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ALGAL BIOFERTILIZERS FROM THE GENUS *Nostoc*: A SUSTAINABLE ALTERNATIVE FOR THE CULTIVATION OF *Echinaceae purpurea* L. IN THE CONDITIONS OF THE REPUBLIC OF MOLDOVA

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Abstract

The present paper presents the experimental results established upon combined application of algal biofertilizers from the genus Nostoc, the species Nostoc gelatinosum Schousboe ex Bornet & Flahault, N. punctiforme (Kützing) Hariot and N. linckia Bornet ex Bornet & Flahault to the cultivation of Echinacea purpurea (L) Moench. The obtained results demonstrated that the application of these biofertilizers had a significant positive effect on several phenological and morphological parameters of the plants. An acceleration of the phenological phases of development was found, with a reduction of the vegetation period by up to 7 days in the variants with the application of algal biofertilizers. Also, a significant increase in leaf area, plant length and biomass production was observed in E. purpurea plants treated with algal biofertilizers compared to controls. The best results were obtained when applying a dose of 30 kg/ha of algal biofertilizer from the genus Nostoc. These results suggest that algal fertilizers from the genus Nostoc can be used as an ecological and efficient alternative for increasing the production of Echinacea purpurea crops. (L) Moench. in the specific conditions of the Republic of Moldova.

Key words*: Nostoc genus, Echinacea purpurea, algal fertilizers, growth.*

INTRODUCTION

Some of the most effective, accessible and harmless biofertilizers widely used in agriculture are those of algal origin (cyanobacteria as they are called today according to their functions are also algae). When applying algal biofertilizers, a positive impact on the soil is attested, manifested by: increasing the degree of loosening, maintaining moisture, improving soil structure, accumulating organic matter (including molecular nitrogen fixation), improving physicochemical properties, stimulating microbiological activity, reducing erosion and other positive effects (Dobrojan, 2024; Karthikeyan et al., 2007).

The use of *Nostoc* algae as biofertilizers in the cultivation of medicinal plants has been analyzed in numerous studies, which have highlighted the positive effects on plant development and their physiological state. Research has shown that the application of these algae can considerably improve the vegetative mass and physiological indicators of plants, due to their ability to fix atmospheric nitrogen and the bioactive compounds they contain and release into the soil. The use of *Nostoc* algae as fertilizers can be achieved both by direct application to the soil and to plants, contributing to a significant improvement in soil quality and plant health.

Research by Obana, Miyamoto, Morita, Ohmori and Inubushi highlighted the beneficial effects of administering the algae *Nostoc* sp. to the soil, within the cultivation of the species *Brassica rapa* var. *peruviridis*. Among the observed results are the increase in the carbon and nitrogen content in the soil, as well as the accelerated development of the plants. The algae also demonstrated a high tolerance to soil drying and salinity, which suggests its potential to contribute to the rehabilitation of degraded soils (Obana et al., 2007).

Chittapun and co-authors confirmed that the application of *Nostoc carneum* and *Nostoc commune* algae and chemical fertilizers at half the doses traditionally used in crop cultivation significantly increased seedlings and the number of grains per plant compared to the control without fertilizer (Chittapun et al., 2018). The same conclusion was reached by Purwani J., Pratiwi E., Sipahutar I A., Husnain who experimented with the combined application of *Chlorogloea* sp. and *Nostoc* sp. algae and 100% N in rice cultivation, which resulted in an increase in crop productivity by 14.75%, increased nutrient absorption and reduced N fertilizer application rates by 25-50% (Purwani et al., 2021).

The combined administration of the algae *Anabaena* sp., Anabaena doliolum, *Nostoc carneum* and *Nostoc piscinale* in corn cultivation has shown an increase in corn yield by about 20-30% compared to variants without administration of algal fertilizers (Prasanna et al., 2016).

Foliar application of *Nostoc piscinale* biomass in corn cultivation in the V6-V7 phenological stage led to earlier plant development, an increase in the number of leaves, an increase in the chlorophyll content of the leaves, the yield of the grains by 6.5-11.5% and the protein content of them (Chittapun et al., 2017).

