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The Coal Humic Product EldORost Shows Fertilizing and Growth Stimulating Properties on Diverse Agricultural Crops

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Abstract: The use of environmentally safe products of natural origin is a global trend today. A particular point of interest is the use of humic fertilizers. This is due to the growing awareness of the positive impact of humic substances on plant growth and development as well as on the quality of agricultural products and soil fertility. Humates are physiologically active substances. As a result, they regulate and intensify metabolic processes in plants and soil, and contribute to the bioavailability of nutrients to plants. EldORost is a new-generation humic product that contains humic substances with a high humification degree. In addition to humates, this product contains a complex of amino acids, macro-, and microelements in a bioavailable form for plants. The product is eco-friendly and completely soluble in water, which is a substantial advantage for drip irrigation systems. It can be used for all types of agricultural crops on a wide diversity of soils and climatic zones. It displays the properties of plant hormones while its optimum concentration is as low as 0.0001% (wt). The efficiency of this novel humic product was tested in laboratory and field tests conducted on potatoes and vegetable crops (tomatoes, cucumbers, cabbage, carrots, onions, beets). The obtained results showed high efficiency displayed in the significantly improved sowing quality of vegetable seeds, nominally increased the germination degree and seed germination energy, intensively stimulated the side root development in plants, accelerated the growth of biomass, increased the fruiting period, and reduced maturation on the yield of potatoes and vegetable crops. The obtained data allowed us to characterize this novel humic product from the perspective of an eco-friendly fertilizer and growth promoter.

Keywords: humic products; EldORost; potatoes; vegetable crops; germination; growth regulator; biostimulator; organic fertilizer; humic substances

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1. Introduction

The interest in organic fertilizers is instantly growing [1,2]. This is primarily due to the fact that environmental problems caused by intense agriculture have attracted the attention of the world community, which has become increasingly concerned about the harm caused to human health by pesticides, agrochemicals, and other products to the soil, water, and air [3]. As a result, consumers have begun to pay more attention to the quality of food and its environmental friendliness. Accordingly, farmers need to take into account this new market trend, paying attention to the product quality and keeping the soil healthy [4]. In Europe, the United States, and other countries, hundreds of active chemical ingredients have been already banned. As a result, more stringent modern safety standards have been adopted, which has led to the emergence of less harmful agrochemicals and to alternative agricultural practices [5]. One of these agricultural practices—"organic farming"—is based on the complete rejection of agrochemicals and implies a return to natural processes to preserving the ecological balance, minimizing the negative impact of agricultural production on the environment, and increasing the yield [6]. "Organic farming" is developing rapidly, but is hampered by the relatively low productivity of organic farming and the high cost of production. This does not allow us to solve the food problem on a global scale in this way [7]. At the same time, the demand for food provisions continues to grow in line with the growth of the world's population, which is why a sharp and complete ban on the use of pesticides and agrochemicals in the near future is impossible. The gradual "greening" of agriculture may be a more viable alternative. The first step in this direction might be the development of new eco-friendly technologies to preserve and increase agricultural productivity. These technologies should be based on a reduction in pesticides and other chemicals used on plants and soil, reorienting chemical production to safer agrochemicals [8].

Currently, in the Republic of Kazakhstan, the vast majority (more than 95%) of the country's farms use industrial mineral fertilizers (NPK) [9]. Excessive use of mineral fertilizers in the southern regions of the country has led to almost complete soil micro-flora destruction and, as a result, to the degradation in soil organic matter. Intensive use of pesticides and agrochemicals has allowed to the problem of crop productivity to be solved, but at the same time, has disturbed the ecological balance in the plant and animal world. Along with weeds, diseases, and pests against which pesticides were used, bees and other useful insects as well as soil-dwelling organisms died. Pesticide residues inhibit the growth of crops, enter human and animal bodies, cause damage to health, and penetrate into water reservoirs where they pose harm to aquatic fauna and flora [10]. The problem of mineral fertilizers is that its efficient use is central in crop production. [11] The complexity of its solution is connected to the high water solubility of K and N fertilizers, which makes them easily washed out of the soil, while P fertilizers, in contrast, are bound by Ca^{2+}, Mg^{2+}, Al^{3+}, and Fe^{3+} ions into inert forms that are not available to plants. The higher rate of mineral fertilizer application causes more intense mineralization of organic matter, depletion of the soil with humus, and possible environmental pollution. We can say that almost the entire territory of the country is located in the zone of risky agriculture [12]. The solution to the problem of greening agriculture in this sense is a significant reduction in the use of traditional pesticides and agrochemicals by increasing their use efficiency, neutralizing residual doses, and replacing them with safer products of natural origin. For this purpose, Kazakhstan needs to adopt a greening agriculture concept, taking into account its natural and climatic features. This concept involves the widespread use of natural, original humic fertilizers, which have unique properties to increase plant resistance to frost, drought, and other adverse factors, mobilizing internal protective and productive reserves in an unstable climate [13,14].

The key role of humic fertilizers in improving agriculture ecology has been shown over more than half a century of research that has accumulated in numerous scientific evidence indicating the vitally important roles of natural humic substances in the "water–soil–plant" ecosystem function [15–17]. Humic substances are natural components of soil, are benevolent to plants, and non-toxic to insects, animals, and humans [18–20]. In the presence of humic acid salts—humates—the assimilation coefficient of mineral nutrition elements by the plant increases sharply. Humate introduction into the basic NPK mixtures improves the growth, development, and productivity of crops, while reducing the mineral fertilizer consumption by 30–50% [21]. It is interesting to note that the mechanism of interaction between humate and macro-nutrients from fertilizers is specific to each of them. Nitrogen assimilation follows the path of metabolic process intensification, while the nitrate formation slows down. Potassium uptake is accelerated by selectively increasing the permeability of the cell membrane. Regarding phosphorus, humate prevents the formation of insoluble phosphates, primarily binding Ca^{2+}, Mg^{2+}, and Al^{3+} ions [22]. The treatment of vegetating plants with humates provides them with a constant supply of microelements necessary for life, and humic compounds effectively transport microelements to plants, while they form complexes with microelements that are easily absorbed by the plant [23]. The application of humates can also restore soil fertility, reduce the use of pesticides and agrochemicals, increase crop yields, improve the nutritional value, taste, and environmental purity of fruits, and reduce the cost of obtaining and harvesting, thus significantly increasing the agriculture profitability [24].

In the Republic of Kazakhstan, the need for "organic farming" was discussed after the issue of careful nature management became acute in order to prevent negative consequences from the contamination of soil, water bodies. and air with residues of agrochemicals as Kazakhstan has all the means to develop the production and export of organic vegetables, since our country has unique agricultural lands that do not use chemicals [25]. The most accessible and adjustable, convenient and acceptable in terms of the production elements of "green technologies" are the selection of resistant and tolerant to pests, natural (non-GMO) varieties and hybrids of vegetable crops; biological vegetable crop rotation; use of organic fertilizers; biological method of plant protection from pests; agronomic method of controlling weeds (with a single application in the case of emergency eco-friendly herbicides); seed treatment against diseases and pest integrated drugs instead of the ground use of toxic pesticides; minimizing technological processes to reduce the mechanical load on the soil; progressive water-saving technologies to prevent the erosion of topsoil (erosion and irrigation); and improving the phytosanitary plantation condition [8].Vegetable crops, due to their agro-biological characteristics, require large amounts of fertilizers and frequent treatment with pesticides. Vegetables, forming high yields of main and by-products, remove a large number of nutrients from the soil, thereby emaciating the soil. Returning the nutrients to soil in the form of fertilizers involves high costs in the purchase of expensive industrial fertilizers, and enters the soil through the toxic elements (heavy metals, chlorine, fluoride, nitrates) in the fertilizers [26]. Vegetable crops are tender, juicy, and have weak resistance to harmful organisms, so they are severely damaged by them. Repeated use of chemicals to combat crop-harmful organisms, unlike organic biostimulants, increases the pesticide load on the environment, which leads to a change in both the properties of agricultural soils and the abundance and species diversity of the soil biota as well as inhibition of the growth and development of cultivated plants [12,27].

