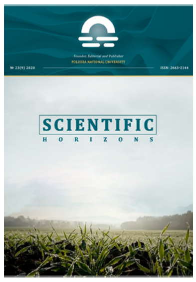
SCIENTIFIC HORIZONS

Journal homepage: https://sciencehorizon.com.ua
Scientific Horizons, 27(9), 73-85



UDC: 633.1:631.54
Doi: 10.48077/scihor9.2024.73

Application of biostimulants in agriculture: Effects on plant growth and yield

Viktoriia Skliar*
Doctor of Biology, Professor
Sumy National Agrarian University
40021, 160 Herasym Kondratiev Str., Sumy, Ukraine
https://orcid.org/0000-0002-1301-7384
Kateryna Kyrylchuk
PhD in Biology, Associate Professor
Sumy National Agrarian University
40021, 160 Herasym Kondratiev Str., Sumy, Ukraine
https://orcid.org/0000-0001-9968-4833
Inna Zubtsova
PhD in Biology, Associate Professor
Sumy National Agrarian University
40021, 160 Herasym Kondratiev Str., Sumy, Ukraine
https://orcid.org/0000-0001-6339-931X
Anna Novikova
PhD in Agriculture, Senior Lecturer
Sumy National Agrarian University
40021, 160 Herasym Kondratiev Str., Sumy, Ukraine
https://orcid.org/0000-0003-1515-5593
Svitlana Yaroshchuk
PhD in Agriculture Science, Associate Professor
Sumy National Agrarian University
40021, 160 Herasym Kondratiev Str., Sumy, Ukraine
https://orcid.org/0000-0001-6125-1979

Article's History:
Received: 13.03.2024
Revised: 05.08.2024
Accepted: 28.08.2024

Abstract. The study aimed to evaluate the effectiveness of the use of biostimulants, such as humic acid preparation, Seaweed algae extract and microbial preparation Baikal-EM, on plant growth and yield. The impact of biostimulants on plant development and crop yields was studied on sugar beet (*Beta vulgaris*) and maize (*Zea mays*). To achieve this goal, field studies were conducted to compare different biostimulants in terms of germination and yield (total crop weight, weight of a single fruit, sugar, starch and

Suggested Citation:
Skliar, V., Kyrylchuk, K., Zubtsova, I., Novikova, A., & Yaroshchuk, Ya. (2024). Application of biostimulants in agriculture: Effects on plant growth and yield. *Scientific Horizons*, 27(9), 73-85. doi: 10.48077/scihor9.2024.73.

**Corresponding author*

protein content). The study was conducted in April-August 2023 in the Sumy district of the Sumy region. Standard agronomic methods, including soil cultivation, measurement of plant growth and yield parameters, and statistical processing of the data were used in the study. The results showed that humic acids and algae extract, when applied separately, provided the highest seed germination and yield. Among all the variants of combined application, the most significant increase in germination rates for beetroot was provided by treatment with a combination of Seaweed and Baikal-EM – 91.7%. For maize, Seaweed with humic acids and Seaweed with Baikal-EM are 92% each. The combination of Seaweed and humic acids had the best effect on the yield of both crops: 460.9 c/ha for beetroot (compared to 325 c/ha without treatment) and 61 c/ha for corn (41.5 c/ha without treatment). The microbial preparation Baikal also demonstrated a positive effect, but its results were lower, and it proved effective in combination with humic acids. The results obtained indicate the feasibility of using humic acids and algae extract to increase plant productivity, while Baikal can be useful for improving the general condition of soil and plants in combination with other fertilisers

Keywords: fertilisation; germination; humic acids; microbial preparations; consortium; algae extract; greening of agriculture

INTRODUCTION

Agriculture is the backbone of the Ukrainian economy and faces many challenges, such as climate change, soil depletion and declining yields, so rationalisation and optimisation are essential. The use of biostimulants is one of the most promising ways to increase crop productivity. These natural or semi-natural substances can activate physiological processes in plants, which in turn has a positive effect on their growth and yield. Among the biostimulants, several groups optimise the plant-soil system and contribute to a more productive use of the natural potential of soils. Algae extracts contain a wide range of bioactive compounds that contribute to the improvement of physiological processes in plants, such as photosynthesis and nutrient assimilation. Humic acids are known for their soil structure improvement, increase in soil fertility and better absorption of nutrients by plants. Microbial preparations activate the beneficial microflora of the soil, which also has a positive effect on plant growth and development.

Among the crops grown in Ukraine, sugar beet and corn are the leading crops. Sugar beet is a key raw material for sugar production; therefore, it is a strategic crop for the food industry (Trembitska & Bohdan, 2023). Ukraine has great potential in growing this crop, but due to imperfect agronomic practices, it lags European countries, despite more favourable climatic conditions. Corn is a multi-purpose crop: a fodder crop for livestock and a raw material for the food industry. It ranks first in the world in terms of gross grain harvest. Reduced planting areas and the need for crop rotation, as well as problems in adapting hybrids, prevent the crop from reaching its potential yield, so optimising the technology for growing these crops is a pressing issue for Ukraine (Donchak & Shkvaruk, 2024). Both crops are sensitive to stress factors, such as insufficient moisture or insufficient mineral nutrition. The use of biostimulants can significantly improve their adaptation to adverse conditions, which is particularly relevant in the context of global climate change (Mokrienko & Kornienko, 2024). It can also solve another global problem faced by humanity – the oversaturation of soil with fertiliser and herbicide residues, which worsens the quality of the soil used for crops.

The feasibility of using biostimulants is widely studied in the world, both in applied and theoretical terms. M. Baltazar *et al.* (2021) present the results of a large-scale review that demonstrates the positive impact of humate-based biostimulants on the productivity of many crops, including corn. The study addressed the molecular mechanisms of biostimulants and proved that they can modify plant metabolism to increase productivity. Y. Yao *et al.* (2020) demonstrated the effect of algal extracts on improving all plant assimilation parameters: photosynthesis, synthesis of sugars, and oils, and activation of defence systems. The beneficial effects of symbiotic microflora are also known, as S. Shirinbayan *et al.* (2019) summarised the results of many studies of microbial preparations, which indicate that they can increase plant resistance and, due to complex mechanisms of action, significantly increase yields. These studies are relevant, but to develop technological schemes for the use of biostimulants, it is necessary to study their effectiveness in the context of certain natural and climatic conditions, considering the characteristics of regional varieties, hence the Ukrainian regional research relevance is determined.

The study of biostimulants in agriculture in Ukraine is becoming more intensive, with many groups of Ukrainian scientists working on their development and testing (Palamarchuk *et al.*, 2021; Prysiazhniuk *et al.*, 2022; Kapitanska, 2022). Research focuses on assessing the impact of various biostimulants on crop productivity, improving their resistance to stress and optimising agronomic practices. M.V. Patyka (2023) highlighted the need to develop and optimise microbial consortia to enhance soil fertility. The author presented author-made developments in the field of microbial biostimulants. O.I. Tsyliuryk *et al.* (2022) studied the effect of different groups of biostimulants on maize growth and showed their effectiveness. Despite the existence of research in the field of corn productivity improvement using biostimulants, no systematic recommendations have been developed yet. The evidence base for the use of biostimulants for sugar beet cultivation in Ukraine is not sufficiently developed, but their wide potential is already well known (Rašovský *et al.*, 2022). The widespread use of biostimulants will improve the economic performance of agricultural production and contribute to the environmental sustainability of the regions. It is necessary to select such biostimulants and their combinations that will ensure maximum productivity and increase the industrial value of crops.

