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The influence of plant growth enhancers on the yield of vegetable crops

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Introduction

The yield of agricultural crops is of great importance to humanity. An important element of modern agronomic technologies in crop production is the use of plant growth enhancers. In small doses, they are able to influence the metabolic processes in plants that leads to significant changes in the growth and development of plants. At the same time, growth stimulants are considered to be an environmentally friendly and economically profitable way to increase the productivity of agricultural crops, which makes it possible to fully realize the potential of plant organisms. Thus, the study of the effect of growth enhancers on yield, taking into account specific soil and climatic conditions, is highly relevant. Today the market offers us a sufficient number of different drugs that are growth stimulants. However, the question remains, which growth regulator to choose and how to use it correctly.

Based on this, **the goal of our research work** is monitoring of growth enhancers while growing leafy vegetables and choosing the best one from the presented ones or their combinations.

In accordance with this goal, **the main tasks** of our work are the following:

- to study the theoretical material on this topic;
- to develop a research plan;
- to grow the culture under equal controlled conditions, but with the use of different growth enhancers;
- to make observation and comparative analysis of the results;
- to get the results and use them when growing cultivated plants in personal plots and at home.

Growth enhancers or stimulants are a group of organic substances that affect the growth and development of plants. They increase the resistance of plants to stress, various diseases, as well as the effects of adverse factors. Therefore, the **hypothesis** of the work is the assumption that various stimulants are indeed capable of accelerating the growth process of cultivated plants.

In this work we introduce you to some of the drugs used to enhance growth, and provide research results on the effect of the stimulants used on the development and productivity of leafy vegetable crops. The results of this work can be used in practice when growing cultivated plants on personal plots, and this is the **relevance** of this work.

1. Analysis of literature data

1.1 History of the study and use of growth stimulants

More than one hundred and thirty years ago, Charles Darwin proved the existence in plants certain substances that enhance cell growth. This substance was called auxin. 60 years ago, the Dutchmen Kegl and Haagen-Smith isolated a line of these substances in pure forms, and the most active of them was heteroauxin (indoleacetic acid). Its industrial synthesis was immediately started, and plant breeders began to use this substance, receiving a significant increase in the percentage of rooting due to the pronounced stimulation of the formation of the lateral root. Gibberellins were studied in Japan in the 1950s, and subsequently gibberellic acids were synthesized. These hormones stimulate intercalary growth of plants in length through cell division below the tops of the organ, for example, in the leaf petioles. In addition, it is these hormones that are secreted by the seed embryos inside the fetus, which stimulates the growth of the pericarp.

Albrecht Daniel Thaer (1752-1828) the famous agronomist and professor of the Berlin University played a significant role in the development and scientific substantiation of the theory of humus nutrition of plants. The French scientist Jean Baptiste Boussingot (1802-1887)

experimentally proved that the nitrogen helps to plant's growth. Jean Boussingo is considered the founder of the science of agrochemistry, his key role is in the study of the mineral nutrition of plants.

Nikolai Kholodny (1882 - 1953) became the founder of the phytohormonal theory of tropisms, which explains the growth movements of plants. He found that increased doses of the phytohormone auxin inhibit root growth or stop it altogether, and a thickening appears in the growth zone.

The Dutch phytophysiologist Frits Went (1903 - 1990) expressed and substantiated the experimental data simultaneously and independently of Kholodny. This hypothesis is known as the Cold-Vent hypothesis.

1.2 Growth stimulants in vegetable growing

Growth stimulants - a substance, having a high biological activity, amplifying cell division, and, therefore, plant growth. Once in plants growth stimulants are included in the metabolic process, affect the activity of biochemical processes and make the plant more viable and its resistance to adverse natural conditions increases. According to their composition, they are divided into natural and synthetic. Phytohormones are natural, and their analogues are synthetic.

The following substances may be present in the growth stimulant:

- Polysaccharides;
- Amino acids;
- Phytohormones;
- Vitamins;
- Humic acids;
- Minerals.

Polysaccharide - a carbohydrate complex form, which along with protein and fat compounds necessary for normal functioning as a vegetable, and animal organisms. They are included in the group of the main sources of energy, which is formed as a result of metabolism in the body. Plants require polysaccharides for faster absorption of nutrients and water by plant cells. Polysaccharides include pectin substances, gums, various mucus, starch, fiber and other substances. One of the most important polysaccharides in plants is starch, which, for example, breaks down into a monosaccharide - glucose. Polysaccharides can accumulate reserves, so that later, breaking down into monosaccharides, give the required amount of nutrients to plant cells.