Organic farming should not be isolated; it should fit seamlessly into the existing agro-industrial complex and become an important part of it, where traditional organic farming (vegetable growing) should be practiced. First of all, it is necessary to focus on local conditions and resources: soil, climate, traditions (product type, demand) in organic farming, skills, knowledge, experience, human resources, varieties (domestic), fertilizers (local organic) agricultural technologies, etc. The use of local organic fertilizers (manure, bird droppings, etc.) is very limited due to small volumes with sufficiently large application rates (20–50 t/ha or more), high costs for their loading, transportation, and introduction into the field. In this aspect, bio-organic fertilizers and biological stimulants used in small doses (0.5–5.0 L/ha) are very important. In recent years, various bio-organic fertilizers and the biologics of stimulating action for soil and plants have been produced and recommended by agricultural producers. However, before recommending new types of bio-fertilizers and biologics for production, it is necessary to study them and evaluate their agronomic, economic, and environmental effectiveness in greenhouse and field experiments [28–30]. The above confirms the relevance and significance of research on the creation of new types of bioorganic fertilizers and bio-stimulants of plant growth and the study of their effectiveness for the widespread introduction of drugs in agricultural production (potato, vegetable).

Our research aimed at the development and study of a new, complex, highly effective organic fertilizer of a humic nature for modern technologies as well as its implementation to reduce the degradation of agricultural soils in arid and semi-arid regions of Kazakhstan and increase the productivity of cultivated plants. We obtained a universal plant growth and development stimulator EldORost from highly oxidized brown coal by extraction with alkaline reagents with the addition of a complex of amino acids, macro-and microelements. EldORost is designed to optimize the production processes of all types of crops for the cultivation of environmentally friendly crop products in any soil and climatic zones [31,32]. The purpose of this work was to evaluate the effect of EldORost on the germination and germination energy of vegetable seeds as well as on the yield of vegetables and potatoes.

2. Materials and Methods

2.1. Materials and Reagents

Seeds were from the vegetable crops tomatoes, cucumbers, cabbage, carrots, onions, and table beets, organic fertilizer EldORost, and sodium Humate of appropriate concentrations were used as a reference; distilled water was used as the control.

2.2. Seed Treatment with the EldORost

To select the most convenient and promising method of seed treatment, the experiments were carried out as follows: (1) a preliminary 3-h soaking of seeds in solutions of the biostimulator EldORost of various concentrations was used (0.01%, 0.001%, 0.0001%, 0.00001%); and (2) plants were grown in solutions of the indicated concentrations. It has been established that the first method of seed treatment is more efficient and is also convenient for use in agricultural technologies.

We studied the effect of the new organic preparation EldORost on the germination energy and germination capacity of tomato, cucumber, cabbage, onion, carrot, and table beet seeds as well as on the biometric parameters of the plants. For the germination tests, 50 seeds were used in four replicates. The optimum concentration for stimulating plant growth was determined as 0.0001%. At this concentration, all parameters reached maximum values. This was used for the determination of biometric indicators such as the length of the ground and underground parts of plants and wet and dry masses. Seeds treated in water served as a control, while seeds treated in 0.0001% sodium humate solution served as a standard. Experimental data showed that the application of higher concentrations of EldORost, nominally, 0.01% and 0.001% solutions inhibited the growth of vegetable plants compared with the plants grown at a concentration of 0.0001%. Further reduction in the concentration led to a decrease in the biometric parameters of the plants.

Thus, the growth-regulating ability of the EldORost humic product was established and the optimum concentration for plant growth stimulation was 0.0001%.

2.3. Studies on Bacterial and Fungal Micro-Flora

The effects of the humic product on the bacterial and fungal microflora were studied using the nutrient medium potato glucose agar (PGA). We used a ranking assessment for the microflora growth and designated it as weak (+), average (++), and intense (+++). The research was conducted in laboratory conditions at the Scientific and Innovative Center "Horticulture and vegetable growing" of the Kazakh National Agrarian University (KazNAU).

The influence of the new plant biostimulator EldORost was studied on the sowing qualities of seeds of the main types of vegetable crops, nominally, on the germination energy and germination capacity of tomato, cucumber, cabbage, carrot, onion, table beet and potato seeds as well as on the microflora. The effect of the EldORost was also studied on the formation of vegetative biomass and the food organs of potatoes and vegetable crops.

Biotesting was performed by soaking seeds in a solution of tested preparations for 3 h. The control seeds were soaked in water. The effects on the seeding quality of the seeds were tested in wet chambers. In each variant, 50 seeds were taken in four replicates.

Germination energy was tested in cabbage and onion on the third day, and in tomato on the fifth day after treatment; the laboratory germination capacity was determined by the number of germinated seeds. For cabbage and onions, it was determined on the seventh day, and for tomato on the tenth day after treatment. These indicators characterize the friendliness of germination and are especially important. The higher the resulting percentage, the friendlier the seedlings will appear. The second data were noted after the final time interval established for each culture. The obtained indicators were summed up, converted into percentages, and the full germination of the tested seeds was established.

2.4. Agrochemical Techniques

We used classical agrochemical methods of soil research [33–38]. To determine the treatment exposure time, seeds were soaked in the solutions for 2, 4, 6, 8, 10, 12, and 24 h. We determined the effect of treatment time on the germination of seedlings and on the growth and development of carrot, onion, tomato, cucumber, cabbage, and table beet plants. Experimental data showed that the carrot seeds germinated 4 days earlier when soaked for 24 h compared to the samples with different treatment times. Onion seeds, when soaked for 4 h–3 days, and cucumber seeds, when soaked for 2 h, sprouted 2 days earlier. In addition, at the specified optimal treatment time for each vegetable plant, the higher values of the lengths of the ground parts of plants were observed, exceeding the control options.

The optimum soaking time for seeds was established as follows: for carrots—24 h, onions—4 h, cucumbers–2 h. Treatment of the seed material of vegetable crops with an organic plant growth stimulator EldORost improved the sowing qualities of the seeds, and increased their germination energy and germination capacity. The new biostimulator can be recommended for the treatment of vegetable seeds. Studies have revealed that the treatment of table beet seeds should be carried out by spraying (moistening) solutions in optimal doses of preparation. Seeds of carrots, onions, and cucumbers soaked in solutions of growth stimulants must be dried before sowing to a loose state in a dark place. Treated beetroot seeds can be sown immediately. Seeds treated with solutions of the preparations should be planted no later than 5–7 days. The new growth stimulator EldORost showed a higher stimulating efficiency in all cultures compared to the reference preparation. Experiments to study the effect of EldORost on the growth, development, and yield of agricultural crops continued in the field and production tests.

2.5. Field Experiments

Demonstration field (shallow-dividing) tests were carried out at the KazNAU experimental station. The soil of the experimental station is dark chestnut (Mollisol), medium loamy in texture. It has a fully developed profile clearly differentiated into genetic horizons. The topsoil contains 2.9–3.0% organic matter; 0.18–0.20% total nitrogen; 0.19–0.20% gross phosphorus. The soil of the site is moderately provided with mobile forms of nutrients. The content of mobile phosphorus is 30–40 mg/kg of soil, exchangeable potassium is 350–390 mg/kg. The amount of absorbed bases is 20–21 meq/100 g of soil. The reaction of the soil solution is slightly alkaline (pH 7.3–7.4). The lowest moisture capacity is 26.6%. the soil structure is loose, weakly expressed. Soil is swamped by irrigation and rainfall, forming a dense crust that disrupts its water and air regime. This negatively affects the production of mass seedlings of small-seeded vegetable crops.