The study aimed to investigate the effect of biostimulants based on algae extract, humic acids and microorganisms, as well as their combinations, on the growth and fertility of sugar beet and corn. Based on the objective, the study set the following tasks: selection of preparations that meet the study criteria; development of preparation application schemes based on manufacturers' recommendations; cultivation of plants with biostimulants and their combinations; evaluation of germination and yield indicators separately for each experimental variant.

MATERIALS AND METHODS

The study was conducted by the method of field experiment, on a field plot located in the central part of the Sumy district of Sumy region. For each treatment option, plots of 10 m^2 were laid out. Crops were sown in mid-April and harvested in early September 2023. Two plant species with different botanical and technical characteristics were used as objects: a representative of dicotyledons – sugar beet (*Beta vulgaris*), hybrid variety Ipel, and a representative of monocotyledons – corn (*Zea mays*), hybrid variety DN Pivyha. Both varieties are listed in the State Register of Varieties and Hybrids. The Ipel beet is a high-sugar beet variety with a yield of 500.9-593.9 c/ha. Sugar content is 17.1-18.0%. Corn variety DN Pivyha, a hybrid of grain, early maturing. Yield: 57.4-84.2 c/ha. Drought resistance 7-9 points. Protein: 9.8-10.3. Starch content 72.7-73.2. The density of beetroot sowing was 10 cm between plants and 50 cm between rows, and corn sowing was 20 cm between plants and 75 cm between rows.

Biostimulants were used as biofertilisers, which affect the root system. Three groups of biostimulants were used: algae extract, humic acids (HA) and microbial preparations. All these biostimulants have a similar direction of action, namely, optimising the plant-soil system, and increasing the availability of nutrients and their absorption by the plant. The aim was to select products containing only the target substances, without additives. The *Ascophyllum* algae extract under the commercial name Seaweed (Terra Aquatica, Ukraine) is a fully organic supplement. The dilution was carried out according to the manufacturer's instructions. It was treated before planting and sprayed at a dose of 2 l/ha three weeks after germination. The preparation based on humic and fulvic acids, commercially known as Humic Acid Concentrate (Organic Group, Ukraine), was applied to the soil before sowing and again 3 weeks after germination at a dose of 3 l/ha. The third preparation was a consortium of microorganisms with the commercial name Baikal-EM (Kisson, Ukraine), containing lactic acid, photosynthesising, nitrogen-fixing bacteria, yeast. It was diluted according to the instructions and tilled before planting, as well as sprayed 4 weeks after the first germination at a dose of 1 litre/ha. The control group of plants was not treated with biologically active substances, instead, it was irrigated with water 3 weeks after germination to simulate the conditions of the experiment.

The square method was used to count seedlings, each plot was divided into 50×50 cm squares, and seedlings were counted in the corners and central square of the plot, and then calculated per hectare. To determine the average weight of the root crop and head of cabbage, 100 fruits were weighed, and the weight was averaged. To calculate the total yield, the entire weight of the harvested crop was converted to a hectare of area. The total carbohydrate content was estimated by the phenol-sulphuric acid method, with glucose as a standard (DuBois *et al.*, 1956). The total protein content was determined by the method of O.H. Lowry *et al.* (1951), using bovine serum albumin as a standard. Statistical analysis was conducted using descriptive statistics, with the F-test used to assess the significance of differences between means. The dependence of the studied indicators on the effect of additives was studied using ANOVA analysis of variance. The authors adhered to the standards of the Convention on Biological Diversity (1992) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (1979).

RESULTS

The first stage of the experiment included the study of the effect of biostimulants on the germination rate of the plants studied. The germination of beetroot was determined from the moment the first seedlings appeared on the soil surface, in the conditions of this experiment, they were observed on the 9th day after sowing. Thus, 9 days after sowing is the first day of observations that were carried out for 5 days. Figure 1 shows the dynamics of emergence. As demonstrated in the graph, fertilisers based on algae extract proved to be the most effective in stimulating beet germination, both as a standalone fertiliser and in combination with humic acids and the microbial preparation Baikal-EM. These fertiliser options contributed to a faster and more synchronised emergence of plants. Other combinations were close to the control values. It should be noted that there was no significant synergistic effect from the combination of fertilisers, therefore, it is likely that the leading role at the germination stage belonged to the algae extract.

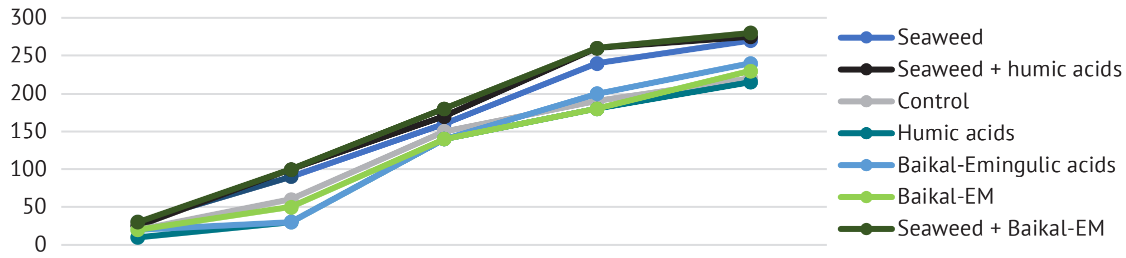


Figure 1. *Germination of Ipel beet seeds under the influence of different biostimulants*
Source: *compiled by the authors*

On the 5th day after the start of the observation, the germination rate of the seeds planted in the soil was calculated. The results were added to Table 1. Notably, the same fertilisers and combinations are used to accelerate germination: Seaweed and its combination with humic acids and Baikal-EM increase the overall germination of beetroot. Treatment with these biostimulants provided germination close to 90%, while without treatment only 73.33% of seeds germinated as seedlings on the 14th day after sowing.

Table 1. *Germination of beetroot seeds of Ipel variety on the 14th day after sowing under the influence of different biostimulants*

Biostimulator	Seaweed	Humic acids	Baikal-EM	Seaweed + humic acids	Baikal-Emingulic acids	Seaweed + Baikal-EM	Control
Similarity, %	90	71.67	76.67	91.67	80	93.33	73.33

Source: *compiled by the authors*

The first sprouts of maize on the soil were observed on the 7th day after sowing the seeds, which was the first day of registration of sprouts. The effect on maize germination was similar, but even more pronounced. The stimulant based on algae extract had the most pronounced positive effect when applied alone. When combined with humic acids and a microbial preparation, a noticeable synergistic effect was observed in each of the variants: the emergence of seedlings on the 3rd day of observation was more intense than in the other variants and control. With a separate application of humic acids, more active germination was observed only on day 3 of the observations, which may indicate different mechanisms of biostimulants' effect (Fig. 2).

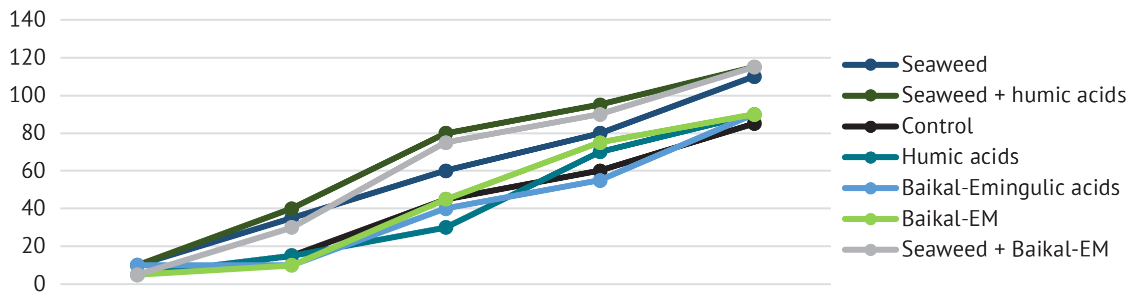


Figure 2. *Germination of maize seeds of DN Pivyha variety under the influence of different biostimulants*
Source: *compiled by the authors*

Total germination at 12 days after sowing is shown in Table 2. It is noticeable that Seaweed and its combinations have a pronounced positive effect on the overall germination of seeds, which, in combination with humic acids, reach more than 88%, while in the control variant without treatment, germination at 12 days was only 68%.