Amino acids - organic compounds, which are actively involved in the process of plant metabolism. In fact, they represent the elements, due to which the construction of plant cells occurs. The formation of amino acids is a very complex process, which plant expends a lot of energy. These substances are formed as a result of photosynthesis, and then participate in many

biochemical processes, helping crops to grow and develop normally throughout the growing season. In addition, the scientists were able to determine, that the amino acids are able to activate the quick recovery mechanisms after exposure to adverse environmental factors , as well as to improve the resistance of plants to various diseases and pests.

Phytohormones are organic compounds, most often weak acids, which are produced in one part of plants, transported to another part, and there they exert a regulatory effect on plant growth. Plant hormones regulate many life processes of plants: seed germination, growth, differentiation of tissues and organs, flowering, fruit ripening and so on. All it really takes place only in the case, if not violated the general principles of care. Plant hormones - stimulants include:

- auxins (was discovered first , stimulates growth, is transported from the tops of the shoots to the roots and causes the growth of adventitious roots);
- gibberellins (affects cell division, causes the effect of stretching the cell wall, increasing the number of cells);
- cytokinins (stimulate cell division, used to accelerate seed growth, stimulate the growth of buds and fruits , delay wilting processes, increase yields);
- brassinosteroids (the last of the open hormones, causing tissue differentiation, slows aging, helps move the extreme, stressful conditions).

In addition to moisture and mineral compounds, present in the composition of the soil , in addition to carbohydrates, resulting from photosynthesis and are the source of energy, plant cells are needed and some other chemical compounds, for example, vitamins.

Vitamins - are complex substances, possessing high bioactivity and stimulating metabolic processes in the plant, outgrowth root mass, responsible for nutrition and reproduction of plants. The main role of vitamins of various groups that fall into the composition of an irrigation solution or soil is to stimulate metabolism and interact with enzymes. If some vitamins are absent in the plant's diet, plant growth is also absent.

Humic acids (*humates*) are a group of elements that stimulate the development and growth of plants. They consist of substances of natural origin, and have a complex effect on the soil. Humate - natural elements, formed in the soil by the decay of plant tissue. These elements are classified as salts, which are based contain sodium or potassium. Humic acids are a component of brown coal, peat and so on, and were formed as a result of biochemical transformations of decomposition products of organic residues with the participation of trace elements, moisture and atmospheric oxygen. Humic acids are a part of the organic mass of peat (25-50%), brown coal (45-60%), oxidized coal (up to 60%), some soils (up to 10%). The benefits of humic acids for the plant organism are undeniable; the following positive effects on plants are noted:

- They are an essential life-sustaining component, necessary for stimulation of plant growth;

- Stimulate the growth and development of the root system , which makes it possible for strong roots to penetrate deep into the soil, saturated with moisture even in an incredible drought;
- Salts of humic acids increase plant resistance to adverse environmental factors;
- Morbidity decreases;
- Accelerate the ripening of fruits.

Minerals are used for plant growth and development. The lack or absence of some substance interferes with the normal development of the plant and can lead to its destruction. Minerals, which are necessary for plants, come in a dissolved form from the soil. For normal life, minerals are required by the plant in various quantities. Most plants need:

- Nitrogen (accelerates the growth of leaves and stems, is necessary for the plant at the beginning of development);
- Phosphorus (promotes the development of the root system, accelerates the ripening of fruits, increases winter hardiness and drought resistance of plants);
- Potassium (involved in the metabolism of plants);
- As well as a small amount of boron, manganese, iron and others.

Thus, all of the above substances are necessary for plant growth and development, the most significant are phytohormones and humic acids. Everything else is necessary for better absorption of nutrients, strengthening immunity and giving the plant strength. To stimulate the necessary processes artificially, it is enough to spray or water the plants with a stimulant solution.

1.3 Description and features of growing the research object

The plant object of research in our work is basil. The herbaceous annual herb basil (*Ocimum basilicum*) is a representative of the species Basil of the Nepetoideae subfamily Lamiaceae family. Basil is a dicotyledonous, flowering plant. In the wild this plant can be found in Iran, Africa, the tropical regions of the American continent, the Caucasus, China, India, southern and central Asia.

Basil has a branching and superficial root system. The straight tetrahedral stem reaches a height of 0.5 - 0.7 m, it is leafy and branched. Rarely toothed oblong-ovate leaf plates are short-petiolate. There are villi on the surface of foliage and shoots.

The violet varieties of this plant have the strongest smell; they are very popular in the Caucasus and Asia. Green basil is most in demand in Europe, and it is also considered the most popular spice in Mediterranean cuisine. The first edible leaves grow during the first month, then the stem begins to grow upward. Before the bush begins to bloom, it begins to exude the strongest odor.

