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Serhii Dymytrov
PhD in Agricultural Sciences, Senior Researcher
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine
https://orcid.org/0000-0002-0377-9596

Vasil Sabluk*
Doctor of Agricultural Sciences, Professor
Institute of Bioenergy Crops and Sugar Beet NAAS
03110, 25 Klinichna Str., Kyiv, Ukraine
https://orcid.org/0000-0002-6124-4346

Mykhailo Gumentyk
Doctor of Agricultural Sciences, Senior Researcher
Institute of Bioenergy Crops and Sugar Beet NAAS
03110, 25 Klinichna Str., Kyiv, Ukraine
https://orcid.org/0000-0001-9052-9650

Formation of productivity of giant miscanthus (*Miscanthus × giganteus*) under symbiosis of its root system with fungi and bacteria

Abstract. The relevance of the subject under study is to increase the yield of dry biomass of giant miscanthus plants by using fungi and bacteria in its cultivation technology. The purpose of this study was to determine the effect of mycorrhization of the root system of this crop by fungi and symbiosis with bacteria on the growth and development of plants and the formation of their productivity. Field studies were conducted at the Veselopodilska Experimental Breeding Station of the Institute of Bioenergy Crops and Sugar Beet of the National Academy of Agrarian Sciences of Ukraine (Poltava region) during 2017-2019 on saline and slightly saline black soil. The significance of the deviation between the experimental variants was determined by the P-level calculated according to the Student's test. The use of symbiosis of fungi and bacteria with the root system of giant miscanthus contributed to positive results in improving plant growth, development and dry biomass yield. The use of biological products Mycofriend, Mikovital, and Florobacillin (fungi *Glomus VS*. and *Trichoderma harzianum* Rifa, *Tuber melanosporum* Vittad and bacteria *Bacillus subtilis* Cohn*)* significantly increased the area of the leaf apparatus (by 6.9-19.0%), the weight of the root system (by 4.1-16.3%), increased plant height (by 3.7-13.6%), and the number of stems (by 5.7-15.1%) compared to the control.

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*Corresponding author

At the same time, there was an improvement in the soil's moisture-holding capacity by 10.3-23.7% and its structural and aggregate state – the proportion of clods 0.25-10.0 mm in size was 3.2-5.7% higher than in the control. The use of mycorrhizal fungi and nitrogen-fixing bacteria contributes to an increase in the yield of dry plant biomass by 1.82-6.11 t/ha compared to the control, which is of practical importance in increasing the raw materials for biofuel production

Keywords: root system weight; leaf area; leaf weight; moisture retention capacity; structural aggregate state; yield

INTRODUCTION

The global energy crisis is one of the world's challenges of the 21st century, and therefore research that complies with international safety guidelines aimed at improving the environmental safety of agricultural production, increasing efficiency and reducing losses is becoming increasingly important (Polovyi *et al.,* 2021).

Giant miscanthus is a perennial crop for agricultural production and, under optimal growing conditions, is suitable for use for a long time (Lopushniak *et al.*, 2021a; Pidlisnyuk *et al.*, 2022). It is known that crop yields increase substantially with the use of fertilisers, and in recent years there has been a growing trend towards local application and pre-sowing seed treatment, which increases the efficiency of their use (Bielashov *et al*, 2022; Kalenska *et al*, 2022). To improve the efficiency of crop growth and development, microorganisms are used to enhance their nutrition (Dymytrov *et al.*, 2021; Prysiazhniuk & Penkova, 2022). This is evidenced by long-term studies with miscanthus conducted in the United States, which show that microbial communities are formed in the endophytic zone of the soil, which have a close correlation with the total number of bacteria and diazotrophs in the rhizosphere of the root system (Ivanina *et al.*, 2021). The results of studies conducted in Germany (Semenchuk *et al.,* 2021) proved the existence of specific N-fixing bacterial species in miscanthus rhizomes, which can fix nitrogen in organ-specific bacterial communities formed in their zone.

