Studying the influence of treating potato seed tubers with hot fog of protective-stimulating preparations

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Abstract. At the moment, a new technique is often used in the technology of potato production and that is pre-treatment of seed material, which is done with the help of chemical, biological and physical methods in complex. Stimulation of plants in the initial period of the growing season requires a special approach. On the one hand, plants need nutrients and, on the other hand, they do not have a developed root system for their production. Therefore, foliar treatment of plants with protective stimulating preparations is an alternative to fertilizer application. Potassium mobilizing bacteria are able to mobilize potassium present in the soil in the root zone of plants. Liquid fertilizers based on humic acids are natural immunomodulators and stimulators of the formation, growth and development of plants, as well as antidepressants and complex nutrition additive. They are suitable for organic farming. Potato seedes were treated with hot fog of protective stimulants at temperatures from 40° C to 60° C immediately before planting. As a result of the studies, the effects of protective-stimulating preparations on plant biometry during the growing season (accumulation of aerial mass) and yield were studied. Hot fog treatment of potato seed tubers with POTASSIUM HUMATE and AZOTOVIT preparations showed the best dynamics of increasing the height of shoots of potato bushes, which exceeded the control by 5.3% and 8.2%. Pre-treatment of potato seed tubers with hot fog of protective-stimulating preparations is an effective method of increasing productivity and it contributes to better products.

1. Introduction
Potato productivity and quality parameters of the obtained tubers are determined by varietal characteristics and the technology of potato production. At the moment, a new technique is often used in potato production and that is pre-treatment of seed material, which is done with the help of chemical, biological and physical methods in complex. The impact on the seed material increases the viability, energy and growth power of tubers, the resistance of plants to diseases and adverse environmental factors.

Five periods of potato development are distinguished [1]. In the first period, the eyes swell, the formation of roots and shoots happen, and it lasts until emergence. The first period is characterized by the fact that growth occurs due to the nutrients of the mother tuber. Tubers in this period are responsive to pre-treatment with protective stimulants.

The second period lasts from the appearance of seedlings and the development of stems with leaves until the appearance of buds. During this period, inter-row treatments to protect plants from diseases...
and pests are carried out. Treating with protective stimulating substances will increase the stress resistance of plants.

The third period lasts from the formation of buds to their flowering. During flowering, there is intensive growth of stolons, the formation of tuberous buds, from which tubers are subsequently formed, which requires a significant amount of nutrients. Therefore, it is important to provide the necessary supply of nutrients in the soil in advance.

The fourth period is characterized by a maximum increase in yield. At this time up to 80% of the mass of tubers is formed. This period lasts from the moment of flowering until the beginning of the withering of the vegetative mass.

During the fifth period, the tops begin to die and dry, physiological ripening and starch accumulation occur, cork tissue is formed on the tuber surface [2].

Stimulation of plants in the initial period of the growing season requires a special approach. On the one hand, plants need nutrients, but, on the other hand, they do not have a developed root system for their production. Therefore, foliar treatment of plants with protective stimulating preparations is an alternative to fertilizer application. Such preparations can increase the digestibility of nutrients, stimulate the development of plants, and have some immune-modulating effect. Recently, protective-stimulating preparations are widely used in agriculture, with preference being given to bacterial ones, based on organic raw materials, as well as humates [3].

Organic plant growth regulators are preparations stimulating the production of special phytohormones or low molecular weight organic substances controlling all processes of plant development in plant tissues. These preparations are represented by biologically active substances (amino acids, proteins, precursors of natural phytohormones), micro- and macro elements, vitamins. They increase viability energy and field germination, resistance to adverse environmental factors and diseases, enhance growth and shaping processes, increase productivity and improve product quality [3, 4].

All organic growth stimulants are usually classified according to the type of responsibility for a certain process in the development of the plant.

Preparations, which include auxins, act as growth regulators for seedlings, as they are responsible for root formation, metabolic processes, and growth of the main shoot. Auxins help in the formation of the ovary, accelerating the ripening process. These substances are produced in roots and upper parts of shoots.

Preparations with cytokinin increase the rate of cell division, accelerating the formation of buds and leaf growth. An increase in the level of this phytohormone prevents premature wilting of the herbage, which significantly prolongs the life cycle of the plant. Cytokinins control the formation of buds and side shoots.

Preparations with biologically active substances from the gibberellin group are called fruit growth stimulants. The thing is that this phytohormone is responsible for the accumulation of beneficial substances in the tissues of the plant, thereby stimulating the accelerated growth of the stem, flowering and fruiting.