Table 2. *Germination of maize seeds of DN Pivyha variety on the 12th day after sowing under the influence of different biostimulants*

Biostimulator	Seaweed	Humic acids	Baikal-EM	Seaweed + humic acids	Baikal-Emingulic acids	Seaweed + Baikal-EM	Control
Similarity, %	88	72	72	92	72	92	68

Source: *compiled by the authors*

After harvesting, the main characteristics of the crop were analysed. The yield of the studied crops per hectare was calculated. Thus, the yield of beetroot was 325 c/ha, which is lower than the average fertility of this variety, it should be borne in mind that there was no treatment in the experiment, so low yields are quite expected. Treatment with all types of biofertilisers led to an increase in yield. The individual treatments did not reveal any significant difference in yields: treatment with Seaweed algae extract led to an increase in yields of 375 ± 12.2 c/ha, humic acids – up to 394.5 ± 9.2 c/ha, Baikal-EM – 382.9 ± 8.9 c/ha (Fig. 3). Thus, the most effective effect on beetroot yield was the addition of humic acids, although all the results are comparable, the difference between the experimental variants is not significant, and in all variants, the difference is significant compared to the control ($p \leq 0.05$). The combination of biofertilisers with each other had an even more pronounced effect compared to individual applications. The combination of algae extracts with humic acids had the most pronounced positive effect on the yield – the weight of harvested roots was 460.9 ± 12.8 c/ha, which brings these indicators closer to the optimal values for this variety. The combination of humic acids with Baikal-EM led to an increase in yield to 426.83 ± 9.2 c/ha. The combination of algae extracts with microbial fertiliser allowed for the harvest of 404.2 ± 8.66 c/ha, i.e. this combination was the least effective in terms of total yield, the indicators did not differ significantly from the individual fertiliser application.

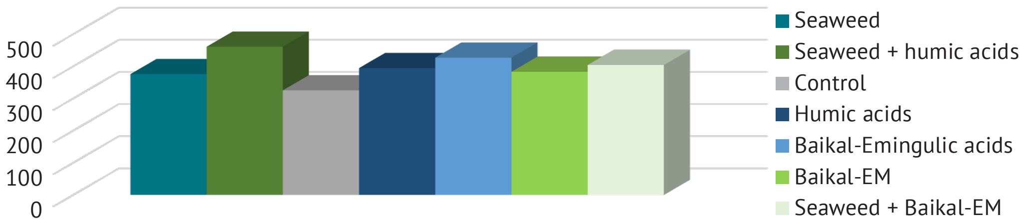


Figure 3. *Yield of beetroot variety Ipel with the introduction of various biostimulants*
Source: *compiled by the authors*

A similar trend towards an increase in yield was observed in the study of maize yields when fertilised with all types of biofertilisers compared to the untreated control, in which the yield was 41.5 ± 4.3 c/ha. These figures are too low for this variety; however, the lack of the necessary micronutrient fertiliser was present in the experiment. The introduction of biostimulants caused a significant increase in yield compared to the control in all variants of the experiment ($p \leq 0.05$). The use of biostimulants separately provided the following yield indicators: Seaweed – 57.53 ± 5.1 c/ha, humic acids – 54.17 ± 3.9 c/ha, Baikal-EM – 52.67 ± 4.8 c/ha (Fig. 4). The results of using all fertilisers for this indicator are comparable and have no significant difference. The combination of algae-based fertiliser and humic acids again demonstrated the best yield increase: 61 ± 5.86 c/ha. The combination of the microbial preparation with humic acids yielded 58.17 ± 5.8 c/ha and with algae extract – 54.33 ± 5.7 c/ha. As can be seen, these results do not significantly improve compared to the separate use of stimulants but are significantly higher than the results of the control plot.

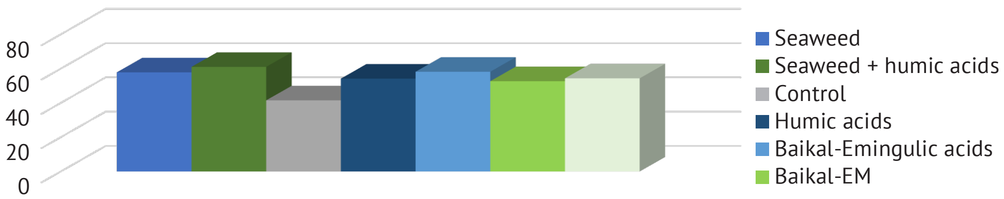


Figure 4. *The yield of maize variety DN Pivyha with the introduction of various biostimulants*
Source: *compiled by the authors*

Moreover, the average weight of one fruit was studied separately, since the overall yield can be increased both by increasing the weight of the fruit and by the survival of more beet plants or by increasing the number of ears of corn per stalk. The average weight of one beetroot in the untreated variant was 352 ± 38.7 g (Fig. 5). The best increase in biomass was provided by the introduction of humic acids, both separately – 400 ± 36 g, and in combination with Seaweed algae extract – 425.3 ± 39.5 g. It should be noted that the separate application of Seaweed fertiliser led to a less significant increase in biomass compared to the control – 368 ± 32 g, thus, the synergistic effect of the combination of these two products is observed. In the group with the introduction of the biological product Baikal-EM, the average weight of the root crop was 395 ± 25.2 g, which is significantly higher compared to the control, but its addition in combination with humic acids did not have a significant increase in yield compared to the separate application of acids: 407 ± 39.5 g. The combination of Baikal-EM and Seaweed also had no synergistic effect: 379 ± 31.4 g, which is lower compared to a separate application of microbial fertiliser.

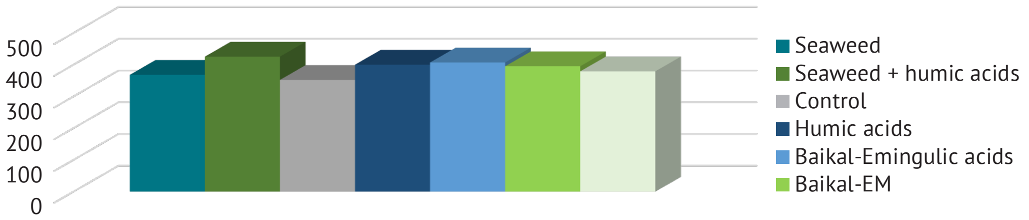


Figure 5. *The average weight of beetroot of Ipel variety under the application of various biostimulants*
Source: *compiled by the authors*

The determination of the weight of corn cobs revealed a slightly different trend in the effect of the preparations. The best performance in a separate application was provided by the preparation based on algae extract: 283 ± 27.6 g, while in the control variant, the average was 216.67 ± 23.4 g (Fig. 6). The use of humic acids and Baikal-EM had a similar effect, the weight of the cob was 255 ± 33.2 and 2596.7 ± 26.1 g, respectively. When these two preparations were combined, a synergistic effect was observed – 298.3 ± 24 g. Furthermore, the weight indicators were quite high when Seaweed and humic acids were combined – 294298.3 ± 29.6 g. The combination of algae extract with a microbial preparation did not lead to an increase in the weight of the head of cabbage compared to a separate application – 260 ± 22.1 g.