According to literary sources on plants (Katelevskij, 2020; Gupta & Abbott, 2021; Nedilska, 2021), microorganisms have a significant role in these communities, enhancing the root system's absorptive capacity, optimizing plant nourishment, and mitigating the adverse effects of drought and soil salinity. The instability of the water balance of plants caused by the instability of several factors negatively affects the physiological processes that underlie the formation of the crop and its quality. Plants need water for all the biochemical reactions that take place in their bodies. The decrease in water leads primarily to a deterioration in photosynthesis and some other biochemical reactions in the plant.

Some authors (Sabluk *et al.,* 2021; Kurhak & Sliusar, 2021; Honcharuk & Prysiazhniuk, 2022) have pointed out that water shortages result in a decrease in chlorophyll biosynthesis, and drought causes its destruction. The plant consumes the most water at the beginning of the growing season and almost all of it is used for transpiration. Droughts and poor soil aeration lead to a decrease in the water content of plant tissues, which adversely affects their growth and development. Under this condition, there is a massive death of roots and a decrease in growth. At the same time, the use of mycorrhizal fungi and nitrogen-fixing bacteria significantly improves the moisture supply and nutrition of plants. This is evidenced by the results of these studies, which for the first time in the Forest-Steppe conditions of Ukraine established the effectiveness of using fungi and bacteria for their symbiosis with the root system of giant miscanthus plants, which contributes to increasing its productivity and is important for biofuel production.

The purpose of this study was to determine the effect of mycorrhization of the root system of the Miscanthus giganteus by fungi and its symbiosis with bacteria on the growth and development of plants and the formation of their productivity.

MATERIALS AND METHODS

Studies to determine the effectiveness of biological products for improving the growth and development of giant miscanthus plants were conducted considering the requirements of the International Convention on Biological Diversity (1992), which make provision for the exclusion of their negative impact on plants, the microbiological state of the soil and the environment, as it concerns the beneficial interaction of fungi and bacteria with the root system of this crop.

Field studies were conducted in 2017-2019 at the Veselopodilska Experimental Breeding Station (VEBS) of the Institute of Bioenergy Crops and Sugar Beet of the National Academy of Agrarian Sciences of Ukraine, located on the left bank of the Dnipro River in the typical Forest-Steppe zone. Soil cover is characterised by a variety of soils, with predominantly saline and slightly saline black soils. The biological products used in the study were Mycovital, Mycofriend, and Florobacillin, which were applied to the soil with a special device in the root zone.

The experiments were carried out in 4 replications, with an area of 25 m^2. According to the programme, the study investigated the effect of these microorganisms on leaf water content and root mass, stem formation, and plant height at different periods of organogenesis (30, 60, 90, and 120 days), as well as the moisture-holding capacity and structural and aggregate state of the soil and dry biomass yield.

To determine the weight of miscanthus leaves, they were selected on the indicated days of the plant vegetation, 25 pcs. from each replicate and weighed on a laboratory balance. The data were processed using statistical methods. The significance of the deviation between variants was determined by the P-level calculated according to the Student's test.

The mass of the root system of plants of this crop was determined at the specified time. For this, 10 plants from each replication were dug up to a depth of 30 cm and cut to the root collar, cleaned of soil, washed with water, dried for 1 hour, and weighed on a laboratory balance.

The area of 100 miscanthus leaves per variant was determined on days 30, 60, 90, 120 of the plant vegetation by scanning them using the Pitiole mobile application software. The height of the plants was measured with a measuring ruler and the number of stems per bush was determined simultaneously. The water-holding capacity of the soil was determined by the difference in the mass of the soil before and after drying. For this, 150 g of soil was taken from each replicate at a depth of 30 cm, weighed, and placed in a drying oven for 5 minutes at 100°C.

To establish the structural and aggregate state of the soil, 100-150 g were taken from each replicate, weighed, sieved on sieves with a mesh diameter of 0.25 and 10.0 mm, and the proportion of lumps of 0.25-10.0 mm in its total mass was determined.