Research conducted by Santini and co-authors showed that foliar application of hydrolysates from the algae *Nostoc* sp., *Anabaena* sp., *Tolypothrix* sp., *Leptolyngbya* sp. and *Arthrospira* sp. to the cultivation of *Ocimum basilicum* L. plants led to plant growth they were effective in plant growth (up to 32%), plant number (up to 24%) and fresh weight (up to +26%) compared to the control variant where the algal fertilizer was not applied (Santini et al., 2022).

Algae of the *Nostoc* genus show promise in application as a fertilizer in the organic cultivation of medicinal plants, especially *Echinacea purpurea* (L) Moench. *Echinacea purpurea* (L) Moench is a perennial plant that is part of the *Asteraceae* family and is originally from North America. *Echinacea* appeared in Europe through co-colonizers and created new medical sensations. As early as 1871, the renowned German physiciane Meier patented an innovative preparation called "blood purifier" the basic component of which was *Echinacea.* In 1915, the immunostimulating effect of *Echinacea* in the treatment of tuberculosis, smallpox, viral diseases was officially demonstrated for the first time. Currently, echinacea preparations are popular throughout the world. According to the World Health Organization, echinacea preparations occupy the first place in the USA and European countries, surpassing even the most well-known medicines such as ginseng and Tibetan mumiyo. *Echinacea* has tonic properties, is an antimicrobial, antiviral, immunoregulatory, antiradiation agent, accelerates the healing of gingivitis, skin ulcers, boils, burns, wounds, urinary tract infections and vaginal mycorrhiza. *Echinaceae* is not toxic and does not cause side effects. According to experts, the plant is the most promising for cultivation, and its production will increase significantly from year to year (Buric et al., 1998; Șevcenco, 1999; Șașco & Șașco, 2009; Teleuţă et al., 2008).

Echinacea purpurea has long been cultivated in Germany, France, the USA and recently in the Republic of Moldova, Romania, Ukraine, Belarus and the European part of the Russian Federation (Berti et al., 2002; Zagumennicov 2011; Hasanova, 2003).

Echinaceae purpurea (L.) has an increased nectar-honey potential during the summer-autumn months. When installing beehives on the *Echinacea* plantation, a nectar production of 60-100 kg/ha, or 75-125 kg/ha of honey can be obtained. At the same time, the plant also has a beautiful decorative appearance due to the large inflorescences and the rich range of colors of the ligulate and tubular flowers, for which it is cultivated and appreciated (Florea & Paşa, 2006). Currently, in the Republic of Moldova a significant plantation of *Echinacea purpurea* (L.) Moench. cultivated in a controlled manner is managed by Melnic who researches and tends to effectively utilize the plant for phytotherapeutic purposes.

Thus, we set ourselves the goal of investigating the morpho-physiological effects attested to *Echinacea purpurea* (L.) Moench. as a result of the application of algal biofertilizers from the genus *Nostoc*.

MATERIALS AND METHODS

In the given experiments, the cyanophyte algae *Nostoc gelatinosum* Schousboe ex Bornet & Flahault, *N. punctiforme* (K ützing) Hariot and *N. linckia* Bornet ex Bornet & Flahault, which are stored in pure culture in the collection of the LCŞ "Algologie V. Șalaru", were used. The experiments in question were carried out in the open field on the lands administered by the GŢ

"Melnic Cristin Victor", which are located in the village of Dobrogea, Republic of Moldova. The research was carried out in the spring-autumn period. The following experimental batches were used in the experiments: 1 – administration of the combined live biomass of *algae N. gelatinosum + N. punctiforme + N. linckia* in the dose of 20 kg/ha; 2 - *N. gelatinosum + N. punctiforme + N. linckia* in the dose of 30 kg/ha; 3 - *N. gelatinosum + N. punctiforme + N. linckia* at a dose of 40 kg/ha; 4 – control variant where no algal biomass was administered. Each experimental variant was mounted on an area of 30 m, in three repetitions. Algae inoculation was carried out at the end of March 2024. During the experiments, phenological indicators, morphological changes and the amount of biomass at harvest of *Echinacea purpurea* (L.) Moench plants were monitored.

