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ANALYSIS OF THE POTENTIAL OF EFFECTIVE MICROORGANISMS IN PLANT PRODUCTION

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ABSTRACT: The natural environment is changing under the influence of human activity and the development of new technologies. One of the ways to restore the balance of the natural environment is to limit conventional agriculture in favour of organic farming based on the use of organic and natural fertilisers, excluding the use of chemical inputs. This action will go a long way in improving biodiversity and natural resource wealth. Fertilisation in modern agriculture is one of the most important agrotechnical procedures in deciding on the size and quality of the obtained crops. In organic farming, soil microorganisms play an important role because they influence the mineralisation of organic carbon and the humification of organic matter, thanks to which nutrients are more easily absorbed by plants. Organic fertilisers, which are Effective Microorganisms, are produced with the use of living microorganisms, which not only supply the soil with nutrients but also allow the inactive nutrients to be made available. Thanks to the better absorption of nutrients, plants develop and grow better, ensuring the best crops, the purchase prices of which from organic farming are very often much higher than in the case of traditional crops. The aim of this study was to present the possibility of using Effective Microorganisms as an ecological and economical alternative to conventional crop production systems using artificial fertilisers.

KEYWORDS: sustainable development, plants, Effective Microorganisms

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Introduction

The natural environment can be considered an intrinsic good that has developed over millions of years of slow evolution. It is the basis for the existence of mankind. Due to the progress in the development of the economy, nature began to transform. The increase in birthrate resulted in more and more human interference in the changes taking place in the environment. In the 20th century, the dynamic economic development of the world, consisting in increasing the share of industry in national economies and urbanisation, led to a significant deterioration of the environment (Fiedler, 2018).

The changes that have taken place in the environment as a result of human activity have clearly marked the surrounding landscape. The branch of the economy with the most significant impact on the natural environment is agriculture. The large-scale use of artificial fertilisers contributes to environmental degradation. Modern agriculture is geared towards maximum production and maximum profit. As a result, environmental costs are neglected, which include impoverishment of landscape values, contamination of ground and surface waters, as well as soil degradation and erosion (Brdulak et al., 2021; Sobiesiak-Penszko et al., 2019).

Currently, great importance is attached to environmental protection and sustainable development. However, it should not be forgotten that sustainable production also aims to increase food production and reduce the incidence of diseases and pests without serious damage to crops. Organic production combines environmentally friendly management practices, supports a high degree of biodiversity, and utilises natural processes. Therefore, it is important to develop new methods to restore the mechanisms of the natural stability of microorganisms and agricultural communities (Hamid et al., 2021).

The deterioration of the natural environment contributes to the search for new, effective biological agents with a broad spectrum of activity. Microbiological preparations, which include properly selected, beneficial microorganisms that commonly occur in the natural environment, are highly effective (Panisson et al., 2021). In this aspect, liquid microbiological preparation Effective Microorganisms is gaining more and more popularity in Poland and in the world (Japan, Western Europe, USA, Brazil). Effective Microorganisms is the trade name for various products developed by Dr Teruo Higa, who is a professor of horticulture at Ryukyus University, a university located in Okinawa, Japan (Piotrowska & Boruszko, 2022; Pszczolkowski & Sawicka, 2018; Talaat et al., 2015).

Addressing human-induced pressure in the form of excessive chemical use in agriculture is made possible through the use of Effective Microorganisms. It is a group of microorganisms, including bacteria and fungi occurring

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in nature, remaining in an undefined state of equilibrium with each other. Organic fertilisers in the form of EM are produced with the use of living microorganisms that can compete for space and/or food with pathogens (Feijoo, 2016; Morocho & Leiva-Mora, 2019).

Over the last several decades, there has been an increasing tendency to use biopreparations containing substances of natural origin. The use of biopreparations improves the health of plants and enables them to absorb nutrients better, resulting in increased yields. This action affects agricultural policy, which aims to shape the volume of agricultural production and maintain its profitability. The scope of action of EM preparations is wide due to their ability to increase the biological activity of the soil and thus prevent putrefactive processes. They can help improve soil structure and fertility by dissolving compounds unavailable to plants. EM improve the physicochemical properties of the soil, break down organic matter and synthesise nutrients needed for plant development (Ludwiczak et al., 2018).

A food policy adapted to the 21st century should take into account a number of criteria, among which are food quality, the environment, social and cultural values, and reasonable and competitive prices. The use of EM in crop production creates favourable habitat for plant growth. The presence of Effective Microorganisms in the soil accelerates the processes of decomposition of organic remains and facilitates the availability of micro- and macroelements to plants. Thanks to better assimilation of nutrients and protection against soil pathogens, plants develop and grow better, which ensures their better yield. The use of microbial preparations in crop production can contribute significantly to the production of high-quality food (Joshi et al., 2019; Nayak et al., 2020).