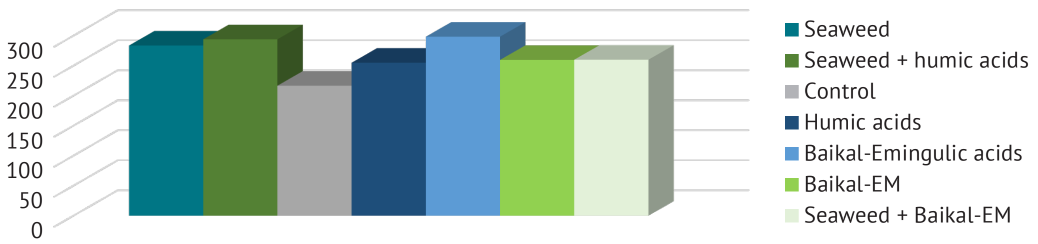


Figure 6. *The average weight of corn cobs of DN Pivyha variety under the application of different biofertilisers and biostimulants*
Source: *compiled by the authors*

To study the qualitative composition of root crops, the amount of sugar in beetroot was determined. The average sugar content in the untreated variant was 10.23 ± 0.25% (Fig. 7), which is quite low for this variety. The introduction of Seaweed biofertiliser led to an increase in this indicator to 15.1 ± 0.36%, which brings them closer to the optimal for this variety. The introduction of humic acids increased the sugar content to 13.3 ± 0.6%, while comparable results were obtained with the addition of Baikal-EM – 12.83 ± 0.3%. Thus, all the preparations had a positive effect on the sugar content of beet, accounting for the increase in total biomass, the preparations significantly increased the productivity of beet. The combination of preparations did not have a significant additive effect on sugar content: Seaweed with humic acids – 15.7 ± 0.3%, Baikal-EM with humic acids – 13.90 ± 0.3%, Seaweed in combination with Baikal-EM – 13.37 ± 0.4%.

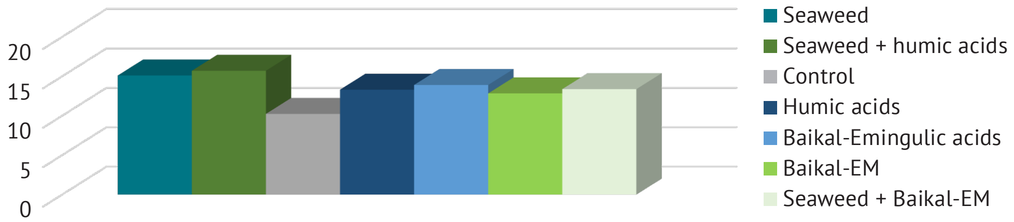


Figure 7. *Sugar content in Ipel beet after treatment with different biostimulants*
Source: *compiled by the authors*

Thus, the sugar content in the root crop increased under the influence of biostimulants, but their combination in the selected combinations does not have a significant impact on productivity compared to a single application. A relevant metric of maize quality is starch content, so this indicator was also studied. In the control group of plants, the average starch content was 66.5 ± 0.5%. All treatments showed a significant positive effect on starch content, and the results were quite homogeneous in all groups. The application of Seaweed provided a starch content of 71.93 ± 0.4%, humic acids – 73.83 ± 0.6%, and Baikal-EM – 72.5 ± 0.5% (Fig. 8). The combination of biofertilisers did not significantly change the indicators compared to the individual application: Seaweed with humic acids – 73.4 ± 0.5%, Baikal-EM with humic acids – 723.9 ± 0.5%, Seaweed in combination with Baikal-EM – 72.5 ± 0.8%.

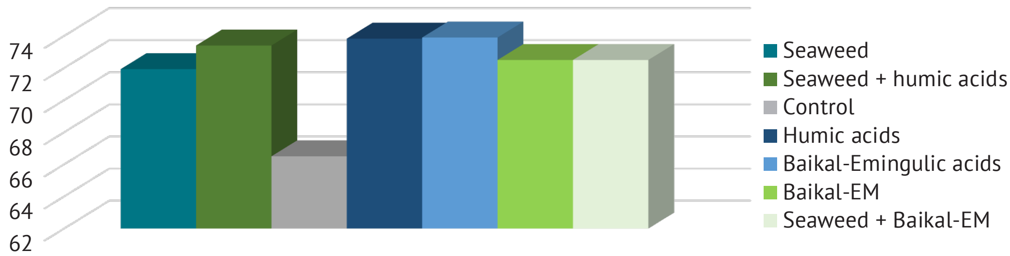


Figure 8*. Starch content in corn variety DN Pivyha after treatment with different biostimulants*
Source: *compiled by the authors*

The protein content of corn can be a relevant metric in the production of oilcake, as it determines its nutritional value. The study of protein content showed that in the control variant, it was at the level of 9.17 ± 0.2% (Fig. 9). The most positive effect when applied separately was demonstrated by a fertiliser based on humic acids – the protein content was 11.27 ± 0.2%. Similar results were obtained with Baikal-EM treatment – 11.03 ± 0.2%. The use of a stimulant based on algae extract had a slightly lower effect – 10.6 ± 0.4%. The combination of Seaweed with Baikal-Em had no synergistic effect, with a protein content of 11.17 ± 0.25%. At the same time, humic acids improved the performance to some extent both in combination with Seaweed – 12.5 ± 0.2%, and with Baikal-EM – 12.2 ± 0.26%. Thus, the combination of fertilisers has a more pronounced effect on the protein content of sugar beet, however, since this indicator is not critical for this crop, the use of such combinations can hardly be considered effective from an economic point of view.

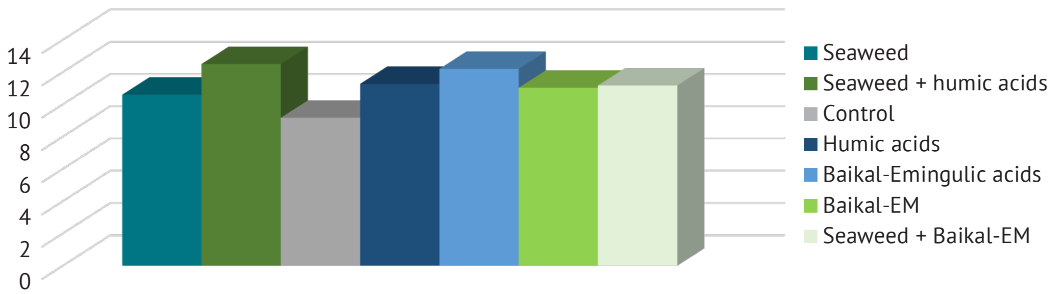


Figure 9*. Protein content in maize variety Ipel after treatment with different biostimulants*
Source: *compiled by the authors*

The protein content of corn is of greater relevance as a technical metric, as it determines its nutritional value, and it also affects the quality of corn flour, which is also produced from this variety. The protein level in corn from the control plot was 8.71 ± 0.15%. The introduction of biostimulants had a positive and equal effect on this indicator: Seaweed provided a protein content of 9.27 ± 0.2%, humic acids – 9.77 ± 0.16%, Baikal-EM – 9.47 ± 0.25% (Fig. 10). The combined use of biofertilisers further improved the results, the most effective was the combination of the microbial preparation extract with humic acids – 11 ± 0.15%, and a slightly lower level – 10.33 ± 0.15% was obtained when processing the combination of humic acids with algae extract. The combination of algae extract with the microbial preparation did not lead to a significant increase in performance compared to the individual application – 9.83 ± 0.16%.