The climate of the foothill zone of southeastern Kazakhstan is sharply continental. The average temperature in July is 22–24 °C, in January 6–10 °C below zero. Spring frosts stop in the third week of April, fall frosts begin in the third week of September or early October.

The agricultural technology of vegetable crops in the experiments is generally accepted for the southeast of Kazakhstan, carried out in accordance with the recommendations of the Kazakh Research Institute of Potato and Vegetable Growing. Kazakh varieties approved for use in the Almaty region were cultivated: white cabbage—Nadyusha; cucumber—Shilde; tomato—Luchezarnyy; table beet—Kyzylkonyr; carrot—Alau; potato—Axor.

Phenological observations were carried out to determine the timing of the onset and passage of the main phenological phases of plant development. Biometric studies were conducted to evaluate biofertilizers on growth processes.

Experiment variants: EldORost—0.0001%; control—untreated seeds; reference—sodium humate—0.0001%.

Experimental plot area—35 m^2 (3.5 × 10 m). Repeatability—four times.

Dates and methods of preparation application (crop development phases): seed dressing before sowing and 2-treatment of crops during vegetation:

- Potatoes: First in the phase of 5–7 leaves, second after 30 days;

- Tomatoes: first in the phase of 2–4 leaves emergence; second in the phase of the beginning of flowering;
- Cucumbers: First one in the phase of appearance of 2–4 leaves; second one at 15-day intervals;
- Cabbage: First one 2–3 days after planting; second one in the phase of leaf whorl-head setting;
- Onions: First in the phase of 2–3 leaves; second at intervals of 10–12 days;
- Carrots: First in the phase of sprouting-formation of 1–2 leaves; second at 10–15 day intervals.

The rate of consumption of the working fluid: soaking—150 mL/ton of seeds; spraying—150 mL/ha.

Features of the current year weather conditions: The average air temperature for 2019 was 7.19 °C in April, 12.35 °C in May, and 17.53 °C in June, which was lower than the long-term data. In July and August, in contrast, there was an increase in air temperature compared to the long-term by 5.1 °C and 1.6 °C, respectively. In general, meteorological indicators for the growing season (April–September) were found for the cultivation of vegetable crops.

2.6. Structural–Chemical Characterization of the Humic Product EldORost

The total content of organic carbon and a C_{HA}/C_{FA} ratio were determined with the use of a TOC analyzer (TOC-L, Shimadzu, Kyoto, Japan).

^{13}C NMR spectra were recorded on a Bruker Avance 400 NMR spectrometer operating at the frequency of 100 MHz using the Carr–Parsell–Maybum–Gill pulse sequence (CPMG) located at the Department of Chemistry, Lomonosov MSU (Moscow, Russia). The spectrum sweep width was 42,735 Hz, the registration time of free induction decay was 0.2 s, the time delay between pulse sequences (Td) was 7.8 s, and the spectrum acquisition time was 12 h. The sample was prepared by dissolving a weight of 70 mg in 0.6 mL of 0.3 M NaOD/D2O placed into a 5 mm NMR tube.

Size exclusion chromatography measurements were conducted using a Prominence SEC-system (Shimadzu), TSK-HW55S gel, 0.028 M phosphate buffer as an eluent, and polystyrene sulfonates as calibrants.

Optical properties were characterized using UV–Vis and fluorescence spectroscopy. Absorption spectra were recorded on a Cary-50 Probe spectrophotometer (Varian, Palo Alto, CA, USA) operating in the UV–Vis regions (200–800 nm) equipped with a quartz cuvette (optical length of 1 cm).

2.7. Statistical Analysis

All obtained data were subjected to mathematical processing by the method of variation statistics [39]. Significance of the difference between the sample averages was assessed using analysis of variance by comparing Fisher's actual criterion (F_{st}) with the theoretical criterion at α = 0.05 (F_{05}), and significance of the difference between the averages was assessed by the value of the lowest significant difference (LSD_{05}). If F_{st} was less than F_{05}, in other words, when there were no significant differences between the sample averages, LSD_{05} was not given.

3. Results and Discussion

3.1. Structural–Chemical Characteristics of the Humic Material within the EldORost Product

The humic material used to prepare the EldORost product was characterized using the methods of ^{13}C NMR spectroscopy, size exclusion chromatography, and optical spectroscopy. The total dissolved organic carbon, the content of ballast compounds, and a ratio of humic to fulvic acids were determined using a total organic carbon (TOC) analyzer. The total content of organic carbon in the humic material was (67 ± 2) g/L or (6.7 ± 0.2)% (wt). The amount of dissolved organic carbon in the product accounted for (45 ± 2) g/L or (4.5 ± 0.2)% (wt). The found amount of organic carbon can be converted to the content of humic substances (HS) using the common value for the content of carbon in the coal HS of 50% (wt). In this case, the content of dissolved HS in the EldORost product can be assessed as 9.0% (wt). The ratio of humic acid (HA) to fulvic acid (FA) in this product accounted for (9.0 ± 0.6). All measurements were run in three replicates. Sign "±" stands for a standard deviation for n = 3. The obtained value points to very high content of HA in the product, which is indicative of aa high humification degree typical of coal HS. The ^{13}C NMR spectrum of humic acids isolated from the EldORost product is given in Figure 1.

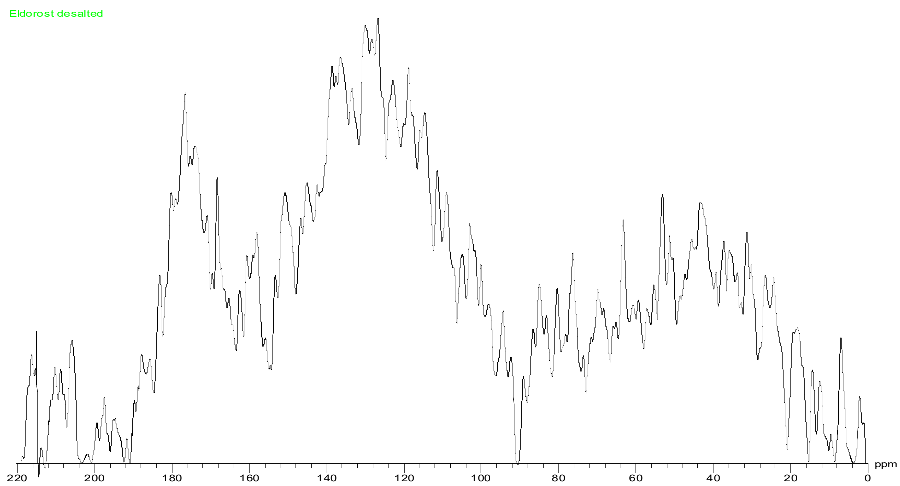


Figure 1. ^{13}C NMR spectrum of humic acids isolated from the EldORost product.

It can be seen that the spectrum is characterized with the highest spectral density within the range of aromatic carbon (Car) assignments from 100 to 165 ppm and accounts for 51.3% of the total carbon. The second largest portion of carbon was within the aliphatic structures and accounted for 32.4%. Among the aliphatic structures, the O-substituted accounted for 16.4%, and the non-substituted aliphatic structures for 15.6%. The ratio of aromatic to aliphatic carbon was 1.6, which was lower compared to HA from leonardite (the corresponding value exceeds 2). At the same time, lignite was characterized with less degraded and more aliphatic character compared to leonardite. As a result, the isolated sample of lignite HA was also more aliphatic compared to leonardite HA. The content of carboxylic groups was 12.9% and the content of the carbonyl groups was 3.4%. In general, the found structural group distribution is typical for lignite HA [40] and is indicative of its hydrophobic character.