RESULTS AND DISCUSSION

In the symbiosis of fungi with the root system of plants, they colonise their organs internally or externally, and bacteria produce metabolites that suppress the development of pathogens and increase plant immunity. Furthermore, phosphorus-mobilising bacteria can convert hardly soluble phosphates from the soil into mineral phosphoric acid salts available to the plant and assimilate both organic and mineral nitrogen. Accordingly, these microorganisms contribute to a substantial improvement in the mineral nutrition of plants, and thus to an increase in their productivity. This is evidenced by studies on the use of biological products with fungi and bacteria for their root application in giant miscanthus plantings (Kalenska *et al.*, 2022).

It was established that the use of mycorrhizal fungi and nitrogen-fixing bacteria improves all elements of growth and development of miscanthus plants and increases their productivity. One of the essential elements of this process is the water content of the leaves, which characterises the level of moisture supply, as this factor largely determines the productivity of photosynthesis and, consequently, the productivity of the crop.

In the experiments conducted, the water content of the leaves of the crop by determining their wet weight in all variants using biological products at different periods of plant vegetation was higher than in the control. At the same time, it was noted that the greatest impact of fungi and bacteria on this indicator is manifested in the early stages of plant growth. Thus, on the 30th day of organogenesis, the water content of miscanthus leaves in the experimental variants was significantly higher than in the control, while on the 90th and 120th day of plant vegetation using all preparations, these indicators were slightly lower, indicating a more intense saturation of leaf cells with water in the younger state (Table 1).

Table 1. Leaf mass of giant miscanthus depending on the symbiosis of fungi and bacteria with its root system (VEBS, 2017-2019)

Plant growing season, days	Weight of 100 leaves												
	Control, g	Mycofriend				Florabacillin				Mycovital			
		g	± to control		P-level	g	± to control		P-level	g	± to control		P-level
			g	%			g	%			g	%	
30	44.0	56.5	12.6	28.6	0.02	48.8	4.9	11.0	0.04	52.4	8.4	19.2	0.03
60	66.2	80.9	14.7	22.2	0.02	72.4	6.3	9.4	0.05	77.3	11.2	16.9	0.03
90	98.1	117.1	19.0	19.4	0.02	106.1	7.9	8.1	0.05	112.0	13.9	14.1	0.03
120	118.8	143.4	24.7	20.8	0.02	129.0	10.2	8.6	0.04	136.8	18.0	15.2	0.03

Source: developed by the authors

Furthermore, this indicator is influenced by other factors, one of which is temperature. The optimum temperature for their development is 15-25°C, and deviations from this temperature in a certain direction negatively affect their condition. The type of microorganism on which the biological product is based is also important. Thus, using the biological product Mycofriend, which is based on the fungi *Glomus* VS and *Trichoderma harzianum* Rifai, the highest leaf water content was obtained, which was higher than the control at different stages of organogenesis.

In the variants with the use of biological preparations Mycovital and Florobacillin, based on the fungus *Tuber melanosporum* Vittad. and the bacteria *Bacillus subtilis* Cohn, the increase in leaf water content compared to the control was slightly less than with the use of the biological preparation Mycofriend.

Root formation is also an essential element of plant growth and development. This process is influenced by many factors, the main ones being soil quality, soil preparation, humidity, and temperature conditions, etc. As for the effect of microorganisms on improving the accumulation of underground plant parts and increasing their mass, there are many examples of their effective use in the world practice. At the same time, much attention is paid to the use of mycorrhizal fungi from different families, as well as many types of bacteria. Notably, in the mycorrhizal interaction between a plant and a fungus, its mycelium colonises the root system and actually becomes its extension, forming densely growing hyphae, and bacteria contribute to the improvement of metabolism and thus have a positive effect on the formation of the root system of plants and increase its mass.

The conducted research confirms the fact of a significant increase in the mass of the root system of miscanthus plants under its mycorrhization by fungi and symbiosis with bacteria in different periods of their vegetation, and this indicator largely depends on the type of biological preparation. This process is particularly affected by Mycofriend (fungi *Glomus* VS and *Trichoderma harzianum* Rifai). In this variant, the weight of the root system increased the most compared to the control. The growth of the root system of plants of this crop is slightly less than that of the variant with Mycofriend, when using Mycovital (fungus *Tuber melanosporum* Vittad.) and Florabacillin (bacteria *Bacillus subtilis* Cohn.).

