



Research Article

Evaluating the impact of biological products with *Arbuscular mycorrhizal* fungi on starch, vitamin C and antioxidant contents in potatoes

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Abstract

The results of a microfield experiment using the biopreparation with 4 varieties of *Arbuscular mycorrhizal* fungi (*Glomus aggregatum*, *Glomus etunicatum*, *Glomus introradices*, *Glomus mosseae*) in growing potatoes were considered in the research paper. The experiment included 2 groups: 1) control one, and 2) treated with biopreparation (AMH). A four-fold replication on the land plot sized 50 square meters was provided. The biopreparation was introduced at a dose of 0.1 g/square meter during potato growing. In mature potato tubers, polarimetric method was used to determine the starch content, a visual titration method to evaluate vitamin C content, spectrophotometric method using Folin reagent for polyphenol content, titration with potassium permanganate for antioxidant activity, and ion-selective electrode on an ion meter – for nitrate content. The research study showed that useful microorganisms such as *Arbuscular mycorrhizal* fungi introduced to the soil when planting Udacha potatoes contributed to improving potato quality. The dry matter, ascorbic acid (vitamin C), starch, polyphenol contents were higher in the tubers from the treatment group compared to those from the control group. As far as the antioxidant activity is concerned, its level was also enhanced in treated potatoes, while the nitrates content decreased.

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1. Introduction

The first person, who drew attention to the soil as a living system with microorganisms being the key factor of its functioning, became V.V. Dokuchaev, the founder of soil science. Soil is the habitat and product of the vital activity activities of various microorganisms. They ensure the biological circulation of substances as well as the processes of creating biomass in plants with a certain qualitative composition.

Climate change and environmental deterioration, decreasing soil fertility, various plant diseases and their susceptibility to insect/pests demand the exploration of new methods for increasing

agricultural yields and improving the quality of plant products. In this view, to reduce the negative impact of the above mentioned factors on plants, the introduction of biopreparations containing *Arbuscular mycorrhizal* fungi (AMF) into the soil may be considered as a promising method.

It was since the mid-19th century when the association between plant roots and fungi was revealed; the term mycorrhiza was introduced in 1885 by the famous scientist Albert Bernhard Frank [1]. Mycorrhiza is a mutual symbiotic association between a fungus and a plant, which plays an important role in the biological and chemical soil properties and,

specifically, in plant nutrition. Arbuscular mycorrhiza is created only by fungi in the division Glomeromycota and are present in 85% of all plant species, including agricultural crops [2].

Arbuscular mycorrhizal fungi colonize the host plant root tissues intracellularly. Arbuscular mycorrhiza hyphae penetrate plant cells, forming structures vesicles and arbuscules (dichotomously branching invaginations), which ensures nutrient exchange. Fungal hyphae invaginate the cell membrane. The structure of arbuscules significantly increases the contact area between hyphae and cell cytoplasm, facilitating the nutritional exchange between them. Through such symbiosis, the fungus, due to its extensive network of hyphae, provides plants with a 10-fold larger surface area for nutrient and moisture absorption from the soil, and the plant, in turn, supplies the fungus with sugars and products of photosynthesis.

Mycorrhiza promotes the transportation of the allelopathic substance juglone, which suppresses the development of competing plants, so the mycorrhizal plant spreads over a larger soil volume. Mycorrhiza also improves the soil structure by means of glomalin substance, which acts as a cementing element for soil particles. Mycorrhizal plants exhibit greater resistance to pests and pathogens due to deep changes in plant metabolism [3].

The colonization of mycorrhiza that is not typical for a given region can have the same impact on the ecosystem as that of invasive species. The effect of mycorrhization strongly depends on specific natural conditions, especially on the availability of nutrients taken from the soil as well as on the concentration of carbon dioxide in the atmosphere. There is an inverse relationship between the development of mycorrhiza and the phosphate content in the soil, i.e. the more the soil is saturated with phosphates and the easier it is for the plant to obtain them, the less the development of mycorrhiza [4]. Also, plants that have improved nutrition due to mycorrhiza can act as bait for pests. The aim of our research was to assess the effects of biopreparations containing *Arbuscular mycorrhizal* fungi introduced into the soil on selected quality indicators of potato tubers.