The molecular weight characteristics of the EldORost humic product were measured with the use of SEC. These were as follows (kDa): M_w = 6.8, M_n = 2.0, M_p = 5.8, P = 3.4, recovery = 20%, where M_w is the weight averaged molecular weight, M_n is the number-averaged molecular weight, M_p is the peak molecular weight, and P is the polydispersity. The obtained values were well in the range reported for coal HA [41]. The optical properties are also indicative of the structural features of HS samples. The UV–Vis spectrum for the EldORost sample is shown in Figure 2.

The UV–Vis spectrum represents a sharply descending curve without characteristic maxima, which is typical for HS. To characterize this type of spectra, a number of parameters can be used. One of them is the specific UV absorbance (SUVA) value at 254 nm, accounting for 0.052 L/mg · cm, which is characteristic for aromatic rich HS such as coal HA. The humification degree (E_4/E_6) was estimated as a ratio of optical densities at 450 and 650 nm [42] and accounted for 3.01 for the sample under study, which is indicative of the high conjugation degree of aromatic rings expected for coal HS. The obtained value was a factor of 5–7 lower compared to the water and soil HA [43]. Another optical parameter was calculated as a ratio of optical densities at 230 and 370 nm and was sensitive to the molecular weight of the HS. It accounted for 7.01, which is indicative of the relatively low molecular weight of the sample used in this study.

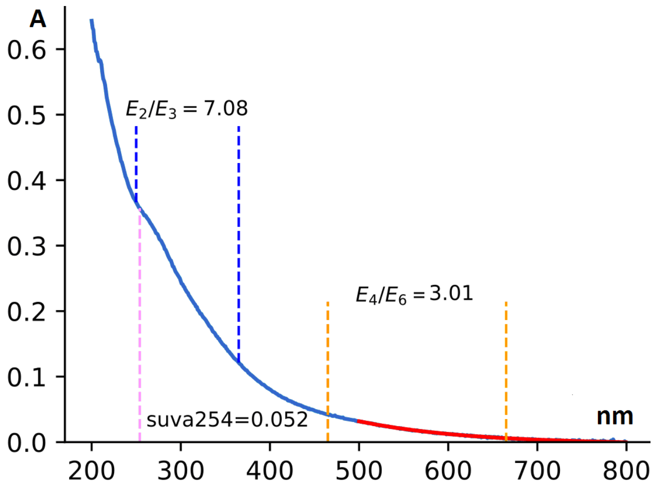


Figure 2. The UV–Vis spectrum and optical parameters calculated for the EldORost humic product in phosphate buffer (0.015 M, pH 7). The solid red line denote the "red region" of the spectrum, the dashed blue and red lines denote the wavelengths, which are used for determination of E_2/E_3 and E_4/E_6 parameters, respectively.

It should be noted that the obtained values of the optical parameters were in full agreement with the data of the ^{13}C NMR spectroscopy on the prevalence of aromatic conjugated structures as well as with the SEC-data on its relatively low molecular weight.

3.2. The Effect of EldORost on the Germination Energy and Germination Capacity of Vegetable Seeds

In all experiments with EldORost, the concentration of 0.0001% was used. Seeds treated in water served as the control and as a standard in a sodium humate solution of 0.0001% concentration. Carrot, onion, cucumber, and beet seeds were germinated in Petri dishes in a thermostat. The experiment was repeated four times. The germinated seeds of crops were counted twice: the first at 5 days after treatment, where we determined the seed germination energy, and the second at 10 days to determine the germination of seeds. Many types of vegetable crops (cabbage, carrots, onions, tomato, beets, etc.) are small-seeded, tightly germinating, and germinate for a long time (20–25 days or more). Here, the situation is exacerbated by the fact that small seeds have low germination energy, weak germination, and are uneven in size. Therefore, in most cases, it is very difficult to obtain fast, friendly, and mass sprouts. As a result, sprouts in the vegetable fields turn out to be sparse, and this, in turn, affects the density of plant standings. On such crops there are more weeds as well as an inefficient use of fertilizers, irrigation water, and agricultural techniques. Ultimately, these all this lead to a significant reduction in the productivity of vegetable plantations.

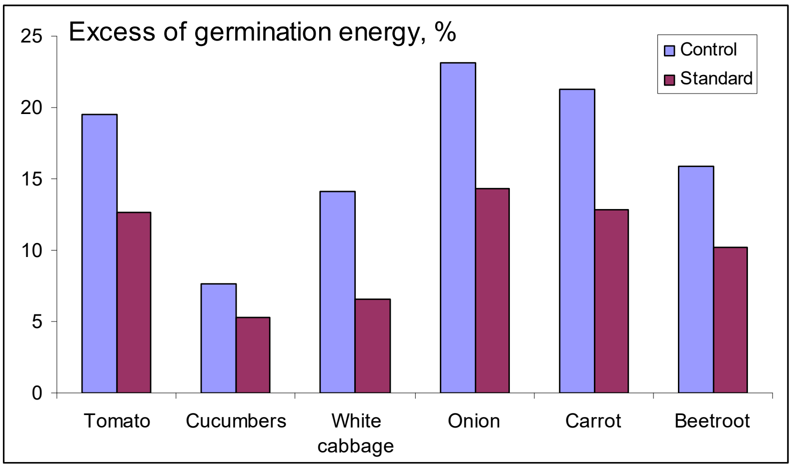
The results of the laboratory experiments showed that the EldORost preparation had a positive effect on the sowing qualities of tomato seeds. The germination energy in these variants of the new organic preparation was 19.5% higher than the control and 12.6% of the standard, and the laboratory germination was higher by 13.8% and 10.0%, respectively. A more intensive growth of seedlings was noted in the experimental variants compared to the control and standard (Table 1).

The novel humic composition EldORost had a larger activating effect on the germination energy and germination of cucumber seeds. The results in Table 1 show that the variants with this preparation had a positive effect on the sowing qualities of cucumber and white cabbage seeds. Here, the best indicators were also in the EldORost variant, where the growth of seedlings was more intensive than in the control and standard (Figure 3).

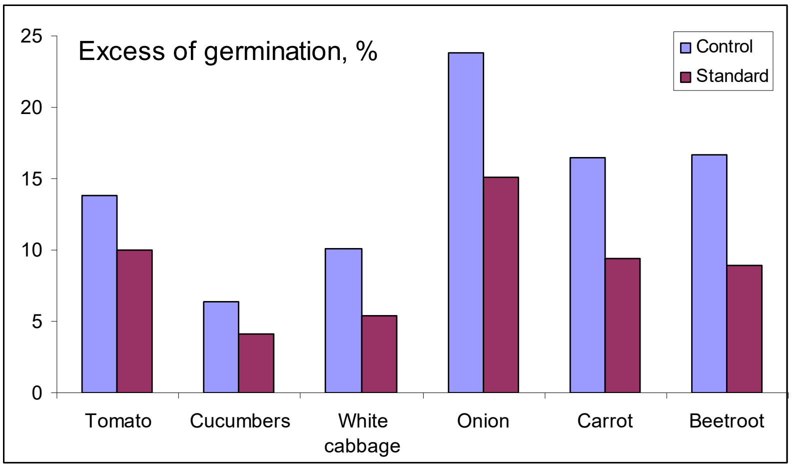
Table 1. The effect of EldORost on the sowing quality and microflora of the vegetable seeds.