Notably, in the first period of vegetation of giant miscanthus plants (30-60 days) and in the later periods of its organogenesis (90-120 days) the difference in root weight compared to the control was insignificant, indicating that this factor did not affect their formation (Table 2).

Table 2. The influence of symbiosis of fungi and bacteria with the root system of Miscanthus giganteus plants on its mass (VEBS, 2017-2019)

Plant growing season, days	Root system weight of 10 plants												
	Control, g	Mycofriend				Florabacillin				Mycovital			
		g	± to control		P-level	g	± to control		P-level	g	± to control		P-level
			g	%			g	%			g	%	
30	122	142	19.8	16.3	0.02	129	7.6	6.3	0.05	135	13.6	11.1	0.04

Table 2. Continued

<table>
<tr><th rowspan="3">Plant growing season, days</th><th colspan="13">Root system weight of 10 plants</th></tr>
<tr><th rowspan="2">Control, g</th><th colspan="4">Mycofriend</th><th colspan="4">Florabacillin</th><th colspan="4">Mycovital</th></tr>
<tr><th>g</th><th>± to control g</th><th>± to control %</th><th>P-level</th><th>g</th><th>± to control g</th><th>± to control %</th><th>P-level</th><th>g</th><th>± to control g</th><th>± to control %</th><th>P-level</th></tr>
<tr><td>60</td><td>138</td><td>157</td><td>19.6</td><td>14.2</td><td>0.02</td><td>145</td><td>6.9</td><td>5.0</td><td>0.05</td><td>151</td><td>12.9</td><td>9.4</td><td>0.04</td></tr>
<tr><td>90</td><td>150</td><td>170</td><td>20.5</td><td>13.7</td><td>0.02</td><td>156</td><td>6.2</td><td>4.1</td><td>0.05</td><td>164</td><td>14.1</td><td>9.4</td><td>0.04</td></tr>
<tr><td>120</td><td>174</td><td>197</td><td>23.6</td><td>13.6</td><td>0.02</td><td>183</td><td>9.6</td><td>5.5</td><td>0.05</td><td>190</td><td>16.6</td><td>9.6</td><td>0.04</td></tr>
</table>

Source: developed by the authors

The formation of a giant miscanthus harvest is a complex process caused by environmental factors and biological characteristics of the growth and development of plants of this crop. The leaf area is of immense importance. It is directly related to the overall development of the plant's ground mass, since most of it is made up of leaves. The leaf surface plays a significant role in absorbing CO_2 and producing photosynthesis. The current study found that the microorganisms based on which the biological products were created contribute significantly to the formation of the leaf surface of giant miscanthus plants. Under the influence of fungi and bacteria, the leaf area of plants of this crop during the growing season was significantly larger than the control (Table 3).

Table 3. Leaf surface area of giant miscanthus plants under symbiosis of its root system with fungi and bacteria (VEBS, 2017-2019)

<table>
<tr><th rowspan="3">Plant growing season, days</th><th colspan="13">Leaf surface area</th></tr>
<tr><th rowspan="2">Control, thous. m²/ha</th><th colspan="4">Mycofriend</th><th colspan="4">Florabacillin</th><th colspan="4">Mycovital</th></tr>
<tr><th>thous. m²/ha</th><th>± to control thous. m²/ha</th><th>± to control %</th><th>P-level</th><th>thous. m²/ha</th><th>± to control thous. m²/ha</th><th>± to control %</th><th>P-level</th><th>thous. m²/ha</th><th>± to control thous. m²/ha</th><th>± to control %</th><th>P-level</th></tr>
<tr><td>30</td><td>17.2</td><td>20.4</td><td>3.3</td><td>19.0</td><td>0.01</td><td>18.7</td><td>1.5</td><td>8.9</td><td>0.04</td><td>19.3</td><td>2.1</td><td>12.3</td><td>0.03</td></tr>
<tr><td>60</td><td>25.6</td><td>30.3</td><td>4.7</td><td>18.3</td><td>0.01</td><td>27.4</td><td>1.8</td><td>6.9</td><td>0.04</td><td>28.7</td><td>3.1</td><td>12.0</td><td>0.03</td></tr>
<tr><td>90</td><td>680.0</td><td>789.1</td><td>109.1</td><td>16.0</td><td>0.02</td><td>729.0</td><td>49.0</td><td>7.2</td><td>0.04</td><td>758.9</td><td>78.8</td><td>11.6</td><td>0.03</td></tr>
<tr><td>120</td><td>1072.1</td><td>1240.3</td><td>168.2</td><td>15.7</td><td>0.02</td><td>1154.1</td><td>82.0</td><td>7.7</td><td>0.04</td><td>1189.9</td><td>117.8</td><td>11.0</td><td>0.03</td></tr>
</table>