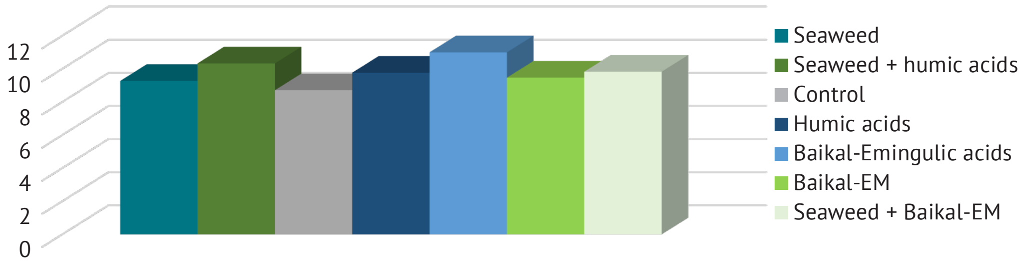


Figure 10*. Protein content in corn variety DN Pivyha after treatment with different biostimulants*
Source: *compiled by the authors*

Thus, the effect of treatment with biostimulants on the studied indicators is positive, and the feasibility of using a combination of biofertilisers should be considered in terms of the importance of protein content for the final product. ANOVA analysis of variance revealed a significant effect of biostimulants on all studied parameters. The findings are summarised in Table 3. Data with a significant difference from the control were conditionally marked. The growth of each indicator was estimated using a semi-quantitative method.

Table 3*. Influence of different biostimulants and their combinations on germination and yield of beetroot variety Ipel*

Type of stimulant	Similarities	Berry mass	Yields, hwt/ha	Sugar contents	Protein content
Seaweed	++	-	+	++	+
Humic acids	-	++	+	+	+
Baikal-EM	-	+	+	+	+
Seaweed + humic acids	++	++	++	++	++
Baikal-Emingulic acids	+	++	++	+	++
Seaweed + Baikal-EM	++	+	++	+	+
Control	-	-	-	-	-

Note: *"-" – increase is not statistically significant; "+" – increase in the indicator within 15%; "++" – increase in the indicator over 15%*
Source: *compiled by the authors*

Table 3 shows that the use of biostimulants had a positive impact on almost all of the identified indicators. It can also be noted that the level of effect of different types of fertilisers is not the same for different indicators, which is due to different mechanisms of influence. It is also noticeable that the combined use of biofertilisers is advisable, as it has a synergistic effect on some of the studied indicators. The best combination for Ipel beet among the studied ones is the combination of algae extract with humic acids, which had a pronounced positive effect on all studied parameters. Comparative data on the effect of biofertilisers on the growth and yield of maize variety DN Pivyha are shown in Table 4. The symbols correspond to those described above. The table shows that the use of all types of biofertilisers led to an increase in the studied indicators, so their application is advisable for increasing yields. The best combination was a combination of stimulants based on algae extract and Baikal-EM. Although the effect on starch and protein content was not very significant, germination and total yield were significantly higher than in the untreated variant.

Table 4*. Influence of different biostimulants and their combinations on germination and yield of maize variety DN Pivyha*

Type of stimulant	Similarities	Cob fruit weight	Yields, hwt/ha	Starch content	Protein content
Seaweed	+	++	++	+	+
Humic acids	-	+	+	+	+
Baikal-EM	-	++	+	+	+
Seaweed + humic acids	++	++	++	+	+
Baikal-Emingulic acids	+	++	++	+	+
Seaweed + Baikal-EM	++	+	+	+	+
Control	-	-	-	-	-

Note: *"-" – increase is not statistically significant; "+" – increase in the indicator within 15%; "++" – increase in the indicator over 15%*
Source: *compiled by the authors*

Thus, based on the generalisation of the data obtained, it is possible to propose the studied types of fertilisers to increase the germination and yield of sugar beet and corn.

DISCUSSION

This study focused on the effects of biostimulants on plant nutrient uptake. All three types of preparations studied – algae extract, humic acids and microbial consortium – contribute to the enhancement of mineral nutrition of the plant, but in different ways: through the influence on the soil structure, root system or rhizosphere. Hence, all methods of influence are effective in improving the indicators selected for observation. The best indicators of beetroot germination and sugar content, as well as increased corn yields, were obtained using Seaweed algae extract and combinations with it. The product under study contains an extract of the algae *Ascophyllum nodosum*. This seaweed is one of the most popular sources of raw materials for biostimulants. P.S. Shukla *et al.* (2019) describe the composition of the algae, it is a source of various bioactive phenolic compounds, including flortanins, and unique polysaccharides: alginic acid (28%), fucoidans (11.6%), mannitol (7.5%), laminarin (4.5%). It is the high content of phenolic compounds that makes this species different from most algae used to produce biostimulants. These substances help improve the absorption of nutrients from the soil, which leads to increased growth and productivity of many plants, including corn. A. Ertani *et al.* (2018) showed the positive effect of algae extract-based biostimulants on improving the morphology of maize root system and enhancing nutrition.

Numerous studies have also attributed the effect of algae to the content of natural hormones, including auxins, cytokinins and gibberellins, which regulate plant growth and development (Panfilova *et al.*, 2019). Their composition increases plant resistance to stressful conditions (drought, disease) by activating antioxidant systems. They also stimulate the processes responsible for seed germination. T. Arioli *et al.* (2023) studied the increase in the number of generative organs (flowers and ovaries) in different crops, which leads to an increase in yield. This study also noted the most pronounced positive effect of algae extract on the rate of seedling formation and germination of corn and beet seeds. R.A. Hamouda *et al.* (2022) demonstrated that the polysaccharide fraction isolated from algae stimulates an increase in carbohydrate and protein content, as well as enhances antioxidant activity, which is consistent with the data obtained in this study on increasing plant sugar content. P.S. Shukla and B. Prithiviraj (2021) studied in detail the mechanisms of algae extract effect on maize metabolism under phosphorus deficiency. It was shown that the addition of the extract increased the content of chlorophyll and carotenoids, as well as had a positive effect on sugar metabolism, which led to an increase in yield and total amino acid content.

The use of humic acids (HAs) is important for improving mineral nutrition, especially in conditions of deficiencies, as they increase the absorption of substances from the soil (Jindo *et al.*, 2020), in this study, no additional mineral nutrition was applied, so the plants did not receive enough of the necessary macro- and microelements. S. Nardi *et al.* (2021) in their meta-review indicate that the size of humic substances affects the sugar content and the intensity of root formation. D.G. Popa *et al.* (2022) indicate that strengthening the root system is a direct mechanism for increasing yields. Substances with a lower molecular weight penetrate the root and affect plant metabolism, while high molecular weight substances contribute to soil structuring in the root zone, the presence of an aromatic ring in the structure of HAs makes them resistant to biodegradation and promotes the formation of complex molecular structures with minerals (Lipczynska-Kochany, 2018).