Trial Variants	Sowing Qualities of Seeds		Growth Intensity of Seedlings	Intensity of Microflora Growth
	Germination Energy, %	Germination, %		
Tomatoes				
Control	82 ± 1	87 ± 4	++ *	++ *
Sodium humate	87 ± 3	90 ± 2	+++	++
EldORost	98 ± 4	99 ± 3	+++	+
F_{st}	83.09	35.22		
F_{05}	3.88	3.88		
LSD_{05}	2.7	3.1		
Cucumber				
Control	92 ± 3	94 ± 4	++	++
Sodium humate	94 ± 6	96 ± 2	+++	++
EldORost	99 ± 5	100	+++	+
F_{st}	5.37	11.42		
F_{05}	3.88	3.88		
LSD_{05}	4.6	2.7		
White cabbage				
Control	85 ± 6	89 ± 1	++	++
Sodium humate	91 ± 4	93 ± 5	+++	++
EldORost	97 ± 6	98 ± 8	+++	+
F_{st}	12.23	10.19		
F_{05}	3.88	3.88		
LSD_{05}	5.2	4.0		
Onion				
Control	78 ± 3	80 ± 1	++	++
Sodium humate	84 ± 6	86 ± 4	+++	++
EldORost	96 ± 7	99 ± 5	+++	+
F_{st}	12.44	89.85		
F_{05}	3.88	3.88		
LSD_{05}	7.9	3.1		
Carrots				
Control	80 ± 2	85 ± 4	++	++
Sodium humate	86 ± 1	91 ± 3	+++	++
EldORost	97 ± 8	99 ± 5	+++	+
F_{st}	46.86	37.26		
F_{05}	3.88	3.88		
LSD_{05}	3.8	3.5		
Beetroot				
Control	82 ± 4	84 ± 6	++	++
Sodium humate	88 ± 5	90 ± 3	+++	++
EldORost	97 ± 2	98 ± 7	+++	+
F_{st}	32.18	19.03		
F_{05}	3.88	3.88		
LSD_{05}	4.0	4.8		

* The signs +. ++, and +++ represent the rang assessment of the effect, nominally, week, medium, strong.



(**a**)



(**b**)

Figure 3. The excess of the EldORost indicators in comparison with the control and the standard. (**a**) Growth in germination energy in comparison with the control and the standard. (**b**) Growth in germination in comparison with the control and the standard.

The new organic fertilizer EldORost had a more active effect on the germination energy and germination of cucumber seeds and cabbage seeds of white cabbage. There were also better indicators in the EldORost variant, where more intensive growth of the seedlings was observed compared to the control and the standard (Table 1). As shown in Figure 3, the composition EldORost had a positive effect on the seed quality of the vegetable crops. Thus, the best indices were observed for onions where the application of EldORost increased the seed germination energy by 23.1% and by 14.3% compared to the control and the germinating ability, respectively, by 23.8% higher than the control, and by 15.1% higher than the standard. The growth of seedlings in these variants is also more intensive (Table 1). A similar pattern was observed in the treatment of carrot seeds. The germination energy of carrot seeds increased when using the preparation 0.0001% EldORost by 21.3% compared to the control and by 12.8% than the standard, and germination was higher by 16.5% and 9.4%, respectively (Table 1). The stimulator EldORost intensively affected the germination energy and germination of beetroots. The data obtained during the processing of beetroot showed that the germination energy of beetroot seeds was 15.9% higher than the control and 10.2% higher than the standard, and germination by 16.7% and 8.9%, respectively.

Laboratory studies of EldORost biofertilizer on germination energy and germination as well as on fungal and bacterial microflora of potato, tomato, cucumber, cabbage, carrot, onion, and beetroot seeds showed that the new plant growth stimulator EldORost had a positive effect on the indicators of seed quality of the vegetable crops. It showed higher stimulating efficiency in all crops compared to the reference preparation.

3.3. The Effect of a New Bio-Organic Plant Growth Stimulator on the Formation of Vegetative Biomass and Food Organs of Potatoes and Vegetable Crops

The value of the formed crop of vegetable crops was closely related to the habitus of plants. The more powerful the development of vegetable plants, the higher their productivity. Vegetable crops with a highly developed biomass are more resistant to diseases and pests, they are able to suppress weeds, and they have better developed photosynthetic activity. All of this contributes to obtaining high yields of vegetables with high quality indicators and environmental friendliness, since fertilizers and irrigation water are used more efficiently, and the use of pesticides against harmful organisms is excluded or reduced to a minimum. Consequently, the development of vegetable plants is of very important agronomic, economic, and ecological importance. Plant habitus, in turn, depends on the soil and climatic conditions of growth and applied agrotechnologies (varieties, fertilization, irrigation, plant protection, etc.). Among the many factors that affect the development of the biomass of vegetable crops, fertilization is central because it provides plant nutrition.

Biometric studies were carried out to determine the intensity of the growth and development of potato and vegetable crops, and the formation of their vegetative biomass and productive organs when using a new bioorganic stimulant in the field. They showed that a new biological product (stimulant) had a significant impact on the morpho-physiological parameters of potatoes and vegetable crops. Thus, Table 2 shows the experimental data of the field experiments, the characteristics of plants treated with different preparations: control (grown without chemicals), sodium humate (reference), and biostimulator EldORost.

Table 2. Comparative characteristics of white cabbage plants (phenophase—technical ripeness).

Experience Variants	The Total Weight of the Plant, g	Number of Leaves, pcs.	Mass of Plant Leaves, g	The Tying of the Heads, %	The Average Diameter of the Head, cm	Average Head Weight, g
Control	3290 ± 6	19 ± 1	1030 ± 4	86.4 ± 3	22.5 ± 4	2260 ± 2
Sodium humate	4185 ± 4	24 ± 5	1315 ± 1	91.7 ± 3	26.4 ± 4	2870 ± 2
EldORost	4618 ± 7	25 ± 6	1398 ± 5	93.1 ± 5	27.8 ± 3	3220 ± 8
F_{st}	37,198.85	1.50	7983.50	2.61	1.66	29,504.17
F_{05}	5.14	5.14	5.14	5.14	5.14	5.14
LSD_{05}	12.2	-	7.5	-	-	9.8

Significant differences were only found in the total weight of the plant, mass of plant leaves, and average head weight.

As can be seen in Table 2, the biometric parameters of cabbage when treated with bioorganic biostimulator EldORost were significantly superior to those of the control plants, and, most importantly, even superior to the standard. If the average weight of a cabbage head on the control variant was 2260 g, on the variant with the reference preparation taken for comparison it was 2870 g, and on the variant with EldORost it was 3220 g. The number of leaves per plant on the control was 19, and on the reference and test variants, it increased and amounted to 24 and 25, respectively. By the weight of leaves, the new preparation (1398 g) exceeded the control (1030 g) and the standard (1315 g). There was an improvement in the tying of heads—93.1% with 91.7% according to the standard and 86.4% at the control. This is very important, because the higher the percentage of tie, the higher the productivity. According to the average diameter and average weight of heads, high rates were achieved in the experiment on the variant with a new plant stimulator of 27.8 cm and 3220 kg. This is much more than the control, and also higher than the reference version. Thus, the new plant growth stimulator showed a high effect on the cabbage culture.

A similar pattern was observed in the field experiments with cucumbers and tomatoes (Tables 3 and 4) where a high stimulating effect was also noted. In the control, the total weight of the plant was 498 g, the length of the main shoot (main stem) was 143 cm, the number of leaves on one plant was 52, and the total weight of fruits (green leaves) on one plant on the day of registration was 184 g. In the reference variant, these indicators were: 576 g; 168 cm; 61; and 235 g, respectively. With the application of the new plant growth stimulator, the main biometric data were as follows: the total weight of the cucumber plant was 648 g, the length of the main (main) shoot was 176 cm, the number of all leaves on one plant was 65, and the total weight of fruits (formed, that is available on the plant on the day of accounting) was 256 g. All this shows the high stimulating effect of the drug EldORost.