Source: developed by the authors

The greatest difference in this indicator compared to the control was obtained on day 120 of organogenesis. A particularly noticeable effect on its growth was noted in the variant with the biological preparation Mycofriend for its root application to the soil, while in the variants with other preparations, a slightly smaller increase in leaf surface was obtained compared to Mycofriend. When using the biological products Mycovital and Florobacillin, the growth of this indicator was 1.08-1.11 times higher than in the control, while in the variants with the biological preparation Mycofriend it was 1.18 times higher.

Plant height is a crucial factor in the productivity of miscanthus giganteus, similar to other aspects of plant growth and development. The higher the stem height, the higher the dry biomass yield, which is an important bioenergy indicator. Mycorrhizal-forming fungi and nitrogen-fixing bacteria play a significant role in determining the height of giant miscanthus plants when introduced at the root.

It was found that in the variants with the use of biological preparations, the plant height was greater than in the control at different periods of plant vegetation (Table 4). Among the biological products, the greatest impact on this indicator was found, as in the previous results, with the use of the biological preparation Mycofriend, and with the use of other products, the increase in plant height compared to the control was slightly inferior to the performance of the Mycofriend preparation.

Table 4. Plant height of giant miscanthus depending on the symbiosis of its root system with fungi and bacteria (VEBS, 2017-2021)

Plant growing season, days	Plant height									
	Control, cm	Mycofriend			Florabacillin			Mycovital		
		cm	± to control		cm	± to control		cm	± to control	
			cm	%		cm	%		cm	%
30	54	62	7	13.6	57	3	6.0	60	6	10.2
60	112	127	15	13.4	119	7	6.3	122	10	8.6
90	188	209	21	11.2	195	7	3.7	201	14	7.2
120	218	244	26	11.7	227	9	4.1	235	17	7.9

Source: developed by the authors

The results obtained on the increase in the height of Miscanthus giganteus plants in variants with mycorrhiza and symbiosis with bacteria indicate a significant influence of this factor on this element of plant growth and development. The structure of the crop is a crucial element of miscanthus productivity, the components of which determine not only the yield of dry biomass, but also its quality. One of the main indicators in the structure of the crop yield is the number of stems per bush. It was found that in the variants with the biological product Mycofriend (fungi *Glomus* VS and *Trichoderma harzianum* Rifai) the number of stems per bush was higher than in the control. A significant increase in this indicator was also observed with Mycovital (fungus *Tuber melanosporum* Vittad.) and Florobacillin (bacteria *Bacillus subtilis* Cohn.) compared to the control (Table 5).

Table 5. Number of stems of giant miscanthus in one bush depending on the symbiosis of its root system with fungi and bacteria (VEBS, 2017-2019)

Indicator	Biological preparations									
	Control, pcs.	Mycofriend			Florabacillin			Mycovital		
		pcs.	± to control		pcs.	± to control		pcs.	± to control	
			pcs.	%		pcs.	%		pcs.	%
Number of stems in 1 bush	66	76	10	15.1	69	4	5.7	72	6	9.4

Source: developed by the authors

The greatest number of stems in the bush, compared to the control, was observed in the variants with the biological preparation Mycofriend. Thus, the root application of biological products helps to increase the yield structure of giant miscanthus due to the improvement of plant nutrition and water balance.

