUSIONS

Studies of the physicochemical characteristics of the sapropel extract have shown that the proportion of amino acids in humic and fulvic acids originating from sapropel is two to three times higher than in the corresponding acids formed on land. The plant treatment technology combining the "HUMIN PLUS" preparation showed the effect of improving the germination energy and germinating ability of seeds. The highest yield of the maize (35.2 Mg·ha$^{-1}$) was observed when this preparation was used. It subsequently positively influenced the formation of an optimal planting density both during the "sowing – germination" period and after the formation of the plant up to harvesting.

The effective application rates of the preparation have been established: during pre-sowing treatment of the material (soaking, spraying) – 20 cm$^3$·dm$^{-3}$ of water; with foliar application (spraying) – 1 cm$^3$·dm$^{-3}$ water or 0.3–0.4 dm$^3$·ha$^{-1}$. At the same time, the increase in yield with a double application of "HUMIN PLUS" was 29% (maize, sugar beetroot), and with a single application (pre-sowing – winter crops) by 10%.

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