2. Materials and methods

We conducted research on the use of a biopreparation containing 4 varieties of *Arbuscular mycorrhizal* fungi (*Glomus aggregatum*, *Glomus etunicatum*, *Glomus introradices* and *Glomus mosseae*) on potatoes in the Ivanovo region (56°59' N, 40°58' E). The experiments were conducted on sod-podzolic medium loamy soil with a humus content of 2.7%, pH - 6.5, P₂O₅ - 145 mg / kg and K₂O - 120 mg / kg.

The average day / night air temperature in May, June, July, August and September 2024 in the crop region was (°C): 15 / 8.6, 19.5 / 12.5, 21.7 / 14.7, 21 / 13.6, 14.4 / 8.8, respectively. Monthly precipitations (mm) were: 80.6 (May), 76.9 (June), 106.6 (July), 71 (August), 44.5 (September).

The experiment used the table potato variety of Russian selection "Udacha". This is an unpretentious, drought-, frost- and stress- resistant variety, growing on all soil types with good air permeability. This variety has an early ripening period of 65-80 days from the moment of emergence. The tubers were smooth, round or round-oval, weighing 100-150 grams.

Before planting potatoes, the plot was fertilized with humus (5 kg/square meter). The experiment included 2 groups: 1) control one, and 2) treated with biopreparation (AMH). Four - fold replication on the land plot sized 50 square meters was provided. The biopreparation was introduced at a dose of 0.1 g/square meter during potato growing. In mature potato tubers, polarimetric method was used to determine the starch content [5], a visual titration method to evaluate vitamin C content [5], spectrophotometric method using Folin reagent - for polyphenol content [5], titration with potassium permanganate for antioxidant activity [6], and ion-selective electrode on an ion meter – for nitrate content.

Data collected were subjected to analysis of variance (ANOVA) and when the differences were significant ($p < 0.05$), a Duncan multiple range test was performed to compare means.

3. Results and discussion

According to the data in Table 1, in the group treated with bio-product the contents of dry matter

Table 1. Contents of dry matter, starch and nitrates in potato tubers

Experimental groups	Dry matter (%)	Starch (%)	Nitrates (%)
Control	18.8 ± 0.2	14.1 ± 0.3	194 ± 8
Treated with AMH	23.0 ± 0.3	16.5 ± 0.3	164 ± 7

Table 2. Indicators of potato antioxidant status

Experimental groups	Antioxidant activity, (mg-eq of gallic acid per g of dry weight)	Ascorbic acid (mg/100 g)	Polyphenols (mg-eq of gallic acid per g of dry weight)
Control	7.3 ± 0.2	18.6 ± 0.7	3.8 ± 0.3
Treated with AMH	8.5 ± 0.3	24.5 ± 0.8	4.6 ± 0.4

and starch in potato tubers increased, and the content of nitrates decreased, compared to the control group. Thus, the dry matter content in the tubers from the control group made up 18.8%, in the tubers from the treatment group using *Arbuscular mycorrhizal* fungi 23.0%, the starch content in the tubers from the control group was 14.1%, and in the tubers from the experimental one 16.5%. When using *Arbuscular mycorrhizal* fungi in potato tubers, the nitrate content decreased from 194 mg / kg (in the control) to 164 mg / kg (in the treatment group). The dry matter content of potato tubers affects the taste and quality of processed products. The main component of potato is starch. It is a reserve carbohydrate in most plants, but its amount is especially high in potatoes. Starch is a polysaccharide ($C_6H_{10}O_5$)_n ($40 \leq n \leq 3000$) that is highly soluble in water. The taste of potatoes depends on the amount of starch, the more starch it has, the tastier is the product. With a higher starch content in tubers, harvest is better and can be maintained longer after the season. In our experiment, the starch content in the tubers from the treated group was 2.4% higher than that in the control one.