RESULTS AND DISCUSSIONS

The application of fertilizers, in optimal doses and concentrations, in the cultivation of *Echinacea purpurea* (L.) Moench. attests to a positive impact on the crop, manifested in particular, on morpho-physiological aspects (Iahtanigova & Culișova 2021).

It is worth mentioning that during the summer season of 2024, a heat wave with a deficit of precipitation was observed on the territory of the Republic of Moldova. The average air temperature for this season was 22.7-25.6ºC in the territory.

The meteorological conditions specific to the research year directly affected the development of algal biofertilizers, which was reflected in the results obtained.

However, the application of algal biofertilizers influenced the phenological phases of the *E. purpurea* culture experimented. Their effect was manifested starting with the stemming phase and up to fruiting. The most significant results were obtained in the variant with the application of algal biofertilizers at a dose of 30 kg/ha where the early appearance of the stemming phase was attested (2 days earlier compared to the control), budding (by 2 days), flowering (by 1 day) and fruiting by 2 days.

The total duration of the vegetation period of the culture in variant no. 2 was 57 days, and in the control group 64 days, which allows us to conclude that algal biofertilizers at a dose of 30 kg/ha ensure the acceleration of the phenological phases of the *E. purpurea* culture. Variant no. 3 manifested a medium impact on the acceleration of the phenological phases of *E. purpurea* by 4 days, and that with no. 1 did not attest to any specific phenological changes (Table 1).

Table 1. Phenological characteristics of *Echinacea purpurea* (L.) Moench. when administered with algal fertilizers

Phenological phases	Duration of the phenological phase, days			
	Variant 1	Variant 1	Variant 1	Variant 1
Increase	13	13	13	13
Stemming	16	14	15	16
Budging	13	11	12	13
Flowering	4	3	3	4
Fruiting	18	16	17	18
Duration of the growing season	64	57	60	64

In all the experimental variants with biofertilizer application, the leaf surface area of the leaves are larger compared to the control variant starting with the stemming phase and until the end of the flowering phase. The most significant results were attested in the variant with the administration of 30 kg/ha of algal biofertilizer where the leaf surface in the development phases from stemming to flowering was 0.9-2.4 cm^2 larger compared to the control variant. The lowest results were attested in the group with the administration of 20 kg/ha of algal biofertilizer where the leaf surface area of the researched plants was 0.27-0.62 cm^2 larger compared to the control (Table 2).

Table 2. Plant leaf surface at different ontogenetic stages of development

Development phases	Leaf area, cm^2			
	1	2	3	Control
Stemming	13.67	14.30	14.07	13.40
Budging	22.65	23.76	23.31	22.21
Flowering	30.72	32.51	32.21	30.10

It is worth mentioning that in the groups with the administration of algal biofertilizer, a dark green color of the plant leaves was observed compared to those in the control variant. The increase in leaf area indicates that the health of the plants is improved and that they have a greater capacity to resist some stress conditions.

The application of experimental algal fertilizers attested the increase in the height of the researched plants. In variants 2 and 3, practically similar heights of the researched plants were attested during the stemming phase (49.60±2.67 - 49.55±2.77 cm), these being 1.30-1.35 cm higher compared to variant 4 (control). The increase in the height of the plants in the variants with administration of algal fertilizers was attested also during the budding phases and until the end of the flowering of the plants. The most significant differences in the height of the plant stem between the variants with administration of biofertilizers and the one without administration were attested at the end of the flowering phase where the height of the plants in the groups with algae application was 1.90-4.49 cm higher than in the control groups (Figure 1). The results in question allow us to conclude that the application of algal biofertilizers has a positive impact on the growth of *E. purpurea* plants.