The aim of this study was to present the possibility of using Effective Microorganisms as an ecological and economical alternative to conventional crop production systems using artificial fertilisers.

According to Borowiak et al. (2021), the use of EM may have a positive effect on the microbial and enzymatic activity of the soil, as well as the intensity of plant photosynthesis, which in turn may result in a reduction in the use of mineral fertilisers and the promotion of sustainable agricultural production.

Olle and Williams (2013) studied the effect of EM preparation on plant growth, yield, quality and protection after application to soil. They found that 70% of the published studies on the subject showed that EM positively affected plant growth. Also, these authors, in another study, found that EM interacts with soil and plant ecosystems. This is to:

- suppression of plant pathogens and other pathogens,
- dissolving minerals,
- energy saving,

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- maintaining the microbiological and ecological balance in the soil,
- increasing the efficiency of photosynthesis and biological nitrogen fixation.

Inoculation of the soil and plant ecosystem with Effective Microorganisms can improve soil quality, soil health, crop quality, growth, and yields. One of the reasons for these effects is that photosynthetic bacteria are the major component of EM. They act synergistically with other microorganisms. to meet the nutritional needs of plants and to reduce the proportion of disease-causing microorganisms. In addition to metabolizing organic compounds, EMs produce simple plant compounds that, when added to the soil, improve their use in agriculture and stabilise the natural ecosystem (Hidalgo et al., 2022; Rastogi et al., 2020).

According to Szewczuk et al. (2016), the EM preparation, which includes carefully selected strains of microorganisms, has a positive effect on the morphological features of plants, their physiological functions and the properties of the substrate. According to Yonghua et al. (2022), the use of EM for Asian ginseng cultivation improved soil fertility and Asian ginseng quality and revealed a connection between soil microbial diversity and physicochemical properties.

Research methods

The study used plant and soil material from the pot experiment in the form of plants and soil after two weeks of the experiment. The content of micro- and macroelements, as well as other elements in plants and four different types of soil available in a garden shop (universal top quality substrate, universal soil, gardening substrate for sowing and quilting and substrate with acid peat), were determined. 4 types of soil and 2 types of plants were selected, which were marked in the further part of the work in various combinations of G1 – G20 and R1 – R14. The soil pH varied from 3.5 to 6.8. They came from the orno-humus level (0-20 cm).

Two plants were selected for research on the potential of Effective Microorganisms: one from the monocotyledonous class, which is wheat (*Triticum aestivum L.*) and one from the dicotyledonous class, which is rapeseed (*Brassica napus L.*). The choice of plants was determined by their belonging to different systematic classes. The research samples were treated with the preparation EM Naturally Active. This preparation consists of lactic acid bacteria (*Lactobacillus casei, Streptococcus lactis*), yeasts (*Candidia utilis, Sacharomyces albus*), photosynthetic bacteria (*Rhodopseudomonas palustrus, Rhodobacter spae*), mold fungi (*Aspergillus oryzomae, Mucor hiemalis and actinomyces, Streptomyces albus*). The preparation EM Naturally Active was registered as organic fertiliser by the decision of the Minister of Agriculture and Rural

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Development, Study No. 281/11 of March 31, 2011. The pot test was carried out at the Department of Environmental Technology, the Bialystok University of Technology, in 2021. The test was carried out in plastic containers with a volume of 150 ml (upper diameter 80 mm), 100 g of air-dry soil was placed and then moistened to 55% of full water capacity. When the soil was already moist, wheat and rapeseed seeds were sown in the amount of 10 seeds per one container. The previous evaluation showed a germination capacity of the test plants seeds of >95%. The tests were carried out in laboratory conditions, at room temperature (20-22°C), with natural lighting lasting 12-16 hours/day. The humidity level was checked daily by checking the weight of a number of selected containers of each combination. The grain of wheat and rapeseed in the test samples was watered with a 1% solution of Naturally Active EM, and the control samples with distilled water. The experiment was carried out for fourteen days (Klimkowicz-Pawlas, 2005).

The content of micro and macro elements and other elements was determined using the method of atomic absorption spectrometry (ASA) (Kornaś et al., 2019). This analytical technique allowed the determination of chemical elements such as B, Al, P, V, Cr, Mn, Co, Ni, Cu, Zn, As, Cd, La, Pb, K, Ca, Na, Mg in samples.