Cultivation takes place in various greenhouses and in open, but protected from the wind, soils, you can also grow basil at home on a windowsill. Basil is a moisture-loving plant. In this regard, it is necessary to ensure that the substrate is slightly damp all the time. Watering should be done almost every day. If you forget to water the bush in time, then its leaves will very quickly lose their turgor. However, you should not water the plant too much, since due to stagnant liquid

in the substrate, rot may appear on the root system. When the plant is watered, it is necessary to loosen the surface of the substrate in the container, do this with a frequency of 1 time in 2-3 days.

Basil is high in nutrients. This plant has many beneficial properties. Basil has been scientifically proven to improve circulation and airway function, stabilize blood sugar levels and protect the body from free radicals that cause cancer. Basil is a stimulating ingredient for the immune system. The plant conducts internal disinfection of the body and creates a specific barrier for viruses and microorganisms. For our experiment, we chose the Purple Salute basil variety. This variety is prized for its good yield and strong, pronounced clove aroma. It is used as a universal seasoning for a wide variety of dishes. The leaves are medium, ovoid in shape, purple in color with a green tint. The rosette is neat, slightly raised, up to 25 cm in diameter.

2. The experiment

2.1 Progress of work

After reviewing the information on growing leafy vegetables at home, we began the practical part of the study. Initially, we decided to conduct an experiment growing spinach, but this experiment turned out to be unsuccessful, but we consider it necessary to mention its course. So, we purchased:

- spinach seeds (Matador variety);
- 10 boxes for seedlings (60x17x15 cm);
- 100 liters of universal soil;
- 25 liters of expanded clay;
- growth stimulants;
- "Potassium humate" for vegetables;
- growth regulator "Aminosol";
- B vitamins, "Pyridoxine", "Cyanocobalamin" and "Thiamine chloride".

In addition, we purchased three Uniel linear LED phytolamps with a power of 15W to compensate poor sunlight in winter.

It was decided to conduct the study in three locations, distributing various stimulants and their combinations among all participants in the work. The following are the names of the participants and the names of the agricultural products for observation:

Latonov Ivan and Maria:

Box 1 - without stimulants (control);

Box 2 - humin;

Box 3 - amino acids;

Box 4 - B vitamins.

Dimitrova Diana:

Box 5 - no fertilizers (control);

Box 6 - amino acids + humin + B vitamins.

Ryabinina Arina:

Box 7 - no fertilizers (control);

box 8 - amino acids + B vitamins;

box 9 - amino acids + humin;

box 10 - humin + B vitamins

The boxes were located by the window for maximum access to daylight. The phyto-lamp was suspended at a distance of 50 cm from the ground surface according to the instructions for lighting leafy vegetables. It was agreed to turn on the lamp from 8:00 to 22:00 every day, thus providing 14 hours of additional lighting.

Further, on October 18, 2020, all participants simultaneously planted spinach seeds. To do this, in each box for seedlings, we poured 2.5 liters of expanded clay (to ensure soil drainage) and 10 liters of universal soil. After moistening the soil with water, we made 8 holes (2 - 3 cm deep) in a checkerboard pattern with a distance of 10 cm between the holes, where we planted spinach seeds, 2 pcs. in each hole. In total, there were 16 seeds in each box.

The air temperature in the room was approximately 20-22 ° C.

On the fifth or sixth day after planting, the first shoots began to appear. It was decided to fertilize the plants with stimulants by spraying the leaves, so we had to wait for the true leaves to form.

The shoots of all the participants in the work developed very slowly. About a month after planting, real leaves began to appear, but after trying to spray boxes 8 and 9, the leaves began to dry out. It was decided not to spray the rest of the plants, but to let them develop better. However, after 4 weeks, no changes in development were noticed; on the contrary, many shoots began to fade. We associate this with the shortest daylight hours a year, low humidity due to the high heating season (20 - 30%) and the whimsical nature of this culture.

Having shown the results to the supervisor, we decided to change the culture to a more unpretentious one and to carry out a new planting of seeds - this time we chose basil, the Purple Salute variety.

We planted basil seeds on December 6, 2020 at a depth of 1 cm, about 40 seeds in each box. On the third day, the first shoots appeared, and after four weeks the plants formed real leaves, and we proceeded to foliar feeding.

We have prepared solutions for spraying according to the following scheme:

- "Humate Potassium" - 6 ml of the preparation for 1 liter of filtered water, 15 ml of solution for one box;
- "Aminosol" - for 1 liter of filtered water 5 ml of the drug, 15 ml of solution for one box;
- Vitamins of group B - for 1 liter of filtered water 3 ml of vitamins, that is, one capsule of each of the three preparations, also 1 ml of solution for one box.

March 3, 2021 we sprayed plants, it was important to do it in the evening, after turning off fitolampy, to avoid burning the leaves. A week later, we repeated the spraying. And after two weeks we started analyzing the interim results.