Table 3. The effect of EldORost on the formation of the cucumber biomass (phenophase—mass fruiting).

Experience Variants	The Total Weight of the Plant, g	Length of the Main Shoot, cm	Number of Leaves, pcs.	Number of Lateral Shoots, pcs.	Fruit Weight per Plant, g
Control	498 ± 1	143 ± 4	52 ± 6	3.0 ± 4	184 ± 4
Sodium humate	576 ± 3	168 ± 6	61 ± 4	3.5 ± 5	235 ± 2
EldORost	648 ± 5	176 ± 8	65 ± 2	3.7 ± 6	256 ± 8
F_{st}	1447.20	22.99	7.13	1.52	146.89
F_{05}	5.14	5.14	5.14	5.14	5.14
LSD_{05}	6.8	12.4	8.6	-	10.6

No significant differences were found between number of lateral shoots.

Table 4. The effect of EldORost on the formation of the tomato biomass (phase-mass harvesting of fruits).

Experience Variants	Total Weight of 1 Plant, g	Plant Height, cm	The Number of Leaves with Petioles on the Plant, pcs.	The Number of Lateral Stems of 1 Plant, pcs.	Number of Fruits per Plant, pcs.	Weight of Fruits per Plant, g
Control	824 ± 4	49 ± 4	28 ± 7	3.5 ± 3	14 ± 5	530 ± 4
Sodium humate	976 ± 6	58 ± 8	35 ± 5	3.8 ± 7	20 ± 6	745 ± 3
EldORost	1215 ± 3	65 ± 2	41 ± 4	4.5 ± 6	28 ± 4	843 ± 5
F_{st}	5732.11	6.89	4.23	2.52	5.77	4613.94
F_{05}	5.14	5.14	5.14	5.14	5.14	5.14
LSD_{05}	9.0	10.6	-	-	10.1	8.2

No significant differences between the number of leaves with petioles on the plant and the number of lateral stems of one plant were found.

In the field experiments with tomato culture, the influence of the new EldORost stimulant on plant growth processes was clearly seen. Therefoore, in this variant, tomato plants were taller (on average 65 cm), leafy (41 pieces), the plant had more fruits (28 pieces), and a larger total weight (950 g). These indicators were significantly higher than the control, and comparatively larger in comparison with the reference variant. This gives reason to consider the new preparation as a plant growth stimulator (Table 5).

The effect of EldORost on the formation of root crops such as table beets and carrots was studied (Table 5). In this case, the above-described dependence was also observed, in other words, the use of EldORost led to an increase in biometric indicators: the mass of beet root was 24.4% higher compared to the control and 13.1% higher compared to the standard, and the mass of carrot root was 29.9% higher compared to the control and 16.5% higher compared to the standard. The picture was similar for other indicators

Significant differences were found in the total plant weight and root weight for both crops as well as in the root length of the beet only.

The use of organic plant regulator contributed to a more intense growth and development of these root crops and the formation of their powerfully developed biomass, and thus increased their productivity. The use of an organic plant growth stimulant was also highly effective on potato crops (Table 6).

Table 5. The effect of EldORost on the biomass of table beets and carrots (phenophase—technical ripeness of root crops).

Experience Variants	Total Weight of the Plant, g	Length of Leaves, cm	Number of Leaves, pcs.	Diameter of Root Crop, cm	Root Crop Length, cm	Root Crop Weight, g
			Beetroot			
Control	324 ± 2	31.2 ± 4	10 ± 7	7.5 ± 6	8.2 ± 3	180 ± 8
Sodium humate	365 ± 3	34.1 ± 6	12 ± 3	8.4 ± 4	9.0 ± 5	198 ± 2
EldORost	391 ± 5	35 ± 4	13 ± 2	8.8 ± 8	9.6 ± 4	224 ± 5
F_{st}	270.24	2.15	0.34	3.44	8.88	47.35
F_{05}	5.14	5.14	5.14	5.14	5.14	5.14
LSD_{05}	7.1	-	-	-	0.82	11.1
			Carrot			
Control	185 ± 7	32 ± 5	8 ± 4	4.0 ± 2	12.5 ± 3	147 ± 6
Sodium humate	236 ± 4	37 ± 6	9 ± 3	4.5 ± 6	13.6 ± 5	164 ± 4
EldORost	267 ± 8	38 ± 3	10 ± 6	4.8 ± 2	16.3 ± 4	191 ± 5
F_{st}	119.60	1.33	0.15	3.34	3.66	57.55
F_{05}	5.14	5.14	5.14	5.14	5.14	5.14
LSD_{05}	13.1	-	-	-	-	10.1

Table 6. The effect of the new plant growth regulator EldORost on the formation of potato biomass (phenophase—intensive tuber formation).

Experience Variants	The Total Weight of the Plant, g	Plant Height, cm	Number of Stems, pcs.	Number of Tubers per Bush, pcs.	Mass of Tubers per Bush, g
Control	760 ± 3	53 ± 6	4.0 ± 1	9 ± 4	405 ± 5
Sodium humate	945 ± 4	65 ± 5	5.2 ± 7	12 ± 2	590 ± 3
EldORost	1127 ± 8	73 ± 3	6.3 ± 5	16 ± 4	711 ± 7
F_{st}	3405.13	13.03	15.88	3.08	2575.34
F_{05}	5.14	5.14	5.14	5.14	5.14
LSD_{05}	10.9	9.7	1.00	-	10.5

No significant differences between the number of tubers per bush were found.

Thus, it can be noted that the new plant growth regulator had a positive effect on the growth processes of potato and vegetable crops, significantly improving their biometric parameters.

It was found that the treatment of wheat seeds with the biostimulator of plant growth and development EldORost significantly improved the structural parameters of vegetable crops, contributed to the formation of a strong root system and growth processes, and increased the plant height, leaf length, number of leaves per plant, number of lateral stems, number of tubers per bush, the number of fruits per plant, the mass of tubers per bush, the total mass of plants, diameter and length of root balls, and yield. For potatoes, due to their physiological needs, it is preferable to use a potassium formulation with a set of trace elements.

3.4. The Effect of the Biostimulator EldORost on the Yield of Potatoes and Vegetable Crops

The productivity of vegetable plantations is of great importance in irrigated vegetable production because each hectare of irrigated arable land has a very high value. This is especially important for the foothills of the southeast of Kazakhstan, where highly fertile soils and sufficient water resources are concentrated. Therefore, new scientific developments should be aimed at increasing the productivity of vegetable crops, which is the main indicator of the effectiveness of agricultural technologies. In this regard, the effect of a new organic plant growth stimulator on the productivity of potato and vegetable crops was studied.

In the field experiment with white cabbage on the control variant, the yield of heads was 30.4 t/ha. In the variant with the reference preparation, 35.0 t/ha was obtained, and in the variant with a new organic plant growth regulator, it was 39.9 t/ha. The additional yield from the new drug was equal to 9.5 t/ha, or 31.3% more than the control (Table 7).

Table 7. The effect of EldORost on the yield of potatoes and vegetable crops.