The importance of this research is pointed out in a number of scientific papers (Katelevskij, 2020; Shuvar *et al.,* 2021), which state that the use of these microorganisms helps to improve the moisture supply of plants and has a positive effect on soil condition. Specifically, it is pointed out that under dry conditions, which are often encountered during the growing season, fungi and bacteria have a positive effect on this process. The scientific works of the above-mentioned authors note that in variants with the use of mycorrhizal fungi, the soil moisture holding capacity increased by 8-10% compared to the control, which is an important indicator in dry periods of plant vegetation. Similarly, the works of several authors (Wang *et al.*, 2021; Lopushniak *et al.,* 2021b) note the significant role of microorganisms in the formation of the structural and aggregate state of the soil.

Thanks to the secretions produced as a result of their vital activity, lumps of soil are formed from its dusty fraction. The present study confirms these conclusions. It was found that in the variants with fungi, the moisture retention capacity of the soil was higher compared to the control due to the penetration of their filamentous hyphae into the finest pores of the soil. As in the previous experiments, the best indicators of soil moisture retention capacity were obtained in the variants with the fungi *Glomus* VS and *Trichoderma harzianum* Rifai (Mycofriend) in the initial period of plant vegetation (on day 30 of organogenesis) – 7 mm more than in the control. With the use of the fungus *Tuber melanosporum* Vittad. (Mycovital preparation), this figure was 5 mm, which is also positive for improving the conditions of growth and development of plants of this crop (Fig. 1).

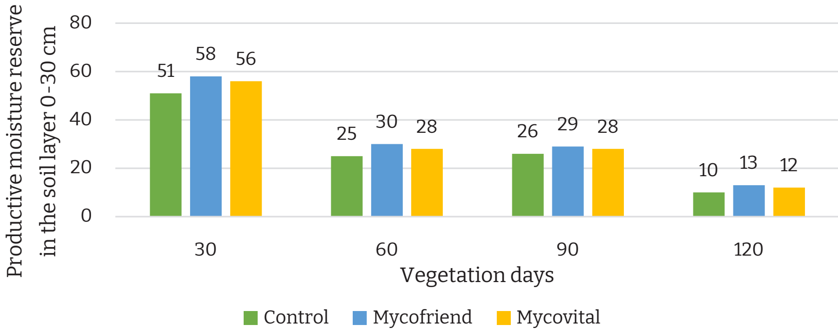

Figure 1. Soil moisture retention capacity depending on the interaction of mycorrhizal fungi with the root system of Miscanthus giganteus plants, VEBS, 2017-2019

As for the impact of fungi on improving the structural and aggregate state of the soil, it was found that it is substantially improved by creating a mycelial network and forming an adhesive component of the glycoprotein-glomatin, which glues part of the fine fraction of the soil, which coincides with the findings of several studies (Yu *et al.*, 2018; Moyano *et al.*, 2020). The proportion of lumps 0.25-10.0 mm in size in its total weight was 3.2-5.7% higher than in the control (Fig. 2).

This is also evidenced by the results of studies on the growth of the root system weight in variants using biological products. According to Table 4, in these variants, the mass of roots is significantly higher than in the control, i.e., due to the growth of fungal hyphae and the formation of arbuscules and vesicles, a mycelial network is created in the soil, which changes the soil structure, primarily affecting the reduction of its dusty fraction. That is, the mycelium of the fungus, developing intensively, forms a network that binds soil particles together. Furthermore, fungi, settling on the root system and entering into a symbiotic relationship with it, can accumulate the adhesive component glycoprotein-glomatin in the soil, which causes parts of its smallest fractions to stick together, forming lumps of various sizes and thus improving its structure.

