# Розділ 3

# ПЛОДООВОЧІВНИЦТВО

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## THE INFLUENCE OF THE BIOLOGICAL ACTIVATOR NUTRILIFE ON THE YIELD AND QUALITY OF ONIONS

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**Rosa R., Franczuk J., Zaniewicz-Bajkowska A., Remiszewski K., Dydiv O., Andrejiová A. The influence of the biological activator nutrilife on the yield and quality of onions**

Belonging to the *Alliaceae* family, onion (*Allium* cepa L.) is one of the most important and popular vegetable and spice crops grown all over the world. Onions are demanding on soil fertility. It is especially demanding to the increased concentration of mineral salts in the soil. At the beginning of the growing season, onion plants must be supplied with nitrogen. A high yield of onions is obtained on light fertile sandy and loamy soils with a pH of 6-7. Correct provision of plants with macro- and microelements can have a beneficial effect on the growth and yield of turnip onions, which is extremely important on poor soils. At the time when environmental protection is becoming an important concern, new friendly methods of stimulating plant growth are being investigated, among others, by applying macroelements, microelements and various growth stimulants to the leaves. One of the new products is Nutrilife, a biological activator. It is a combination of macro- and microelements (EDTA), humic and fulvic acids, enzymes and amino acids. The field experiment was carried out in east-central Poland, 85 km east of Warsaw, on Luvisol soil. The aim of the studies was to determine the effect of Nutrilife applied to leaves during the BBCH 19 stage, with the simultaneous reduction of nitrogen or phosphorus soil doses by half, on the yield and the content of dry matter and sugars in onion. The Nutrilife activator allowed half reducing mineral nitrogen or phosphorus doses, while the yield was the same as in the case of full NPK treatment. The effect of Nutrilife on onion dry matter content was dependent on the weather conditions in the years of research and the applied mineral fertilizer treatment. There was no significant effect of the activator on the total sugar content.

**Key words:** *Allium cepa* L., biostimulator, dry matter, foliar application, yielding, total sugars.

**Роса Р., Франчук Ж., Заневич-Байковська А., Ремішевський К., Дидів О., Андрійова А. Вплив біологічного активатора Нутрілайф на врожайність та якість цибулі ріпчастої**

Цибуля ріпчаста (Allium cepa L.), що належить до родини цибулевих ( *Alliaceae*), є однією з найважливіших, найбільш поширених овочевих і пряних культур, вирощуваних в усьому світі. Цибуля ріпчаста вимоглива до родючості ґрунту, особливо до підвищеної концентрації мінеральних солей у ньому. На початку вегетації рослини цибулі необхідно забезпечити азотом. Високий урожай цибулі одержують на легких родючих супіщаних та суглинистих ґрунтах, в яких pH 6-7. Правильне забезпечення рослин макро- і мікроелементами може сприятливо

впливати на ріст і врожай цибулі ріпки, що надзвичайно важливо на бідних ґрунтах. В епоху турботи про захист навколишнього середовища шукають нові, дружні методи стимулювання росту рослин, наприклад, позакореневим підживленням макро- і мікроелементами, а також позакореневим підживленням різними біостимуляторами росту. Одним із нових препаратів є біологічний активатор Нутрілайф. Це поєднання макро- і мікроелементів (EDTA), гумінових і фульвокислот, ферментів і амінокислот. Польові дослідження проводили в Центрально-Східній Польщі, за 85 км на схід від Варшави, на ґрунті типу *Luvisol*. Визначено вплив позакореневого підживлення Нутрілайф у фазі BBCH 19 з підживленням азотом або фосфором на врожайність та біохімічні показники цибулі ріпчастої. Доведено, що застосування активатора сприяло збільшенню загального врожаю, а також частки товарного врожаю цибулі ріпчастої в загальному врожаї, проте урожайноутворювальний ефект залежав від внесених мінеральних добрив. Активатор *Nutrilife* дав змогу вдвічі зменшити мінеральне підживлення азотом або фосфором, зберігши при цьому врожайність, як і при повному внесенні *NPK*. Вплив *Nutrilife* на вміст сухої речовини цибулі залежав від умов навколишнього середовища в роки досліджень і використовуваної схеми мінеральних добрив. Істотного впливу активатора на загальний вміст цукру в цибулі не виявлено.