Experience Variants	Average Yield, t/ha	Additional Yield		Average Yield, t/ha	Additional Yield		Average Yield, t/ha	Additional Yield	
		t/ha	%		t/ha	%		t/ha	%
	White cabbage heads			Cucumber greens			Tomato		
Control	30.4	-	-	17.2	-	-	28.5	-	-
Sodium humate	35.0	4.6	15.1	19.7	2.5	14.5	32.3	3.8	13.3
EldORost	39.9	9.5	31.3	22.4	5.2	30.2	38.4	9.9	34.7
F_{st}	254.55			55.14			199.00		
F_{05}	4.26			4.26			4.26		
LSD_{05}	0.95			1.13			1.14		
	Table beet			Carrot root			Potato tuber		
Control	26.1	-	-	23.7	-	-	19.3	-	-
Sodium humate	29.8	3.7	14.2	27.8	4.1	17.3	22.5	3.2	16.6
EldORost	33.6	7.5	28.7	31.6	7.9	33.3	26.4	7.1	36.8
F_{st}	139.25			142.60			143.34		
F_{05}	4.26			4.26			4.26		
LSD_{05}	1.02			1.05			0.96		

Thus, the laboratory and demonstration field tests conducted on potatoes and the main vegetable crops (tomato, cucumbers, cabbage, carrots, onions, beets) showed a high efficiency of the growth stimulator EldORost, the indicators of which exceeded the known reference drug. The preparation significantly improved the sowing qualities of seeds, increasing the germination and seed germination energy, and intensively stimulating the root formation in plants. It also accelerates the growth processes: increases the height of plants, the length of leaves, the number of leaves on the plant, the number of lateral stems, the number of tubers on the bush, the number of fruits on the plant, the mass of tubers from the bush, the total mass of plants, and the diameter and length of the root crop. It increased the yield, the period of fruiting, reduced the term of crop ripening by 10–12 days, and improved the consumer properties of the obtained agricultural products. EldORost had a positive effect on the productivity of potatoes and major vegetable crops, significantly increasing the productivity of their yield compared to the control variants of the field experiments, with an additional yield as follows: cabbage—31.3%, cucumbers—30.2%, tomatoes—34.7%, table beets—28.7%, carrots—33.3%, and potatoes—36.8%.

EldORost is a ballast less preparation of a humic nature of a new generation with a high degree of humification. The product contains easily soluble physiologically active salts of humic and fulvic acids (humates and fulvates), a complex of amino acids, macro- and microelements in a form accessible to plants. It is an environmentally friendly product, completely soluble in water, which is extremely convenient for drip irrigation systems. It is designed for all types of crops in any soil and climate zones, acts as plant hormones, and the optimal concentration of the drug is 0.0001%. The preparation is used for pre-sowing seed treatment, foliar treatment during the vegetation period as an independent fertilizer, and post-harvest soil treatment. Its application does not require changing the existing agricultural technologies—it is compatible with any plant protection agents and other fertilizers. It is used in the form of a working solution both independently and in tank mixtures with plant protection agents and soluble fertilizers within the planned treatments. It increases the efficiency of mineral fertilizers and pesticides, reducing their use by 20–40%. It is characterized by economical production and use: pre-sowing seed treatment—200 g/t, crop spraying: grains—150 g/ha, post-harvest soil treatment—400 g/ha.

The results obtained in laboratory and field experiments on potatoes and the main vegetable crops showed a high efficiency of the humic nature growth stimulator EldORost.

This confirms that the use of humic compounds are the most promising direction in agricultural technology. Their use is actively expanding, especially in connection with the desire to make agriculture as environmentally friendly, efficient, and economical as possible [18–23]. We conducted tests for cereals, legumes, and other types of vegetable crops [38]. In future work, we plan to select the growing conditions and application rate separately for each crop and there will be additional reports on this research.

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References

1. Calvo, P.; Nelson, L.; Kloepper, J.W. Agricultural uses of plant biostimulants. *Plant. Soil* **2014**, *383*, 3–41. [CrossRef]
2. Van Eerd, L.L.; Turnbull, J.J.D.; Bakker, C.J.; Vyn, R.J.; McKeown, A.W.; Westerveld, S.M. Comparing soluble to controlled-release nitrogen fertilizers: Storage cabbage yield, profit margins, and N use efficiency. *Can. J. Plant Sci.* **2018**, *98*, 815–829. [CrossRef]
3. Sivakumar, M.V.; Gommes, R.; Baier, W. Agrometeorology and sustainable agriculture. *Agric. For. Meteorol.* **2000**, *103*, 11–26. [CrossRef]
4. Schloter, M.; Dilly, O.; Munch, J. Indicators for evaluating soil quality. *Agric. Ecosyst. Environ.* **2003**, *98*, 255–262. [CrossRef]
5. Hillocks, R.J. Farming with fewer pesticides: EU pesticide review and resulting challenges for UK agriculture. *Crop Prot.* **2012**, *31*, 85–93. [CrossRef]
6. Rigby, D.; Cáceres, D. Organic farming and the sustainability of agricultural systems. *Agric. Syst.* **2001**, *68*, 21–40. [CrossRef]
7. Eyhorn, F.; Muller, A.; Reganold, J.P.; Frison, E.; Herren, H.R.; Luttikholt, L.; Mueller, A.; Sanders, J.; Scialabba, N.E.-H.; Seufert, V.; et al. Sustainability in global agriculture driven by organic farming. *Nat. Sustain.* **2019**, *2*, 253–255. [CrossRef]
8. Mandavi, M. Role of eco-friendly agricultural practices in indian agriculture development. *Int. J. Agric. Food Sci. Technol.* **2013**, *4*, 11–15.
9. Kaldiyarov, D.A.; Sharipov, A.K. Development of the concept of the optimum mechanism of government administration by economy of agro- industrial complex of the Republic of Kazakhstan. *Life Sci. J.* **2014**, *11*, 394–400.
10. Mustafayeva, B.; Kaltayeva, S.; Saparova, A.; Alimkulova, E.; Kulbayeva, M. The Impact of Agricultural Environmental Pollutions on the Population's Quality of Life. The Experience of Kazakhstan. *J. Environ. Manag. Tour.* **2019**, *10*, 161–170. [CrossRef]
11. Davydov, R.; Sokolov, M.; Hogland, W.; Glinushkin, A.; Markaryan, A. The application of pesticides and mineral fertilizers in agriculture. *MATEC Web Conf.* **2018**, *245*, 11003. [CrossRef]
12. Grigoruk, V.V. *Organicheskaja Produkcija Sel'skogo Hozjajstva: Mirovoj Opyt, Potencial Proizvodstva, Emkost' Rynka, Jeffektivnost' (Organic Agricultural Products: World Experience, Production Potential, Market Capacity, Efficiency)*; Publishing House LEM: Almaty, Kazakhstan, 2014; pp. 154–166.
13. Mosa, A.A. Effect of the Application of Humic Substances on Yield, Quality, and Nutrient Content of Potato Tubers in Egypt. In *Sustainable Potato Production: Global Case Studies*; Springer: Dordrecht, The Netherlands, 2012; pp. 471–492. [CrossRef]
14. Berlyn, G.P.; Sivaramakrishnan, S. The use of organic biostimulants to reduce fertilizer use, increase stress resistance, and promote growth. *USDA For. Serv. -Gen. Tech. Rep.* **1997**, *389*, 106–112.
15. García-Mina, J.M.; Antolín, M.C.; Sanchez-Diaz, M. Metal-humic complexes and plant micronutrient uptake: A study based on different plant species cultivated in diverse soil types. *Plant Soil* **2004**, *258*, 57–68. [CrossRef]
16. Trevisan, S.; Francioso, O.; Quaggiotti, S.; Nardi, S. Humic substances biological activity at the plant-soil interface. *Plant Signal. Behav.* **2010**, *5*, 635–643. [CrossRef]
17. Aguirre, E.; Lemenager, D.; Bacaicoa, E.; Fuentes, M.; Baigorri, R.; Zamarreño, A.M.; García-Mina, J.M. The root application of a purified leonardite humic acid modifies the transcriptional regulation of the main physiological root responses to Fe deficiency in Fe-sufficient cucumber plants. *Plant Physiol. Biochem.* **2009**, *47*, 215–223. [CrossRef]