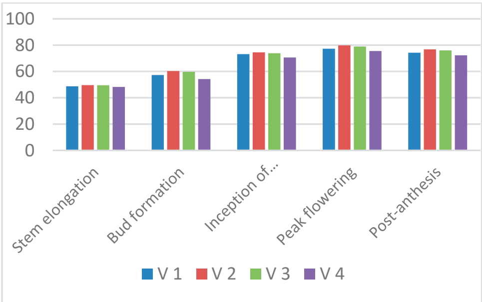

Figure 1. Changes in stem height in *Echinacea purpurea* (L.) Moench. different phenological growth phases, cm

From the data presented in table 3 it is observed that the application of algal biofertilizers has been shown to increase the biomass of *E. purpurea.* As in the case of the other analyzed indicators, the highest amount of biomass (11.02±0.44 t/ha) was shown in variant no. 2, being followed by that with no. 3 (10.98±0.46 t/ha) and 1 (10.21±0.41 t/ha). Thus, we find that when applying algal fertilizers from the genus *Nostoc,* in the investigated doses, in the directed cultivation of *E. purpurea* seedlings, the increase in plant biomass by 0.18-0.99 t/ha is shown, which means that the algae has a quantitatively positive influence on the crop.

Table 3. Changes in *Echinacea purpurea* (L.) Moench. biomass attested to the administration of algal fertilizers, t/ha

Experimental variants			
1	2	3	4
10.21±0.41	11.02±0.44	10.98±0.46	10.03±0.43

Species of cyanobacteria from the genus *Nostoc*, used as biofertilizers, generate a positive impact on both soil quality and the development of various plant species, significantly contributing to stimulating growth processes and increasing crop yields (Tadesse, 2022).

Previous research has shown that the application of *Nostoc piscinale* biomass in *Oryza sativa* L. crops stimulated plant growth and development processes, manifested by the elongation of the root system and shoots, as well as by increasing the chlorophyll content in their leaves (Go Oco et al., 2024).

The application of the biomass of the cyanobacteria *Nostoc carneum* and *Nostoc punctiforme* as a biofertilizer, in the cultivation of the species *Matricaria chamomilla* L., had a significant effect on the overall growth of the plant, including the development of the root system, as well as on the increase in the essential oil content. (Zarezadeh et al., 2020).

The use of the biomass of the cyanobacteria *Amorphonostoc punctiforme, Stratonostoc linckia* and *Anabaena variabilis* in cotton cultivation has shown a positive influence on plant development, contributing to increasing their productivity with values ranging between 23.3% and 37%. (Musaev & Umarova, 1967).

The application of the suspension of cyanobacteria *Anabaena torulosa, Nostoc calcicola, Nostoc ellipsosporum, Trichormus doliolum* and *Oscillatoria* sp. in the culture of the medicinal plant *Thymus vulgaris* L. revealed a favorable effect, manifested by the intensification of enzymatic activity, the increase in lignin content and the enhancement of plant resistance to biotic and abiotic stress (Rasuli et al., 2023).

Foliar administration of the cyanobacterium *Spirulina platensis* in the cultivation of

Amaranthus gangeticus, Phaseolus aureus and *Solanum lycopersicum* species demonstrated a beneficial effect, evidenced by increasing plant productivity, as well as by increasing the content of nitrogen (N), phosphorus (P) and potassium (K) in plant biomass (Gaia et al., 2021).

The research conducted by our team has highlighted similar results, which allows us to state that the application of fertilizers based on the studied *Cyanobacteria* stimulates the growth of the analyzed plants, as well as increases their biomass.

CONCLUSIONS

The research carried out has highlighted the positive effect attested to the administration of algal fertilizers consisting of the combination of the species *Nostoc gelatinosum* Schousboe ex Bornet & Flahault, N. *punctiforme* (Kützing) Hariot and *N. linckia* Bornet ex Bornet & Flahault in the cultivation *of Echinacea purpurea* (L.) Moench. The application of algal fertilizers has been attested to the acceleration of the phenological phases of development (by 1-2 days), the reduction of the vegetative period (by 4-7 days) the increase of the leaf area (by 0.27-0.62 cm^2), the length of the plants (by 1.90-4.49 cm) and the amount of biomass (by 0.18-0.99 t/ha) of *Echinacea purpurea* (L.) Moench.

The most significant results were attested to the administration of algal biofertilizers from the genus *Nostoc* at a dose of 30 kg/ha, which is recommended for application to the directed cultivation of *Echinacea purpurea* (L.) Moench.

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