**Ключові слова:** *Allium cepa* L., біостимулятор, позакореневе підживлення, урожайність, суха речовина, загальні цукри.

**Problem setting.** Onion (*Allium cepa* L.) is one of the most important commercial crops not only in Poland and Ukraine but also in the world. According to the Food and Agriculture Organization (FAO), it is the third most cultivated vegetable in the world by production quantity, with a total of 104.5 million tons produced in 2020. In the European Union 6.6 million tons of onions were produced, about 663.9 thousand tons of which in Poland [5]. In the EU, Poland ranks third in the production of this vegetable [4]. In Ukraine, the production of onions in 2020 was about 1.03 million tons [5].

In terms of protection of the natural environment, new friendly methods of stimulating plant growth are being developed, among others, through the foliar use of macro- and microelements and various growth biostimulants [21]. One of the new products is Nutrilife, a biological activator. It is a combination of macro- (2242 mg P $L^{-1}$, 1888 mg K $L^{-1}$, 1330 mg Na $L^{-1}$, 691 mg Ca $L^{-1}$, 356 mg S $L^{-1}$, 3.13 mg Mg $L^{-1}$) and microelements (EDTA), humic and fulvic acids, enzymes and amino acids [12].

**Analysis of recent research and publications.** The use of mineral fertilizers is an important element affecting the onion growth and yield and the profitability of its cultivation. Nitrogen is necessary in the synthesis of chlorophyll, proteins and enzymes. Phosphorus is needed for the proper growth and development of the root system, the formation of phosphoproteins and phospholipids, ATP and ADP. However, too high doses of these elements supplied to the soil as mineral fertilizers can weaken plant growth and thus reduce the quantity and quality of the onion yield. High doses of mineral fertilizers also pose a threat to the natural environment. Biostimulants are used to reduce the doses of mineral fertilizers on crops. Currently, new agronomic strategies are being introduced into plant production on the increasing scale, using scientific knowledge about the physiological and metabolic processes taking place in crops [19].

From the economic and environmental point of view, it is most desirable to improve the uptake and efficiency of fertilizer nutrients in the plant-soil-fertilizer system [13; 20]. One solution to these problems may be the use of biostimulant products, rich, among others, in amino acids and humic and fulvic acids and replacing and/or supplementing conventional mineral fertilizers [17]. Biostimulants are natural compounds that initiate plant physiological processes directly contributing to higher yields. Therefore their primary function is not to provide nutrients or to protect plants from pathogens [18; 23], and the reaction of plants to the product, but not its composition, decides about classifying it as a biostimulant. A very wide range of materials are used as stimulants, including organic, inorganic substances and microorganisms, like humic and fulvic acids, algae extracts, protein hydrolysates, mycorrhizal fungi, or nitrogen-fixing bacteria [1; 18]. A stimulant product may contain a mixture of ingredients from different sources with the use of different production methods.

Conducting research on biostimulants, scientists respond to the deepening problems of growing plants in stressful conditions caused by, among others, increasingly rapid climate change [8; 20]. According to Matysiak [14] and McKeown et al. [15], environmental stresses can cause 30–70 % of crop yield losses.

**Problem statement.** The aim of the study was to determine the impact of the Nutrilife biological activator, with mineral nitrogen or phosphorus doses reduced by 50%, on the quantity and quality of the onion yield (*Allium cepa* L.).

**The main materials and methods.** The field experiment was carried out in 2018–2019 in east-

central Poland (52º14'N, 22º10'E) on Luvisol soil. Its average organic carbon concentration was 1.36–1.40 %, with pH in $H_2O$ of 7.1–7.3 and hums layer 30–40 cm deep. The total macronutrient content in 1 $dm^3$ of the soil was as follows: 14 mg of $NO_3$-N; 33 mg of $NH_4$-N; 52 mg of P; 151 mg of K; 1220 mg of Ca; 66 mg of Mg (average of 2018–2019). The Spirit variety of onion (Bejo Zaden) was used in the experiment set up in a split-block design with three replications.