Due to the fact, that the defense of our scientific work should take place in two stages (at the beginning of February among fifth grade students and at the beginning of March among seventh graders), we decided not to interrupt the experiment at the end of January, but after making intermediate measurements, wait for the final results by the end of February. Thus, below are presented the results, we were able to estimate at the time of the first protection.

So, on January 29, we measured the shoots in height, estimated the number of leaves and the size of the largest of them. The measurement results are shown in table 1:

Table 1. The results of processing basil with various growth stimulants

Box number	Max. height of shoots, cm	Max. length of a leaf plate, cm	Max. number of true leaves per plant, pcs
one (control)	3.7	0.3	2
2 (potassium humate)	4.5	1.7	4
3 (aminosol)	five	0.9	2
four (B vitamins)	4,3	1.1	2
five (control)	3 , 9	0.6	2
6 (aminosol + humate + vit . B)	7.2	4	6
7 (control)	four	0.9	2
8 (aminosol + vit . B)	7	3.8	6
9 (aminosol + humate)	4.5	2.6	4
10 (humate + vit . B)	4.9	2,3	4

Thus, despite the overall weak development of the plant, we all - still managed to notice the difference between shoots with different dressing. The best results among the use of single preparations were shown by basil shoots in the box number 3, treated with a solution of potassium humate. The maximum plant height was 4.5 cm, and the maximum length of the leaf

plate was just over 1.7 cm. In this case, the shoots formed 4 true leaves, which is important for a leafy vegetable crop.

However, the result of using combined feeding showed different results. Since, in the box number 8 after using a solution of aminosol and B vitamins, basil shoots reached 7 cm, and 6 true leaves were formed. And the length of the leaf plate was 3.8 cm.

The highest results were recorded in the box number 6, treated with a combination of all three drugs: potassium humate, aminosol and B vitamins. The height of the shoots has reached 7.2 cm, the number of true leaves is 6, the maximum length of the leaf plate is 4 cm.

At the same time, the weakest indicators were observed in control boxes number 1, 5 and 7, not treated with fertilizers. None of the shoots stood out in development, and in general, it is obvious that the lack of sunlight and humidity made themselves felt.

Thus, the effectiveness of feeding was evident. And at this stage, we conclude that when planting basil in unfavorable conditions of low light and low air humidity, the use of a combination of all three drugs (potassium humate, aminosol and B vitamins) is most effective. Our experiment continues.

2.2. Characteristics of the stimulants used and the effect of the selected drugs on the growth of the culture

Let us dwell in a little more detail on the description of the drugs mentioned in the practical part of the work. The objects of our experimental study were the following drugs that stimulate plant growth:

- potassium humate balanced with trace elements;
- aminosol amino acid complex;
- B vitamins (pyridoxine, cyanocobalamin, thiamine)

The growth promoters selected are generally available and can be found on the shelves of any specialty store or department.

Potassium humate is a complex fertilizer with microelements, intended for usage for all types of crops. It stimulates plant physiology and growth, restores soil fertility, increasing the content of humic substances in it. It provides rational nutrition, is an active stimulator of the immune system and plant growth. Increases the resistance of plants in stressful situations (frost, low or high temperatures, chemical burns, hail or the consequences of diseases). The content of nutrients in the preparation is not less than: humic acids 80 gram per liter, nitrogen - 20%, phosphorus - 2, potassium - 25, trace elements - copper, zinc, manganese, cobalt, iron.

Aminosol is a liquid organic fertilizer based on a protein hydrolysate. It is a source of amino acids for the normal development and growth of plants. It increases the yield of vegetables, stimulates growth, promotes the development of a healthy root system, reduces stress during transplanting, improves survival, and is suitable for feeding indoor plants. Mass fraction of nutrients, %: organically bound nitrogen - 9, amino acids - 55.

B vitamins group is complex substances, organics with a varied chemical composition, possessing high bioactivity and stimulating metabolic processes in the plant, the growth of the root mass, which is responsible for the nutrition and reproduction of plants. The use of B vitamins promotes faster germination of seeds, increased growth and healthier appearance of plants, as well as accelerating the flowering of plants.

Conclusion

Growing vegetables at home during the winter season is not an easy task, and the correct use of effective growth stimulants can greatly simplify this process. Having done this research work, we came to the following conclusions:

- the abundance of information about various plant growth stimulants requires careful study and analysis before deciding on the use of one or another agricultural product;
- originally developed by us a plan on growing spinach was adjusted in the process, as it showed a negative result, however, changing the culture to basil still allowed to complete the study;
- we managed to grow basil shoots to the size required for foliar treatment with growth stimulants, and we were able to test three drugs (potassium humate, aminosol and B vitamins);
- a comparative analysis of the results presented in Table 1, allowed us to conclude that the combination of all three drugs is the most effective: potassium humate, aminosol and B vitamins.

The results of this work can be used when choosing growth stimulants for growing plants at home or on personal plots or gardens.

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