18. Bogoslovskij, V.N.; Levinskij, B.V.; Sy'chev, V.G. *Agrotexnologii Budushhego (Agrotechnologies of the Future)*; Kniga I "Energeny"; Antikva: Moscow, Russia, 2004; 164p.
19. Levinskij, B.V. *Vsjo o Gumatah (All About Humates)*; Korf-Poligraf: Irkutsk, Russia, 2000; 75p.
20. Perminova, I.V. From green chemistry and nature-like technologies towards ecoadaptive chemistry and technology. *Pure Appl. Chem.* **2019**, *91*, 851–864. [CrossRef]
21. Shahein, M.M.; Afifi, M.; Algharib, A.M. Assessing the effect of humic substances extracted from compost and biogas manure on yield and quality of lettuce (*Lactuca sativa* L.). *Am.-Eurasian J. Agric. Environ. Sci.* **2014**, *14*, 996–1009. [CrossRef]
22. Afif, E.; Barrón, V.; Torrent, J. Organic matter delays but does not prevent phosphate sorption by cerrado soils from Brazil. *Soil Sci.* **1995**, *159*, 207–211. [CrossRef]
23. Mackowiak, C.; Grossl, P.; Bugbee, B. Beneficial Effects of Humic Acid on Micronutrient Availability to Wheat. *Soil Sci. Soc. Am.* **2001**, *65*, 1744–1750. [CrossRef]
24. Pettit, R.E. Organic matter, humus, humate, humic acid, fulvic acid and humin: Their importance in soil fertility and plant health. *CTI Res.* **2004**, *10*, 1–7.
25. Lukhmanova, G.K.; Sakibaeva, K.S.; Seisekenova, M.B.; Kuralbayeva, R.E.; Orysbayeva, M.S. Improving the Competitiveness of Crop Production in the Republic of Kazakhstan. *J. Soc. Sci. Res.* **2018**, *3*, 178–181.
26. Bulgari, R.; Cocetta, G.; Trivellini, A.; Vernieri, P.; Ferrante, A. Biostimulants and crop responses: A review. *Biol. Agric. Hortic.* **2014**, *31*, 1–17. [CrossRef]
27. Chen, Y.; Aviad, T.; MacCarthy, P.; Clapp, C.E.; Malcolm, R.L.; Bloom, P.R. Effects of Humic Substances on Plant Growth. In *Humic Substances in Soil and Crop Sciences: Selected Readings*; ACSESS: Madison, WI, USA, 1990; pp. 161–186. [CrossRef]
28. Aitbayev, T.E.; Mamyrbekov, Z.Z.; Aitbayeva, A.T.; Turegeldiyev, B.A.; Rakhymzhanov, B.S. The Influence of Biorganic Fertilizers on Productivity and Quality of Vegetables in the System of "Green" Vegetable Farming in the Conditions of the South-East of Kazakhstan. *Online J. Biol. Sci.* **2018**, *18*, 277–284. [CrossRef]
29. Leme Filho, J.F.; Thomason, W.E.; Evanylo, G.K.; Zhang, X.; Strickland, M.S.; Chim, B.K.; Diatta, A.A. The synergistic effects of humic substances and biofertilizers on plant development and microbial activity: A review. *Int. J. Plant Soil Sci.* **2020**, *32*, 56–75. [CrossRef]
30. Halpern, M.; Bar-Tal, A.; Ofek, M.; Minz, D.; Muller, T.; Yermiyahu, U. The Use of Biostimulants for Enhancing Nutrient Uptake. *Adv. Agron.* **2015**, *130*, 141–174. [CrossRef]
31. Zhilkibayev, O.; Glubokiy, V. Creation and Introduction of new Complex Highly Effective Organic Regulator of Plant Growth for an Increase in the Yield of Agricultural Cultures. In Proceedings of the XIII International Scientific-Applied Conference «Technological Aspects of Modern Agricultural Production and Environmental Protection», Almaty, Kazakhstan, 8–11 November 2017; pp. 95–97.
32. Zhilkibayev, O.T.; Shoinbekova, S.S.; Sarsenbaeva, G.B.; Aitbayev, T.E.; Tukenova, Z.A. Universal Organic Fertilizers "EldORost" Based on Humic Substances. Book of Abstracts. In Proceedings of the Fifth International Conference of the CIS IHSS on Humic Innovative Technologies «Humic Substances and Living Systems» (HIT-2019), Moscow, Russia, 19–23 October 2019; p. 70. [CrossRef]
33. Judin, F.A. *Metodika Agrohimicheskih Issledovanij (Methodology of Agrochemical Research)*; Kolos: Moscow, Russia, 1980; 366p.
34. Dospehov, B.I. *Metodologija Polevogo Opyta (Methodology of Field Experience)*; Agropromizdat: Moscow, Russia, 1985; 351p.
35. Belik, V.F.; Belik, F.; Soavt, I. *Metodika Opytnyh Rabot v Ovoshhevodstve i Bahchevodstve (Methodology of Experimental Work in Vegetable Growing and Melon Growing)*; Research Institute of Vegetable Farming NGO on Vegetable Growing "Russia"; Agropromizdat: Moscow, Russia, 1992; 318p.
36. Sokolov, A.V. *Agrohimicheskie Metody Issledovanija Pochv (Agrochemical Methods of Soil Research)*; Nauka: Moscow, Russia, 1975; 656p.
37. *Metodicheskie Ukazanija po Registracionnym Ispytanijam Fungicidov, Protravitelej i Biopreparatov v Rastenievodstve (Methodological Guidelines for Registration Tests of Fungicides, Seed Dressers and Biopreparations in Crop Production)*; Almaty-Akmola; 1997; 64p.
38. Filippova, O.I.; Kulikova, N.A.; Konstantinov, A.I.; Grigoryeva, I.O.; Zhilkibayev, O.T. Beneficial effect of "EldORost" on Seed Germination Energy of Wheat, mung beans and Radish. Book of Abstracts. In Proceedings of the Fifth International Conference of the CIS IHSS on Humic Innovative Technologies «Humic Substances and Living Systems» (HIT-2019), Sailing Club "Vodnik", Moscow, Russia, 19–23 October 2019; p. 70. [CrossRef]
39. De Smith, M.J. *Statistical Analysis Handbook. A Comprehensive Handbook of Statistical Concepts, Techniques and Software Tools*; The Winchelsea Press, Drumlin Security Ltd.: Edinburgh, Scotland, 2018; 638p.
40. Volikov, A.B.; Mareev, N.V.; Konstantinov, A.I.; Molodykh, A.A.; Melnikova, S.V.; Bazhanova, A.E.; Gasanov, M.E.; Nikolaev, E.N.; Zherebker, A.Y.; Volkov, D.S.; et al. Directed synthesis of humic and fulvic derivatives with enhanced antioxidant properties. *Agronomy* **2021**, *11*, 2047. [CrossRef]
41. Perminova, I.V.; Frimmel, F.H.; Kudryavtsev, A.V.; Kulikova, N.A.; Abbt-Braun, G.; Hesse, S.; Petrosyan, V.S. Molecular weight characteristics of humic substances from different environments as determined by size exclusion chromatography and their statistical evaluation. *Environ. Sci. Technol.* **2003**, *37*, 2477–2485. [CrossRef]
42. Chen, Y.; Senesi, N.; Schnitzer, M. Information provided on humic substances by E4/E6 ratios. *Soil Sci. Soc. Am. J.* **1977**, *41*, 352–358. [CrossRef]
43. Senesi, N.; Miano, T.M.; Provenzano, M.R.; Brunetti, G. Spectroscopic and compositional comparative characterization of IHSS reference and standard fulvic and humic acids of various origin. *Sci. Total Environ.* **1989**, *81*, 143–156. [CrossRef]