One of the ways humates affect the soil is by improving its structure, they contribute to the formation of soil aggregates, which increases aeration and water retention capacity. They also affect the absorption of nutrients, increasing the bioavailability of macro- and microelements, and activating the processes of their absorption by the root system (Bulgakov *et al.*, 2017). M. Olaetxea *et al.* (2016) described the mechanism of humic acids' effect on the roots, which enhances the ability to absorb substances and distribute them in the stem, associated with increased ATPase activity, enzyme activation and increased absorption of nitrates and other minerals from the soil. Increased root hair activity leads to better water and nutrient absorption. The result is an activation of metabolism: HAs stimulate photosynthesis, respiration and protein synthesis, which leads to an increase in the energy potential of plants. In addition, they can activate hormonal processes, which promote shoot and leaf growth.

A.C. Souza *et al.* (2022) demonstrated in a study on maize that HA treatment regulates the activity of enzymes – kinases and phosphatases. Genes related to hormones (auxins, gibberellins, cytokinin, ethylene, abscisic acid, brassinoids, jasmonic and salicylic acids), as well as many other transcription factors, are also activated. M. Baltazar *et al.* (2021) review indicates that despite the simple chemical composition of humic acids, they can regulate the activity of thousands of genes in plants that regulate all metabolic pathways, including respiration, photosynthesis, and phytohormone activity. A. Godara and M. Bakshi (2021) focus on increasing the yield value of various fruit and vegetable crops when treated with humic acids, which is due to an increase in the content of sugars, proteins and oils, due to the activation of assimilation processes. HAs are commonly used in combination with fulvic acids, similar to the present study. One of the important effects observed with the addition of HAs in this study was an increase in the sugar content of beetroot. These findings are consistent with those of the review by J. Hudda *et al.* (2020), which showed an increase in sugar content after HA treatment in different crops within 20%. Z. Braziene *et al.* (2021) showed a positive effect of fulvic acids on seed germination and an increase in the overall yield of various crops, including sugar beet.

The microbiological preparation Baikal-EM contains a consortium of microorganisms that increase the microbiological activity of the soil. It consists of several groups of microorganisms, including lactobacilli (*Lactobacillus* spp.), yeasts (*Saccharomyces* spp.), cyanobacteria (*Nostoc* spp.), and bacteria of the Bacillus genus. This consortium has a balanced composition of microorganisms normally found in soils, so it does not disturb natural biomes, but can only enrich them (Burdina & Priss, 2016). S. Shirinbayan *et al.* (2019) in their review describe numerous mechanisms of influence exerted by symbiotic organisms. Cyanobacteria, including Nostoc, are active producers of auxin. Bacteria of the Bacillus genus are producers of auxins, gibberellins, and cytokines. They also have antagonistic effects against many groups of pathogens. W.F. Viera-Arroyo (2020) pointed out the following mechanisms of the symbiotic effect of Bacillus bacteria: antagonistic inhibition of pathogenic microflora of the rhizosphere, stimulation of root biomass growth and stimulation of microelements absorption. The average positive effect on crop productivity reaches 20%. R. Singh *et al.* (2023) in their review of microbial stimulants provide evidence that beneficial bacteria can increase the productivity of many crops, including corn, by up to 25% and reduce the need for mineral fertilisers by up to 50%.

S. Shirinbayan *et al.* (2019) showed the effectiveness of Azotobacter bacteria in increasing growth and potassium and phosphorus uptake by maize under drought conditions. L. Nephali *et al.* (2021) studied the mechanisms of maize fertility improvement in response to microbial consortium treatment. An increase in the main components of the tricarboxylic acid cycle changes in the profile of phenols and lipids were recorded, and at the cellular level, this was manifested in cell wall thickening, membrane remodelling, and improved osmoregulation, which increased drought resistance. M.E.-S. Shalaby and M.F. Shalaby (2008) present the results of a study on the effectiveness against Fusarium infection of sugar beet and, as a result, increase in crop productivity. Thus, consortia of microorganisms contribute to improving the microbiological composition of the soil, increase the availability of nutrients and activate fermentation processes, help protect plants from pathogens and increase their resistance to stress. These data are supported by the results of this study, which demonstrated improved germination and plant productivity under the influence of a consortium of microorganisms.

The study demonstrated a synergistic effect on the germination and yield of both crops. The interaction between HAs and microbial consortia has been confirmed in many studies, and attention has also been paid to the study of mechanisms of interaction. E. Di Iorio *et al.* (2022) point to the interaction between humic acids and rhizosphere microorganisms, which can lead to an increase in the yield of various crops. Several aspects of synergistic interaction have been identified: HAs can be metabolised by microorganisms to release biologically active substances, and they can serve as substrates and adaptogens for microbial survival. Moreover, HAs are involved in redox reactions as an electron acceptor, thus changing the buffering properties of the soil (Xi *et al.*, 2016), which creates a favourable environment for the development of many beneficial microorganisms. M. Rašovský *et al.* (2022) demonstrated the positive effect of microbial biostimulants on sugar content, while the combination of soil bacteria with humic acids proved to be the most effective for increasing the overall yield of root crops. Thus, numerous scientific data from other researchers confirm the effectiveness of the studied groups of biostimulants in increasing plant resistance, growth and yield, which is consistent with the results of the current study.

CONCLUSIONS

The use of fertilisers contributed to a faster and more synchronised emergence of plants. The best results were obtained with the use of a biostimulants based on Seaweed algae extract. In particular, in the case of beetroot, seed germination exceeded 90% when treated with algae extract, while the control group showed only 73.33%. Similar results were observed for maize, where the maximum germination rate reached 88% with the treatment and 68% in the control group. The yield data were also significant compared to the untreated control. The treatment with humic acids increased the yield of beetroot to 394.5 c/ha, and with algae extract to 375 c/ha, while the yield was 325 c/ha in the control variant. The corn yield had the highest increase when treated with algae extract – 57.53 c/ha, while the control value was 41.5 c/ha. Among the combinations of biostimulants, the most effective was the combination of algae extract and humic acids, which increased the yield of beet up to 460.9 c/ha and corn up to 61 c/ha, thus achieving optimal values for these varieties. Another important effect of the treatment with these stimulants was an increase in the sugar content of beet, which significantly increases its commercial value. It is possible to state of a pronounced synergistic effect of fertilisers that exceeds the benefits of individual applications.

Baikal-EM demonstrated good results in terms of seed germination, although the yield was lower compared to humic acids and algae extract. It has proven itself well in combination with humic acids, which may indicate that it is advisable to use it in combination with other fertilisers to achieve maximum results, and the product expands the potential for improving the overall condition of plants. The data obtained are particularly important as the treatment with other types of fertilisers and herbicides was limited in the experimental conditions. It should be noted that the potential of using bio-fertilisers can be much higher when combining them with other types of fertilisers. Biostimulants can be useful in reducing the cost of mineral and organic fertilisers, and herbicides, and increase plant resistance to water shortages. This opens up opportunities for further research to find optimal combinations of biostimulants and their dosage to achieve maximum effect.

The use of only two hybrids of the studied crops, cultivation within one experimental field plot and the lack of standard mineral nutrition led to the limitation of the results of this study. To verify the reproducibility of the data, it is necessary to continue research with other varieties and hybrids, as well as in areas with different agronomic and climatic characteristics. In the future, it is also recommended to investigate the effect of different growing conditions on the effectiveness of biostimulants, as well as their long-term impact on soil fertility. Further research in this area could lead to a significant improvement in the results and efficiency of agronomic practices.

ACKNOWLEDGEMENTS

None.

CONFLICT OF INTEREST

None.

REFERENCES

[1] Arioli, T., Mattner, S.W., Islam, M.T., Tran, T.L.C., Weisser, M., Winberg, P., & Cahill, D.M. (2023). Applications of seaweed extracts in agriculture: An Australian perspective. *Journal of Applied Phycology*, 36(2), 713-726. doi: 10.1007/s10811-023-03120-x.