The nitrate content in vegetables is an indicator of food safety, since their accumulation above the maximum permissible concentrations (MPC) can cause functional disorders in humans or animals (food poisoning, metabolic disorders, oxygen starvation due to hemoglobin blocking, etc.). Receiving regular nitrate overdoses may cause even more serious health consequences. In our study, when *Arbuscular mycorrhizal* fungi were applied to the potato tubers, the nitrate content was 15.5% lower than the control group. Moreover, in both groups, the

nitrate contents were below the accepted MPC (250 mg / kg).

The data presented in Table 2 show that the antioxidant status of potato tubers increased when *Arbuscular mycorrhizal* fungi were added to the soil. The antioxidant activity in potato tubers of the control group was 7.3 mg-eq of gallic acid per g of dry weight, and in the treatment group it was 8.5. The content of ascorbic acid (vitamin C) in potato tubers of the control group was 18.6 mg/100 g, and in the treated group - 24.5 mg/100 g. The content of polyphenols in potato tubers in the control group was 3.8 mg-eq of gallic acid per g of dry weight, and in the treated group, it was 4.6.

Among the various biologically active compounds in plants, antioxidants constitute the most important group that determines the functional significance of agricultural products in human nutrition, as plants are the main sources of natural antioxidants for humans. Antioxidants help plants resist various forms of oxidative stress, adapt to constantly changing environmental conditions, and alter the expression of genes involved in the body's response to biotic and abiotic stresses [7].

One of the most important natural antioxidants is vitamin C (ascorbic acid) and it is involving in several biochemical processes. Unlike plants, the human body is not able to synthesize this vitamin, so it must be systematically supplied with food. In our experiment, the content of ascorbic acid in potato tubers from the treated group was 5.9 mg / kg higher, compared with that from the control one.

Polyphenols have high antioxidant activity and powerful anticarcinogenic properties. They combine

several different groups of compounds, such as anthocyanins, coumarins, lignins, flavonoids, tannins, quinones, and phenols. The antioxidant activity of polyphenols is determined by the number of free hydroxyl groups and the degree of conjugation of unsaturated side chains with aromatic rings [8]. In addition to their high antioxidant activity, these compounds exhibit a synergistic effect with other natural antioxidants. In our experiment, the content of polyphenols in potato tubers from the group in which *Arbuscular mycorrhizal* fungi were applied, was 21% higher than that in the control one. Higher levels of polyphenols contribute to improved antioxidant activity, that is, to a higher rate at which antioxidants neutralize free radicals. General antioxidant activity [9] is a key factor determining the protective biological effects of plants on the human body. In our research experiment, the antioxidant activity of potato tubers was 16.4% higher in the group where *Arbuscular mycorrhizal* fungi were used than in the control one. Previous research has shown that the general antioxidant activity of various potato variants was significantly lower without the adding of beneficial microorganisms [10].

4. Conclusions

The study showed that useful microorganisms such as *Arbuscular mycorrhizal* fungi *Glomus aggregatum*, *Glomus etunicatum*, *Glomus introradices*, and *Glomus mosseae* introduced to the soil when planting Udacha potatoes contributed to improving potato quality. The contents of dry matter, ascorbic acid (vitamin C), starch and polyphenols were higher in the tubers from the treatment group compared to those from the control group. As far as the antioxidant activity is concerned, its level was also enhanced in treated potatoes, while the content of nitrates decreased.

Authors' contributions

Protocol writing, statistical analyses, field work, laboratory analyses and drafted the manuscript, SZ.

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Availability of data and materials

All data will be made available on request according to the journal policy.

Conflicts of interest

The author declare that she has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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