Growth regulators to treat seedlings, which include brassins, significantly increase the resistance of young plants to adverse weather conditions and pests. Brassins are responsible for the plant’s immune system.

Microbiological fertilizers are biological products based on strains of bacteria and fungi. They convert soil substances into a form convenient for plants, decompose pesticides and inhibit the growth of pathogens. These preparations are environmentally friendly, do not harm the environment, enhance the growth and development of plants, make plantations resistant to infections in the soil, increase the yield and shelf life of products, and improve soil fertility. Microbiological fertilizers are divided into nitrogen-fixing and phosphorus and potassium-mobilizing ones. Depending on the type of microorganisms included in their composition, various natural processes are activated in the soil.

Nitrogen-fixing fertilizers consist mainly of nitrogen-fixing bacteria (Azospirillum sp. and Rhizobium sp.), which help plants absorb molecular nitrogen from the air by converting it into
ammonium and nitrate forms convenient for plants. Nitrogen-fixing bacteria contribute to the development of plants by producing vitamins, auxins and gibberellins, which significantly affect plant growth, and also increase viability, the seedling growth in the early stages and increase the yield of crops (especially legumes) by 10–25%.

The composition of phosphorus and potassium mobilizing fertilizers includes beneficial soil bacteria (Bacillus megaterium var. Phosphaticum, Pseudomonas striata, Frateuria aurentia), which turn insoluble phosphorus and potassium compounds into forms accessible to plants. Phosphorus solubilizing bacteria form organic acids (citric, succinic, lactic, etc.), hormones (indole acetic acid, gibberellins, etc.) and enzymes (phytase, nuclease, lecithinase, etc.) help in solubilization of insoluble phosphates in a form absorbed by the plant, and also improve plant growth and increase crop yields.

Potassium mobilizing bacteria are able to mobilize potassium present in the soil in the root zone of plants. They work well on all types of soils especially those with low potassium content.

Humic acids (humic and fulvic acids) are natural organic compounds that are isolated from products of plant (leaves, roots, branches, trunks), microbial (protein bodies of microorganisms) or animal (animal remains) origin by exposure to alkali solutions. The composition of humic fertilizers includes humic acids, fulvic acids, amino acids (Arginine, Histidine, B-phenylallonin, Proline, etc.). Useful microorganisms (ammonifiers), fungi, as well as a complex of macro- and microelements (magnesium, potassium, sodium, calcium, iron, phosphorus, nitrogen, zinc, etc.) are added to many compositions. The forms of humic preparations are diverse from liquid to granular complex fertilizers.

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Liquid fertilizers based on humic acids are natural immuno-modulators, stimulators of the formation, growth, development of plants and antidepressants, as well as complex nutrition additives. They are used at all stages of growth, starting from seed treatment before sowing and ending with soil cultivation after harvesting. They are suitable for organic farming. Soft potassium humic fertilizers effectively act as stimulants of root formation and growth. They are used for pre-treatment of seeds, tubers, bulbs, and when grafting. When micronutrients are included in the fertilizer, the plant's immunity is enhanced. Efficiency also lies in the fact that they improve the composition and structure of the soil. Improving the microbiological composition of the soil occurs due to the large number of amino acids, vitamins and beneficial microorganisms. The earth after application is saturated with nitrogen and phosphorus. When regular use, the growth of humus in the soil is noticeable, which makes possible to reduce its density, improve air and water permeability, increase photosynthesis processes and facilitate the respiration of plant cells.

Humic fertilizers have the greatest influence on root crops (potatoes, beets, carrots, radishes, onions, etc.). Tomatoes, cabbage, eggplant, peppers, pumpkin, grain crops respond well to the preparation. When applied, the growth and ripening periods are accelerated, the size and palatability of fruits increase, the amount of nitrates decreases, and the sugar in the composition increases.

The use of biological preparations together with mineral fertilizers makes it possible to halve the dose of their application, since the bacteria increase the absorption of microelements by plants, by increasing the volume of the root system and its adsorbing activity. As a result of this, the assimilation of nutrients is activated.

Bacteria, which are an integral part of preparations, are able to attract soil nitrates to metabolism. Amino acids and proteins are formed from them. Useful microflora, which is a part of preparations, contributes to the most complete disclosure of the potential of the variety, which applies to both quantitative and qualitative parameters of agricultural products (many years of testing have shown an increase in the content of gluten in cereals, sugar in sugar beets, oil in sunflowers, etc.). In addition, plants do not accumulate nitrates and nitrites.