Two experimental factors were examined: A) biological activator (A1: control without biological activator, A2: Nutrilife, a biological activator); B) different doses of mineral fertilizers (B1: 100 % of the NPK dose for onion, B2: 50 % N + 100 % PK, B3: 50 % P + 100 % NK). The area of an experimental plot was 20 $m^2$ and the area of the whole experimental field was about 195 $m^2$.

The field was prepared at the turn of March and April. Mineral fertilizers were applied in appropriate combinations according to the adopted scheme. Their doses were adjusted to the soil content kg before sowing + 100 top dressing), 45 kg P and 120 kg K per 1 ha. Mineral fertilizers were applied in the form of urea (before sowing), ammonium nitrate (top dressing), triple superphosphate and potassium sulphate. After the application of mineral fertilizers, a cultivating aggregate was used to mix them with the soil, loosen it and to level the area of the field before sowing seeds. The seeds of onion were dressed (Zaprawa Nasienna T and Biosept 33 SL) and sown at a seeding rate of 6 kg·$ha^{-1}$ on 12 April (2018) and 5 April (2019) with 30 cm spacing. After sowing, the experimental plots were sprayed with the Stomp 330 EC herbicide. Another herbicide, Goal 480, was applied first after the plants emerged and then two-three weeks later. Weeding was done mechanically during the later stages of the onion growing season. If necessary, other treatments were performed on the basis of an up-to-date integrated onion protection programme. The Nutrilife activator (1 L $ha^{-1}$) was sprayed with appropriate combinations on June 22, 2018 and June 20, 2019, during the 9 leaf stage (BBCH 19).

Onion was harvested by hand on 28 August in 2018 and on 29 August in 2019. The area of each plot to be harvested was 6.6 $m^2$. The total and marketable yields of bulbs (t $ha^{-1}$) were determined after the harvest. From each plot, a sample of bulbs was collected (about 1 kg) to determine dry matter content by drying them to constant weight at 105 °C. Total sugar content was determined by the Luff-Schoorl method [3].

The results were statistically processed with ANOVA for the split-block design. The significance of differences between means was determined with Tukey's test at the significance level of $p \leq 0.05$. All the calculations were performed with the Statistica PL 13.0 software (Statsoft, USA).

Meteorological data provided by the IMGW-PIB Hydrological and Meteorological Station in Siedlce in 2018–2019 confirmed climate change and the dynamism of weather conditions in this part of Europe (Table 1).

*Table 1*

**Weather condition in the experiment area, 2018–2019 (Siedlce Meteorological Station, Poland)**

| Years | Month | | | | | Mean / Sum | |
|---|---|---|---|---|---|---|---|
| | IV | V | VI | VII | VIII | IV-VIII | I-XII |
| Air temperature (°C) | | | | | | | |
| 2018 | 12.9 | 16.4 | 18.1 | 19.9 | 19.8 | 17.4 | 9.2 |
| 2019 | 9.4 | 13.0 | 21.5 | 18.0 | 19.3 | 16.2 | 9.9 |
| *1981-2010* | *8.0* | *13.6* | *16.2* | *18.4* | *17.7* | *14.8* | *7.8* |
| Precipitation (mm) | | | | | | | |
| 2018 | 41.6 | 25.5 | 74.7 | 97.5 | 27.1 | 266.4 | 509.1 |
| 2019 | 8.9 | 113.9 | 28.6 | 40.3 | 72.1 | 263.8 | 475.9 |
| *1981-2010* | *32.1* | *56.9* | *70.9* | *65.6* | *67.1* | *292.6* | *526.5* |

**Results and discussion.** The average total and marketable yields of onion were 36.7 and 35.0 t $ha^{-1}$ in 2018 and 44.6 and 43.4 t $ha^{-1}$ in 2019 (Table 2, 3). The yield obtained in 2019 was significantly higher than in 2018. Undoubtedly, this was due to more favourable weather conditions for onion growth in the second year of research. Statistical analysis of the results showed a significant impact of the Nutrilife biological activator on the onion yield. A significant increase in the total yield compared to plants without

the activator was observed in 2019, and in the marketable yield in both years. On average across the years of research and mineral fertilizer doses, the total yield of onion treated with Nutrilife was higher by 21.5 %, and the marketable yield by 25 %. In addition, a significant interaction of the Nutrilife activator with mineral fertilizers was observed. On average, across the years of the research, onion grown in combination with the Nutrilife activator and the 100 % NPK fertilizer dose produced significantly higher total and marketable yields than plants grown without the activator and fertilized with a half dose of nitrogen (50 % N + 100 % PK). It was also found that reducing the doses of nitrogen or phosphorus by 50 % and spraying plants with the Nutrilife activator resulted in yields similar to those of plants grown without the activator and with the full mineral fertilizer dose (100 % NPK).