[2] Baltazar, M., Correia, S., Guinan, K.J., Sujeeth, N., Bragança, R., & Gonçalves, B. (2021). Recent advances in the molecular effects of biostimulants in plants: An overview. *Biomolecules*, 11(8), article number 1096. doi: 10.3390/biom11081096.

[3] Braziene, Z., Paltanavicius, V., & Avizienytė, D. (2021). The influence of fulvic acid on spring cereals and sugar beets seed germination and plant productivity. *Environmental Research*, 195, article number 110824. doi: 10.1016/j.envres.2021.110824.

[4] Bulgakov, V., Adamchuk, V., Nozdrovický, L., & Ihnatiev, Y. (2017). Theory of vibrations of sugar beet leaf harvester front-mounted on universal tractor. *Acta Technologica Agriculturae*, 20(4), 96-103. doi: 10.1515/ata-2017-0019.

[5] Burdina, I., & Priss, O. (2016). Effect of the substrate composition on yield and quality of basil (*Ocimum basilicum* L.). *Journal of Horticultural Research*, 24(2), 109-118. doi: 10.1515/johr-2016-0027.

[6] Convention on Biological Diversity. (1992, June). Retrieved from https://zakon.rada.gov.ua/laws/show/995_030#Text.

[7] Convention on International Trade in Endangered Species of Wild Fauna and Flora. (1979, June). Retrieved from https://zakon.rada.gov.ua/laws/show/995_129#Text.

[8] Di Iorio, E., Circelli, L., Angelico, R., Torrent, J., Tan, W., & Colombo, C. (2022). Environmental implications of interaction between humic substances and iron oxide nanoparticles: A review. *Chemosphere*, 303, article number 135172. doi: 10.1016/j.chemosphere.2022.135172.

[9] Donchak, L., & Shkvaruk, D. (2024). Current state and prospects for the development of agriculture in the Vinnytsia region. *Ekonomika APK*, 31(2), 23-31. doi: 10.32317/2221-1055.202402023.

[10] DuBois, M., Gilles, K.A., Hamilton, J.K., Rebers, P.A., & Smith, F. (1956). Colorimetric method for determination of sugars and related substances. *Analytical Chemistry*, 28(3), 350-356. doi: 10.1021/ac60111a017.

[11] Ertani, A., Francioso, O., Tinti, A., Schiavon, M., Pizzeghello, D., & Nardi, S. (2018). Evaluation of seaweed extracts from *Laminaria* and *Ascophyllum nodosum* spp. as biostimulants in *Zea mays* L. using a combination of chemical, biochemical and morphological approaches. *Frontiers in Plant Science*, 9, article number 00428. doi: 10.3389/fpls.2018.00428.

[12] Godara, A., & Bakshi, M. (2021). Effect of application of bio stimulants like humic acid and vermiwash on the growth, quality and yield of plant – A review. *Plant Cell Biotechnology and Molecular Biology*, 22(19-20), 22-30.

[13] Hamouda, R.A., Hussein, M.H., El-Naggar, N.E., Karim-Eldeen, M.A., Alamer, K.H., Saleh, M.A., Al Masoudi, L.M., Sharaf, E.M., & El-Azeem, R.M.A. (2022). Promoting effect of soluble polysaccharides extracted from *Ulva* spp. on *Zea mays* L. Growth. *Molecules*, 27(4), article number 1394. doi: 10.3390/molecules27041394.

[14] Hudda, J., Godara, A., & Kukreja, S. (2020). Effect of application of humic acid and vermiwash on the growth, quality and yield of plants: A review. *International Journal of Current Microbiology and Applied Sciences*, 9(11), 1277-1284. doi: 10.20546/ijcmas.2020.911.149.

[15] Jindo, K., Canellas, L., Albacete, A., dos Santos, L.F., Rocha, R.L.F., Baia, D.C., Canellas, N.O.A., Goron, T.L., & Olivares, F.L. (2020). Interaction between humic substances and plant hormones for phosphorous acquisition. *Agronomy*, 10(5), article number 640. doi: 10.3390/agronomy10050640.

[16] Kapitanska, O. (2022). *Plant biostimulants. State of the market, types and features of application*. Retrieved from https://www.agronom.com.ua/biostymulyatory-roslyn-stan-rynku-vydy-ta-osoblyvosti-zastosuvannya/.
[17] Lipczynska-Kochany, E. (2018). Humic substances, their microbial interactions and effects on biological transformations of organic pollutants in water and soil: A review. *Chemosphere*, 202, 420-437. doi: 10.1016/j.chemosphere.2018.03.104.
[18] Lowry, O.H., Rosebrough, N.J., Farr, A.L., & Randall, R.J. (1951). Protein measurement with the Folin phenol reagent. *Journal of Biological Chemistry*, 193(1), 265-275. doi: 10.1016/S0021-9258(19)52451-6.
[19] Mokrienko, V., & Kornienko, T. (2024). Formation of productivity of maize hybrids of different ripening groups in the Forest-Steppe region. *Plant and Soil Science*, 15(1), 52-62. doi: 10.31548/plant1.2024.52.
[20] Nardi, S., Schiavon, M., & Francioso, O. (2021). Chemical structure and biological activity of humic substances define their role as plant growth promoters. *Molecules*, 26(8), article number 2256. doi: 10.3390/molecules26082256.
[21] Nephali, L., Moodley, V., Piater, L., Steenkamp, P., Buthelezi, N., Dubery, I., Burgess, K., Huyser, J., & Tugizimana, F. (2021). A metabolomic landscape of maize plants treated with a microbial biostimulant under well-watered and drought conditions. *Frontiers in Plant Science*, 12, article number 676632. doi: 10.3389/fpls.2021.676632.
[22] Olaetxea, M., Mora, V., García, A.C., Santos, L.A., Baigorri, R., Fuentes, M., Garnica, M., Berbara, R.L.L., Zamarreño, A.M., & Garcia-Mina, J.M. (2016). Root-shoot signaling crosstalk involved in the shoot growth promoting action of rhizospheric humic acids. *Plant Signaling & Behavior*, 11(4), article number e1161878. doi: 10.1080/15592324.2016.1161878.
[23] Palamarchuk, V.D., Vinnik, O.V., & Kovalenko, O.A. (2021). Starch content in corn grain and bioethanol yield depending on vegetation conditions and factors of cultivation technology. *Agrarian Innovations*, 5, 143-156. doi: 10.32848/agrar.innov.2021.5.23.
[24] Panfilova, A., Korkhova, M., Gamayunova, V., Fedorchuk, M., Drobitko, A., Nikonchuk, N., & Kovalenko, O. (2019). Formation of photosynthetic and grain yield of spring barley (*Hordeum vulgare* L.) depend on varietal characteristics and plant growth regulators. *Agronomy Research*, 17(2), 608-620. doi: 10.15159/AR.19.099.
[25] Patyka, M.V. (2023). Formation of the microbial biome of soils and systems based on it as a key basis for balanced agricultural production. In *Materials of the IV All-Ukrainian scientific and practical conference "Scientific and innovative development of agricultural production as a guarantee of food security of Ukraine: Yesterday, today, tomorrow"* (pp. 282-284). Kyiv: National Academy of Agrarian Sciences, National Research Library of Ukraine, Institute of History of Agrarian Science, Education and Technology, Institute of Agriculture of the Carpathian Region of the National Academy of Agrarian Sciences of Ukraine.
[26] Popa, D.G., Lupu, C., Constantinescu-Aruxandei, D., & Oancea, F. (2022). Humic substances as microalgal biostimulants-implications for microalgal biotechnology. *Marine Drugs*, 20(5), article number 327. doi: 10.3390/md20050327.
[27] Prysiazhniuk, O.I., Prysiazhniuk, L.M., Melnyk, S.I., & Hryniv, S.M. (2022). *Sugar beet – Breeding, seed production and cultivation technology*. Vinnytsia: Tovory LLC.
[28] Rašovský, M., Pačuta, V., Ducsay, L., & Lenická, D. (2022). Quantity and quality changes in sugar beet (*Beta vulgaris* Provar. Altissima Doel) induced by different sources of biostimulants. *Plants*, 11(17), article number 2222. doi: 10.3390/plants11172222.
[29] Shalaby, M.E.-S., & El-Nady, M.F. (2008). Application of *Saccharomyces cerevisiae* as a biocontrol agent against *Fusarium* infection of sugar beet plants. *Acta Biologica Szegediensis*, 52(2), 271-275.
[30] Shirinbayan, S., Khosravi, H., & Malakouti, M.J. (2019). Alleviation of drought stress in maize (*Zea mays*) by inoculation with *Azotobacter* strains isolated from semi-arid regions. *Applied Soil Ecology*, 133, 138-145. doi: 10.1016/j.apsoil.2018.09.015.
[31] Shukla, P.S., & Prithiviraj, B. (2021). *Ascophyllum nodosum* biostimulant improves the growth of *Zea mays* grown under phosphorus impoverished conditions. *Frontiers in Plant Science*, 11, article number 601843. doi: 10.3389/fpls.2020.601843.
[32] Shukla, P.S., Mantin, E.G., Adil, M., Bajpai, S., Critchley, A.T., & Prithiviraj, B. (2019). *Ascophyllum nodosum*-based biostimulants: Sustainable applications in agriculture for the stimulation of plant growth, stress tolerance, and disease management. *Frontiers in Plant Science*, 10, article number 00655. doi: 10.3389/fpls.2019.00655.
[33] Singh, R., Kaur, S., Bhullar, S.S., Singh, H., & Sharma, L.K. (2023). Bacterial biostimulants for climate smart agriculture practices: Mode of action, effect on plant growth and roadmap for commercial products. *Journal of Sustainable Agriculture and Environment*, 3(1), article number e12085. doi: 10.1002/sae2.12085.
[34] Souza, A.C., Olivares, F.L., Peres, L.E.P., Piccolo, A., & Canellas, L.P. (2022). Plant hormone crosstalk mediated by humic acids. *Chemical and Biological Technologies in Agriculture*, 9, article number 29. doi: 10.1186/s40538-022-00295-2.
[35] Trembitska, O., & Bohdan, S. (2023). Evaluation of the effect of sugar mud and organic fertilizers on the productivity of sugar beets in the conditions of Podillia. *Ukrainian Black Sea Region Agrarian Science*, 27(4), 90-98. doi: 10.56407/bs.agrarian/4.2023.90.