Bacterization improves the phosphorus nutrition of plants, converting sparingly soluble phosphorus compounds into readily available forms. This is especially true for chernozem soils.

Industrial humic preparations obtained from natural resources (coal, peat, bottom sediments, organic waste, etc.) to a large extent inherit the properties of humic substances of the feedstock. Therefore, in terms of functional activity, they act as ameliorants, preparations for detoxification, remediation, reclamation of degraded and contaminated soils, as well as plant growth stimulants.
(improved nutrition and respiration of plants, seed viability, increased length and biomass of seedlings, increased enzymatic activity, but low amount of heavy metals and radionuclides) [4].

In addition, the big advantage of using biological preparations is the technology of their use. It is quite simple and does not require additional costs for the purchase of special equipment. The treatment of seeds with biological preparations is carried out mechanically on the day of sowing or the day before, using existing machines for treatment. In small farms manual treatment is possible, including the use of sprayers [3, 5, 6].

Skillful use of the already created set of biological preparations is able not only to affect the environmental situation positively, but also to increase the efficiency of agricultural production.

2. Materials and methods
For protective stimulant preparations, highly dispersed aerosols should be used. Fine aerosols can be obtained by dispersion or condensation methods. The greatest dispersion is obtained with the condensation method. In the condensation method, liquid protective stimulants are evaporated by mixing with fume gases. Their vapors form hot fog [5].

Potato seedes were treated with hot fog of protective stimulants at temperatures from 40°C to 60°C immediately before planting. An aqueous solution of protective stimulants with a concentration of 80 to 150 ml/l was poured into the tank of the hot fog generator. Treating of potato seedes with hot fog was carried out at a distance of 0.5-0.8 m from the generator nozzle to the tubers. The time of treatment ranged from 5 to 8 s per 10 kg of potatoes.

The treatment of tubers before planting was carried out by installing a belt conveyor, with an aerosol chamber located above it. In the side chamber there was an opening for the intake of hot fog of protective stimulating substances. The aerosol treatment chamber covered the conveyor belt in the tuber treatment area and provided free movement of the conveyor belt with tubers. Depending on the speed of the conveyor, the length of the chamber for aerosol treatment, which provided the necessary processing time, was selected. The hot fog generator could be positioned both along and across the direction of movement of the conveyor belt. The hot fog generator was selected based on the required productivity of the hot fog formation, for example, with a flow rate of the working solution of about 0.05-0.08 l/min.

When turned on, the conveyor belt moves the potato seed tubers for aerosol treatment and unloads them in a vehicle or container for pre-storage. The treatment is allowed to be carried out in containers with special openings for the passage of hot fog, however distribution of tubers in an even layer increases the treatment efficiency, as the fog is distributed more evenly. The supply of hot fog protective substances is carried out by the generator of hot fog mounted on a special stand [6–11].

For potato pre-treatment, three types of protective-stimulating substances were used: humic preparations POTASSIUM HUMATE and ECOROST, as well as microbiological preparation AZOTOVIT. After treatment with the above-mentioned preparations' hot fog, the potato seed tubers were planted in beds. Studies of Lotona potatoes were conducted on a plot of 0.2 ha.

Field experiments had three replications and plots were located systematically. The experiment included three options and the control:
1. POTASSIUM HUMATE hot fog.
2. AZOTOVIT hot fog.
3. ECOROST hot fog.
4. Control (without treatment of tubers).

As a result of the studies, the effects of protective-stimulating preparations on plant biometry during the growing season (accumulation of the aerial mass) and yield were studied.

Liquid protective stimulating preparations were diluted with water in a proportion of 1:10, and then they were used as hot fog for pre-treatment of potato seeds.

3. Results and discussion
The density of potato plants was determined by the number of bushes, and then the total number of
shoots in the bush was calculated. Based on the calculation, the average number of shoots in the bush was obtained. The calculation results were rounded to the first decimal place.

It was established that tall plants, in comparison with short ones, gave a high and high-quality yield. Potato stalk growth continued until the end of the flowering period. In the subsequent period, the main energy was spent on the development of seeds and tubers. And in case of unfavorable conditions for the development of full-fledged tubers, nutrients of shoots were mobilized and this effect was used when chemical removal of tops.