*Table 2*

**Onion total yield (t·ha$^{-1}$)**

| Treatment | | 2018 | 2019 | Mean |
|---|---|---|---|---|
| Mineral | 100 NPK | 37.5 a | 40.7 ab | 39.1 ab |
| | 50 N + 100 PK | 31.8 a | 34.7 a | 33.2 a |
| | 50 P + 100 NK | 33.3 a | 42.4 ab | 37.8 ab |
| Mineral + Nutrilife | 100 NPK | 40.8 a | 55.2 b | 48.0 b |
| | 50 N + 100 PK | 34.4 a | 50.5 ab | 42.5 ab |
| | 50 P + 100 NK | 42.5 a | 44.2 ab | 43.4 ab |
| Mineral | | 34.2 a | 39.2 a | 36.7 a |
| Mineral + Nutrilife | | 39.2 a | 50.0 b | 44.6 b |
| Mean | | 36.7 A | 44.6 B | |

* Means followed by different lowercase letters in columns and different uppercase letters in rows differ significantly at $p \leq 0.05$.

*Table 3*

**Onion marketable yield (t·ha$^{-1}$)**

| Treatment | | 2018 | 2019 | Mean |
|---|---|---|---|---|
| Mineral | 100 NPK | 34.5 a | 39.3 ab | 36.9 ab |
| | 50 N + 100 PK | 30.6 a | 32.5 a | 31.6 a |
| | 50 P + 100 NK | 32.1 a | 40.3 ab | 36.2 ab |
| Mineral + Nutrilife | 100 NPK | 38.2 a | 55.0 b | 46.6 b |
| | 50 N + 100 PK | 33.3 a | 49.4 b | 41.3 ab |
| | 50 P + 100 NK | 41.4 a | 44.1 ab | 42.7 ab |
| Mineral | | 32.4 a | 37.4 a | 34.9 a |
| Mineral + Nutrilife | | 37.6 b | 49.5 b | 43.6 b |
| Mean | | 35.0 A | 43.4 B | |

* Means followed by different lowercase letters in columns and different uppercase letters in rows differ significantly at $p \leq 0.05$

In the experiment, the effect of the Nutrilife biostimulant was prominent, especially in 2019 with a higher average air temperature and a lower amount of precipitation during the onion growing season. However, biostimulants used in the cultivation of various plant species and during changing weather conditions had contradictory effects. Some studies have shown beneficial results [7; 9; 11; 23], while others have not recorded a significant effect on cultivated plants [1; 6]. Sulewska et al. [21] found that the effect of biostimulants and foliar fertilizers was significantly affected by weather conditions in a given growing season. On the other hand, the results of the experiment conducted by Francke et al. [6] indicated that the biostimulants had little effect on the yield and parameters of shallot onion grown for early harvest. Whereas, the positive effect of biostimulants on the endive yield was observed by Gajc-Wolska et al. [7], and on raspberry yield was shown by Grajkowski and Ochmian [9]. Mikulewicz et al. [16] observed differences in the onion yield depending on the type of amino acid biostimulants. The positive effect of

biostimulants produced from seaweed extracts on the biometric parameters of onion was also noted by Abbas et al. [2], Hidangmayum and Sharmain [11] and Szczepanek et al. [22]. Hafez and Geries [10] found that biostimulant application had a positive effect on the average weight of bulbs and their yield, regardless of the year of research. The bulbs with the greatest weight, as well as their yield, were obtained when the plants were treated with humic acid, or with organic fertilizer from fermented tea. Those authors argued that the beneficial effect of humic acid contained in biostimulants might be due to its effective role in the early stages of onion growth, greater accumulation of dry matter and stimulation of the structure of metabolic products, which then move to fleshy scalelike leaves, causing an increase in the onion diameter and an increase in the yield.