[36] Tsyliuryk, O.I., Izhboldin, O.O., & Sologub, I.M. (2022). Effect of plant growth stimulants on biometric parameters and yield of corn in the Northern Steppe. *Agrarian Innovations*, 15, 59-66. doi: 10.32848/agrar.innov.2022.15.9.
[37] Viera-Arroyo, W.F. (2020). Role of beneficial microorganisms in sustainable agriculture. *Journal of the Selva Andina Biosphere*, 8(2), 67-68. doi: 10.36610/j.jsab.2020.080200067x.
[38] Xi, B., Zhao, X., He, X., Huang, C., Tan, W., Gao, R., Zhang, H., & Li, D. (2016). Successions and diversity of humic-reducing microorganisms and their association with physical-chemical parameters during composting. *Bioresource Technology*, 219, 204-211. doi: 10.1016/j.biortech.2016.07.120.
[39] Yao, Y., Wang, X., Chen, B., Zhang, M., & Ma, J. (2020). Seaweed extract improved yields, leaf photosynthesis, ripening time, and net returns of tomato (*Solanum lycopersicum* Mill.). *ACS Omega*, 5(8), 4242-4249. doi: 10.1021/acsomega.9b04155.

Використання біостимуляторів у сільському господарстві: ефекти на ріст та врожайність рослин

Вікторія Скляр
Доктор біологічних наук, професор
Сумський національний аграрний університет
40021, вул. Герасима Кондратьєва, 160, м. Суми, Україна
https://orcid.org/0000-0002-1301-7384
Катерина Кирильчук
Кандидат біологічних наук, доцент
Сумський національний аграрний університет
40021, вул. Герасима Кондратьєва, 160, м. Суми, Україна
https://orcid.org/0000-0001-9968-4833
Інна Зубцова
Кандидат біологічних наук, доцент
Сумський національний аграрний університет
40021, вул. Герасима Кондратьєва, 160, м. Суми, Україна
https://orcid.org/0000-0001-6339-931X
Анна Новікова
Кандидат сільськогосподарських наук, старший викладач
Сумський національний аграрний університет
40021, вул. Герасима Кондратьєва, 160, м. Суми, Україна
https://orcid.org/0000-0003-1515-5593
Світлана Ярощук
Кандидат сільськогосподарських наук, доцент
Сумський національний аграрний університет
40021, вул. Герасима Кондратьєва, 160, м. Суми, Україна
https://orcid.org/0000-0001-6125-1979

Анотація. Метою роботи була оцінка ефективності використання біостимуляторів, таких як препарат гумінових кислот, екстракт водоростей Seaweed та мікробний препарат Байкал-ЕМ, на показники росту та врожайності рослин. Досліджувався вплив біостимуляторів на розвиток рослин та врожайність сільськогосподарських культур: цукрового буряка (*Beta vulgaris*) та кукурудзи (*Zea mays*). Для досягнення мети були проведені польові дослідження, в яких порівнювалися різні біостимулятори за показниками схожості та врожайності (загальна маса врожаю, вага окремого плоду, вміст цукру, крохмалю та білка). Дослідження проведене в період квітня-серпня 2023 року в Сумському районі Сумської області. У дослідженні використовувалися стандартні агрономічні методи, включаючи обробку ґрунту, вимірювання параметрів росту та врожайності рослин та статистичну обробку отриманих даних. Результати показали, що гумінові кислоти та екстракт водоростей при окремому внесенні забезпечили найвищі показники схожості насіння та врожайності. Серед усіх варіантів комбінованого внесення, для буряка найбільш суттєвий ріст показників схожості забезпечила обробка комбінацією Seaweed з Байкал-ЕМ – 91,7 %. Для кукурудзи – Seaweed з гуміновими кислотами та Seaweed з Байкал-ЕМ – по 92 %. Комбінація Seaweed з гуміновими кислотами найкраще вплинули на врожайність обох культур: 460,9 ц/га для буряка (порівняно з 325 ц/га без обробки) та 61 ц/га для кукурудзи (41,5 ц/га без обробки). Мікробний препарат Байкал також продемонстрував позитивний вплив, але його результати були дещо нижчими, ефективно показав себе в комбінації з гуміновими кислотами. Отримані результати свідчать про доцільність використання гумінових кислот і екстракту водоростей для підвищення продуктивності рослин, тоді як препарат Байкал може бути корисним для покращення загального стану ґрунту та рослин у комплексі з іншими добривами

Ключові слова: удобрення; схожість; гумінові кислоти; мікробні препарати; консорціум; екстракт водоростей; екологізація агросфери