The height and number of potato shoots was determined by the agricultural technology of cultivation and soil and climatic conditions. The height of the stems also depended on the harm caused by diseases and agricultural pests. The height of the potato shoot plants was measured when lateral shoots appeared, and it was done last after the growth stopped.

In the process of monitoring the development of potato plants, it was found that 2 weeks after planting the viability rate in the control was 73.6%, and options with treatments had the following data: ECOROST hot fog (85.6%), AZOTOVIT hot fog (81.3%) and POTASSIUM HUMATE hot fog (78.0%). Hot fog treatment accelerated the physiological development of seed tubers. Further observations made it possible to elucidate the pattern of vegetative development depending on the time and preparation for pre-treatment. The greatest stimulating ability was shown by the treatment with ECOROST and POTASSIUM HUMATE hot fog (Figures 1, 2, 3). The action of AZOTOVIT hot fog later appeared at the last stage of development of the potato bush. The action of the preparations was not only an increase in the height of the shoots of plants, but an increase in the number of shoots in each bush. The greatest number of shoots was observed with the plants treated with POTASSIUM HUMATE and AZOTOVIT hot fog.

Figure 1. Distribution of the height of potato shoots (May 29, 2019) pre-treated with various preparations.
Figure 2. Distribution of the height of potato shoots (June 09, 2019) pre-treated with various preparations.

Figure 3. Distribution of the height of potato shoots (June 16, 2019) pre-treated with various preparations.
Table 1. Average values of height (cm) and the number of shoots of potato bushes

| Option                        | May 29, 2019 |           | June 09, 2019 |           | June 16, 2019 |           |
|-------------------------------|--------------|-----------|---------------|-----------|---------------|-----------|
|                               | Height of    | Number of | Height of     | Number of | Height of     | Number of |
|                               | shoots, mm   | shoots, pcs | shoots, mm   | shoots, pcs | shoots, mm   | shoots, pcs |
| Control (without treatment)   | 23.7         | 3.62      | 23.8          | 3.99      | 29.0          | 4.08      |
| ECOROST hot fog               | 23.3         | 4.24      | 23.3          | 4.52      | 28.2          | 4.76      |
| AZOTOVIT hot fog              | 21.3         | 4.09      | 21.3          | 4.46      | 27.2          | 4.81      |
| POTASSIUM HUMATE hot fog      | 21.9         | 4.39      | 21.9          | 4.97      | 28.3          | 4.97      |

Hot fog treatment of potato seed tubers with POTASSIUM HUMATE and AZOTOVIT preparations showed the best dynamics of increasing the height of shoots of potato bushes, which exceeded the control by 5.3% and 8.2%. It was also possible to notice a significant increase of the vegetative mass due to the development of additional shoots in these options. The analysis of the crop structure showed that plants treated with POTASSIUM HUMATE and AZOTOVIT preparations had the largest number of tubers of large and medium fractions (Figure 4). This was due to the development of the vegetative mass of plants, as well as their root system. By enzymatic and chemical interaction on organic components of the soil the complex effect of temperature exposure (heating) and the formation of a protective film on the surface of seed tubers, disinfecting and stimulating seeds in the early stages of development, improves absorption of organic components by plants [11].

Figure 4. Potato yield structure pre-treated with various preparations.

The yield analysis showed that the yield structure and the yield itself are highly correlated, the plants and seed tubers pre-treated with POTASSIUM HUMATE and AZOTOVIT preparations have the highest yields (Table 2). This is due to the good development of the vegetative mass of plants, as
well as their root system. It should be noted that the content of micro doses of nutrients of potash fertilizers, as well as potassium-mobilizing soil bacteria improve the growth and development of additional shoots of potatoes. Therefore, the content of nitrogen-containing humates should be supplemented by the introduction of fertilizers to form the necessary soil balance.

| Parameter                       | POTASSIUM HUMATE | AZOTOVIT hot fog | ECOROST hot fog | Control (without treatment) |
|--------------------------------|------------------|------------------|-----------------|----------------------------|
| Yield, dt/ha                   | 204.45           | 202.1            | 160.95          | 136                        |

4. Conclusion
The research results showed that pre-treatment of potato seed tubers with hot fog protective-stimulating preparations is an effective method of increasing the yield and it contributes to better products. Protective-stimulating preparations used in pretreatment of potato seeds in the form of hot fog stimulate physiological processes, increasing field germination, the growth of the vegetative mass and productivity.

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