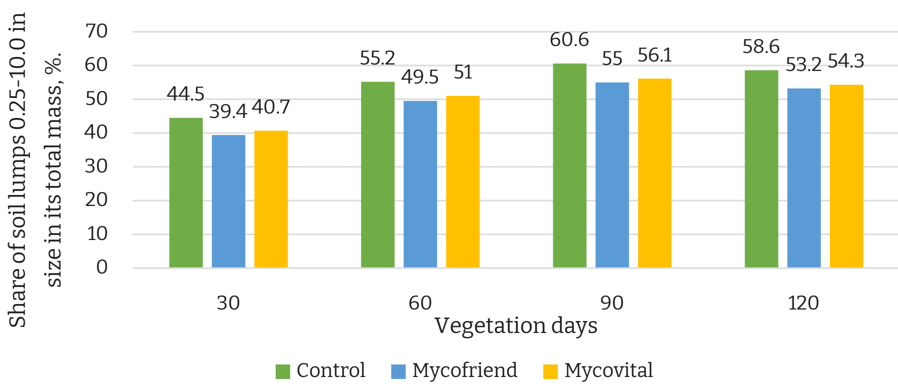

Figure 2. Proportion of lumps 0.25-10.0 mm in size in the symbiosis of mycorrhizal fungi with the root system of giant miscanthus plants, VEBS, 2017-2019

As a result of the positive impact of microorganisms on plant growth and development and soil quality, the use of mycorrhizal fungi and nitrogen-fixing bacteria contributes to a significant increase in the productivity of giant miscanthus. In the experiments conducted, the yield of dry biomass of this crop in variants with the use of biological products based on fungi *Glomus* VS, *Trichoderma harzianum* Rifai and *Tuber melanosporum* Vittad. (Mycofriend and Mikovital) and bacteria Bacillus subtilis Cohn. (*Florobacillin*) was significantly higher than the control (Fig. 3).

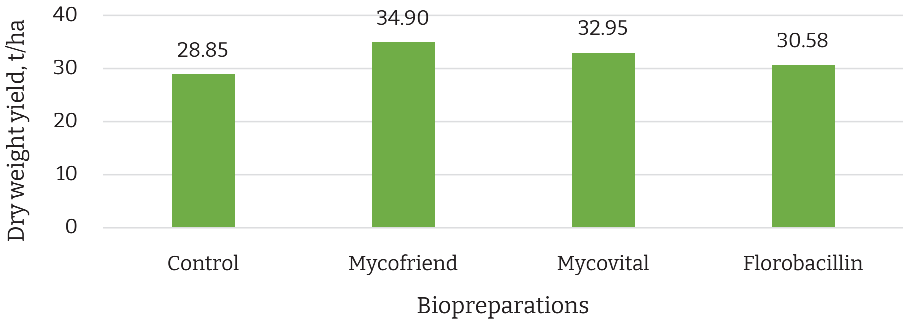

Figure 3. Yield of dry biomass of Miscanthus giganteus plants under symbiosis of its root system with fungi and bacteria, VEBS, 2017-2019

The type of microorganism plays a major part. In the variants with Mycofriend (fungi *Glomus* VS and *Trichoderma harzianum* Rifai), the yield of dry biomass of miscanthus was the highest compared to other preparations and control. The latter indicates that this biopreparation has the greatest positive effect on all elements of growth and development of miscanthus giganteus plants and, accordingly, contributes to the highest yield of dry biomass of this crop.

CONCLUSIONS

Mycorrhization of the root system of miscanthus giganteus by fungi *Glomus* VS and *Trichoderma harzianum* Rifai (Mycofriend), *Tuber melanosporum* Vittad (Mikovital) and its symbiosis with bacteria *Bacillus subtilis* Cohn (Florobacillin) contribute to the improvement of plant growth and development and increase their productivity.

Under this condition, by determining the dry mass of the leaves, their water content increased by 8.1-28.6% compared to the control, which indicates the ability of fungi to form many branches of filamentous hyphae, which significantly increase the area of water absorption by the root system from the soil, penetrating into its thinnest pores. The mass of the root system of Miscanthus giganteus in the variants with root application of fungi and bacteria to the soil was 4.1-16.3% higher than in the control due to the formation of mycelial network around the root hairs and the formation of arbuscules and vesicles by fungi. The role of bacteria in this is to help improve metabolism in the root system, which in turn affects its weight.