The Nutrilife activator increased the share of the onion marketable yield in the total yield in relation to objects with exclusive mineral fertilization (Fig. 1). On average across the years of the research, the highest share of the marketable yield was recorded at applying the combinations of 50 % N + 100 % PK and 50 % P + 100 % NK with the Nutrilife activator.

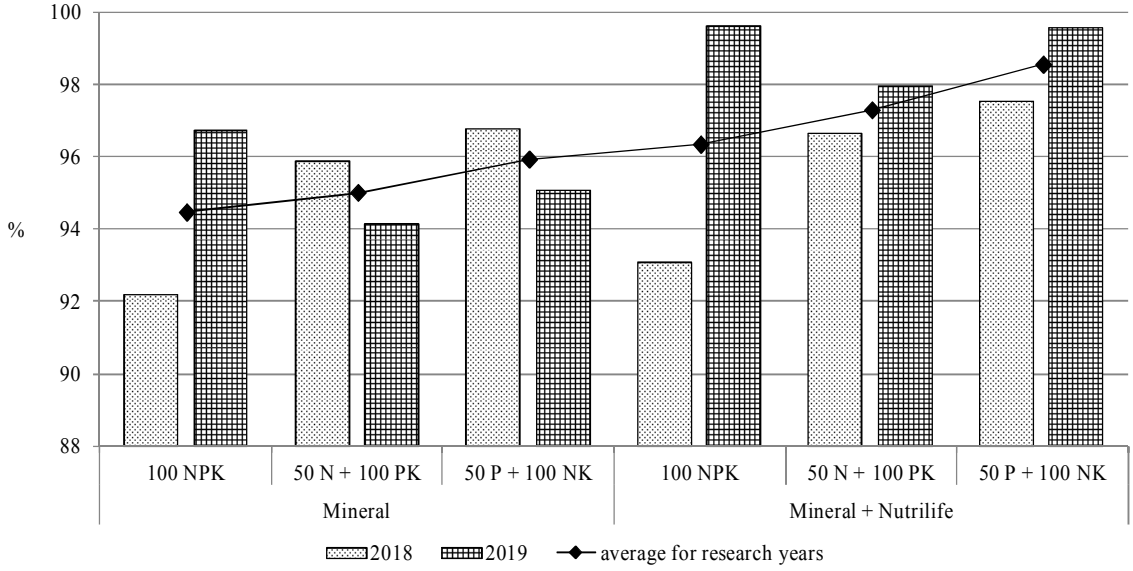


*Fig. 1. The share of marketable yield in the total yield*

*Table 4*

**The content of dry matter in onion (%)**

| Treatment | | 2018 | 2019 | Mean |
|---|---|---|---|---|
| Mineral | 100 NPK | 12.8 ab | 9.2 a | 11.0 a |
| | 50 N + 100 PK | 13.3 b | 12.4 cd | 12.8 b |
| | 50 P + 100 NK | 12.5 ab | 11.5 bc | 12.0 ab |
| Mineral + Nutrilife | 100 NPK | 11.6 a | 12.4 cd | 12.0 ab |
| | 50 N + 100 PK | 11.9 ab | 10.3 ab | 11.1 a |
| | 50 P + 100 NK | 12.4 ab | 13.4 d | 12.9 b |
| Mineral | | 12.9 a | 11.0 a | 11.9 a |
| Mineral + Nutrilife | | 12.0 a | 12.0 b | 12.0 a |
| Mean | | 12.4 B | 11.5 A | |

* Means followed by different lowercase letters in columns and different uppercase letters in rows differ significantly at $p \leq 0.05$

Onion grown in 2018 contained on average of 12.4 %DM, which was by 0.9 % more than in 2019 (Table 4). This difference was statistically significant. In 2019 Nutrilife foliar application increased onion dry matter content as compared to plants from objects with exclusive mineral fertilization. Statistical analysis of

the results also showed a significant interaction of Nutrilife with mineral fertilizers. In 2018, onion treated with 50 % N + 100% PK contained significantly more dry matter (13.3 %) than that treated with 100 % NPK and sprayed with the Nutrilife activator (11.6 %). In contrast, in 2019, with better weather conditions, the largest amount of dry matter was found in onion fertilized with 50 % P + 100 % NK and treated with Nutrilife (13.4 %). A similar amount of dry matter was also found in onion from the plots with 50 % N + 100 % PK and Nutrilife + 100 % NPK (12.4 % each). A significantly smaller amount of dry matter was found in plants treated with 100 % NPK and 50 % N + 100 % PK and treated with Nutrilife (9.2 and 10.3 %, respectively). Regardless of the year of the research, the most beneficial effect on dry matter accumulation was achieved by the treatment with the half dose of P and the full dose of N and K combined with the application of Nutrilife or with the half dose of N and the full dose of P and K without the activator. Mikulewicz et al. [16] found that dry matter content of the Spirit F1 onion variety increased significantly after the use of two biostimulants: Calleaf Aminovital and Maximus Amino Protect. However, the biostimulants had no effect on dry matter in the case of the Red Baron variety. Biostimulants (Effective Micro-organisms or a biostimulant containing amino acids, macro- and microelements and vitamins) used in the research of Francke et al. [6] reduced the dry matter content of shallot as compared to the control.

*Table 5*

**The total sugar content in onion (g·100g$^{-1}$ FM)**

| Treatment | | 2018 | 2019 | Mean |
|---|---|---|---|---|
| Mineral | 100 NPK | 4.29 a | 4.18 a | 4.23 a |
| | 50 N + 100 PK | 3.94 a | 4.05 a | 4.00 a |
| | 50 P + 100 NK | 4.59 a | 4.37 a | 4.48 a |
| Mineral + Nutrilife | 100 NPK | 4.35 a | 3.94 a | 4.14 a |
| | 50 N + 100 PK | 4.63 a | 4.25 a | 4.44 a |
| | 50 P + 100 NK | 4.25 a | 4.02 a | 4.13 a |
| Mineral | | 4.27 a | 4.20 a | 4.24 a |
| Mineral + Nutrilife | | 4.41 a | 4.07 a | 4.24 a |
| Mean | | 4.34 B | 4.14 A | |

*Means followed by different lowercase letters in columns and different uppercase letters in rows differ significantly at $p \leq 0.05$

The average total sugar content of onion in 2018 was 4.34 g 100 g$^{-1}$ FM (Table 5), which was significantly higher than in 2019. There was no significant effect of Nutrilife and mineral fertilizers on onion sugar content. Similarly, Mikulewicz et al. [16] found no changes in the content of total and reducing sugar in three varieties of onion after the use of two biostimulants. On the other hand, Francke et al. [6] reported that biostimulants decreased the sugar content of shallot onion in relation to the control.

**Conclusions.** The activator contributed to an increase in total and marketable yield and to the share of marketable onion yield in the total yield. But the effect of biostimulant depended on the dose of mineral fertilizers. The Nutrilife activator application allowed to reduce the doses of mineral nitrogen or phosphorus by half without negative effect on yield of onion. The effect of Nutrilife on onion dry matter content was dependent on the weather conditions and the applied mineral fertilizer treatment. There was no significant effect of the activator on the total sugar content.

## References

1. Effect of seaweed extract on productivity and quality attributes of four onion cultivars / Abbas M., Anwar J., Zafar-ul-Hye M. et al. *Horticulturae*. 2020. No 6 (2). P. 28.

2. EU 2009. Commission Regulation NO 152/2009. Official Journal of the European Union L54. P. 1–130.

3. EUROSTAT 2021. Agricultural production – crops. URL: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agricultural_production_-_crops#Vegetables (Accessed 16 June 2022).

4. FAOSTAT 2021. Onions production in 2019, Crops/Regions/World list/Production Quantity (pick lists). UN Food and Agriculture Organization, Corporate Statistical Database. URL: http://www.fao.org/faostat/en/#data/QC/visualize (Accessed 26 April 2021).

5. Francke A., Majkowska-Gadomska J., Kaliniewicz Z., Jadwisieńczak K. No effect of biostimulants on the growth, yield and nutritional value of shallots grown for bunch harvest. *Agronomy*. 2022. No 12 (5). P. 1156.