The height of miscanthus giganteus plants in the variants with fungi and bacteria was 3.1-13.6% higher than in the control, which indicates more favourable conditions for the growth and development of plants of this crop in the variants using these microorganisms. In these variants, the number of stems per bush also increased by 5.7-15.0% compared to the control, which is an important component in the formation of crop productivity.

The leaf surface area of Miscanthus giganteus plants in experiments with fungi and bacteria at different growing seasons was 6.9-19.0% larger than the control, which underlies efficient solar energy absorption and creation of organic products.

Apart from the positive effect of fungi on plant growth and development, the use of these microorganisms helps improve the soil moisture retention capacity and its structural and aggregate state. In the variants with mycorrhizal fungi *Glomus* VS and *Trichoderma harzianum* Rifai and *Tuber melanosporum* Vittad, the soil moisture retention capacity was 10.0-25.7% higher, and the proportion of lumps 0.25-10.0 mm in size exceeded the control by 3.2-5.7%. The yield of dry biomass of giant miscanthus in variants with biological products was higher than the control by 1.82-6.11 t/ha, which had a positive effect on the supply of biofuel raw materials to the market. This area of research has the potential for further development in other highly productive crops used as feedstocks to produce diverse types of biofuels.

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None.

CONFLICT OF INTEREST

The authors of this study declare no conflict of interest.

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Сергій Георгійович Димитров

Кандидат сільськогосподарських наук, старший науковий співробітник
Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна
https://orcid.org/0000-0002-0377-9596

Василь Трохимович Саблук

Доктор сільськогосподарських наук, професор
Інститут біоенергетичних культур і цукрових буряків НААН
03110, вул. Клінічна, 25, м. Київ, Україна
https://orcid.org/0000-0002-6124-4346

Михайло Ярославович Гументик

Доктор сільскогосподарських наук, старший науковий співробітник
Інститут біоенергетичних культур і цукрових буряків НААН
03110, вул. Клінічна, 25, м. Київ, Україна
https://orcid.org/0000-0001-9052-9650

Формування продуктивності міскантуса гігантського (*Miscanthus × giganteus*) за симбіозу його кореневої системи з грибами та бактеріями

Анотація. Актуальність обраної теми полягає у підвищенні врожайності сухої біомаси рослин міскантуса гігантського за використання грибів та бактерій у технології його вирощування. Метою дослідження є встановлення впливу мікоризації кореневої системи цієї культури грибами та симбіозу з бактеріями на ріст і розвиток рослин та формування їх продуктивності. Польові дослідження проводили в умовах Веселоподільської дослідно-селекційної станції Інституту біоенергетичних культур і цукрових буряків Національної академії аграрних наук України (Полтавська область) упродовж 2017-2019 рр. на чорноземі солонцюватому та слабо солонцюватому. Суттєвість відхилення між варіантами дослідів визначали за показником P-level, розрахованим за критерієм Стьюдента. Використання симбіозу грибів і бактерій з кореневою системою міскантуса гігантського сприяло отриманню позитивних результатів у покращенні росту, розвитку рослин та підвищенні врожайності сухої біомаси. Зокрема, за використання біопрепаратів Мікрофренд, Міковітал, та Флоробацилін (гриби *Glomus VS.* і *Trichoderma harzianum* Rifa, *Tuber melanosporum* Vittad та бактерії *Bacillus subtilis* Cohn*)* істотно зростала площа листкового апарату (на 6,9-19,0 %), маса кореневої системи (на 4,1-16,3 %), збільшилась висота рослин (на 3,7-13,6 %) та кількість стебел (на 5,7-15,1 %) порівняно з контролем. Водночас, відмічається покращення вологоутримуючої здатності ґрунту на 10,3-23,7 % і його структурно-агрегатного стану – частка грудочок розміром 0,25-10,0 мм була більшою від контрольних на 3,2-5,7 %. Використання мікоризоутворюючих грибів і азотофіксуючих бактерій сприяє зростанню порівняно з контролем врожайності сухої біомаси рослин на 1,82-6,11 т/га., що має практичне значення у збільшенні сировини для виробництва біопалива

Ключові слова: маса кореневої системи; площа листків, маса листків; вологоутримуюча здатність; структурно агрегатний стан; врожайність