6. Gajc-Wolska K., Kowalczyk K., Nowecka M., Mazur K., Metera A. Effect of organic-mineral fertilizers on the yield and quality of endive (*Cichorium endivia* L.). *Acta Scientiarum Polonorum, Hortorum Cultus*. 2012. No11. P. 189–200.

7. Grabowska A., Kunicki E., Sękar A., Kalisz A., Wojciechowska R. The effect of cultivar and biostimulant treatment on the carrot yield and its quality. *Vegetable Crops Research Bulletin*. 2012. No 77 (1). P. 37–48.

8. Grajkowski J., Ochmian I. Influence of three biostymulants on yielding and fruit quality of three primocane raspberry cultivars. *Acta Scientiarum Polonorum, Hortorum Cultus*. 2007. No 6. P. 29–36.

9. Hafez E., Geries L. Onion (*Allium cepa* L.) growth, yield and economic return under different combinations of nitrogen fertilizers and agricultural biostimulants. *Cercetari Agronomice in Moldova*. 2018. No 5 (3). P. 69–88.

10. Hidangmayum A., Sharma R. Effect of different concentration of commercial seaweed liquid extract of *Ascophylum nodosum* on Germination of onion (*Allium cepa* L.). *International Journal of Science and Research*. 2017. No 6 (7). P. 1488–1491.

11. URL: http://www.bio-energy.lt/en/produktai/dirvos-gerinimo-preparatai/nutrilife (Accessed 23 April 2021).

12. Jardin P. Plant biostimulants: Definition, concept, main categories and regulation. *Scientia Horticulturae*. 2015. No 196. P. 3–14.

13. Marschner P. Marschner's mineral nutrition of higher plants. 3rd edition. London: Elsevier, 2011.

14. Matysiak K. Technologicznie i interwencyjnie. *Wiadomości Rolnicze Polska*. 2010. No 66 (3). P. 6.

15. McKeown A. W., Warland J., McDonald M. R. Long-term climate and weather patterns in relation to crop yield: a minireview. *Canadian Journal of Botany*. 2006. No 84 (7). P. 1031–1036.

16. Mikulewicz E., Majkowska-Gadomska J., Jadwisieńczak K., Francke A. Effect of selected biostimulants on the yield and quality of the common onion (*Allium cepa* L.). *Acta Agrophysica*. 2019. No 2 (1). P. 57–65.

17. Physiological, nutritional and metabolomic responses of tomato plants after the foliar application of amino acids aspartic acid, glutamic acid and alanine / Alfosea-Simón M., Simón-Grao S., Zavala-Gonzalez E. A. et.al. *Frontiers in Plant Science*. 2021. No 11. P. 581.

18. Rouphael Y., Colla G. Synergistic biostimulatory action: designing the next generation of plant biostimulants for sustainable agriculture. *Frontiers in Plant Science*. 2018. No 9. P. 1655.

19. Screening of microalgae liquid extracts for their bio stimulant properties on plant growth, nutrient uptake and metabolite profile of / Mutale-Joan Ch., Redouane B., Najib E. et. al. *Solanum lycopersicum* L. *Scientific Reports*. 2020. No 1 (1). P. 2820.

20. Souri M. K. Plants adaptation to control nitrifcation process in tropical region; case study with Acrocomia totai and *Brachiaria humidicola* plants. *Open Agriculture*. 2016. No 1 (1). P. 144–150.

21. Sulewska H., Kruczek A. Assessment of the stimulating effect of Bio-algeen S 90 on selected species of crops. *Selected ecological issues in the modern world*. PIMR Poznań, Monograph. 2005. Vol. 2. P. 203–209.

22. Szczepanek M., Wszelaczyńska E., Pobereż J., Ochmian I. Response of onion (*Allium cepa* L.) to the method of sea-weed biostimulant application. *Acta Scientiarum Polonorum, Hortorum Cultus*. 2017. No 16. P. 113–122.

23. Yakhin O. I., Lubianov A. A., Yakhin I. A., Brown P. H. Biostimulants in plant science: A global perspective. *Frontiers in Plant Science*. 2017. No 7. P. 2049.

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