The content of metals in plants was determined after microwave mineralisation in nitric acid (V) and perhydrol. In the case of soil for microwave mineralisation, a mixture of nitric acid (V) with concentrated hydrochloric acid was used (Najduch et al., 2021). Before each series of determinations, at least five calibration solutions were prepared from the standard solution of the element, covering the concentration range to be determined. For each element, a calibration curve was plotted with readings of the concentrations of the calibration solutions. During the analysis of the samples, the blank solution and the test sample solution were sucked successively into the flame, and the absorbance value of a given element was measured. The element concentration corresponding to the absorbance values of the sample was read from the plotted calibration curve.

Experimental setup:

G1 – a control sample of the highest quality universal substrate, on which wheat grew for fourteen days watered with distilled water,

R1 – a control sample of 14-day-old wheat growing on the highest-quality substrate watered with distilled water,

G2 – a research trial of the highest quality universal substrate, on which wheat grew for fourteen days, watered with 1% Naturally Active EM solution,

R2 – a research trial of 14-day-old wheat growing on a top-quality substrate watered with 1% Naturally Active EM solution,

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G3 – a control sample of universal soil, where wheat grew for fourteen days, watered with distilled water,
R3 – a control sample of 14-day-old wheat growing on universal soil watered with distilled water,
G4 – research trial of universal soil, where wheat grew for fourteen days, watered with 1% Naturally Active EM solution,
R4 – research trial of 14-day-old wheat growing on universal soil watered with 1% solution of Naturally Active EM,
G5 – control test of the potting soil for sowing and quilting, on which wheat grew for fourteen days watered with distilled water,
R5 – a control sample of 14-day-old wheat growing on a horticultural substrate for sowing and quilting watered with distilled water,
G6 – a research trial of a horticultural substrate for sowing and quilting, on which wheat grew for fourteen days, watered with 1% Naturally Active EM solution,
R6 – research trial of 14-day-old wheat growing on a horticultural substrate for sowing and quilting with 1% Naturally Active EM solution,
G7 – a control sample of acid peat, on which wheat grew for fourteen days watered with distilled water,
R7 – a control sample of 14-day-old wheat growing on acid peat watered with distilled water,
G8 – research trial of acid peat, on which wheat grew for fourteen days, watered with 1% solution of EM Naturally Active,
R8 – research trial of 14-day-old wheat growing on acid peat watered with 1% Naturally Active EM solution,
G9 – a control sample of the highest quality universal substrate, on which rapeseed grew for fourteen days watered with distilled water,
R9 – a control test of 14-day-old rapeseed growing on a universal substrate of the highest quality watered with distilled water,
G10 – a research trial of a universal top-quality substrate, on which rapeseed grew for fourteen days, watered with a 1% solution of EM Naturally Active,
R10 – research trial of 14-day-old rapeseed growing on a universal substrate of the highest quality watered with 1% solution of EM Naturally Active,
G11 – a control sample of universal soil, on which rapeseed watered with distilled water grew for fourteen days,
R11 – a control sample of 14-day-old rapeseed growing on universal soil watered with distilled water,
G12 – a research trial of universal soil where rapeseed grew for fourteen days, watered with 1% Naturally Active EM solution,
R12 – research trial of 14-day-old rapeseed growing on universal soil watered with 1% solution of EM Naturally Active,

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G13 – control test of potting soil for sowing and quilting, on which rapeseed grew for fourteen days watered with distilled water,
R13 – a control test of 14-day-old rapeseed growing on a horticultural substrate for sowing and quilting watered with distilled water,
G14 – a research trial of a horticultural substrate for sowing and quilting, on which rapeseed grew for fourteen days, watered with 1% Naturally Active EM solution,
R14 – a research trial of 14-day-old rapeseed growing on a horticultural substrate for sowing and quilting with 1% Naturally Active EM solution,
G15 – a control sample of sour peat on which rapeseed grew for fourteen days watered with distilled water,
G16 – a research trial of sour peat, on which rapeseed grew for fourteen days, watered with 1% solution of EM Naturally Active.

Results of the research

The results of the determination of elements by atomic absorption spectrometry (ASA) are presented in Table 1, Table 2, Table 3, and Table 4. The content of heavy metals and other metals in soils was determined by the type of soil, EM watering and the type of plants that grew in a given soil.

The largest increase in the number of elements among the soils after wheat cultivation was recorded in the G2 object (universal substrate of the highest quality, on which wheat grew for fourteen days, watered with 1% EM solution), in which nine out of ten elements determined in relation to the control G1 (universal the highest quality substrate on which wheat grew for fourteen days, watered with distilled water). A significant increase in the content of elements was also observed in object G4 (universal soil, where wheat grew for fourteen days, watered with 1% EM solution), in which seven out of ten determined elements had a higher content, and two elements Cd and V out of ten had the same content with respect to the control object G3 (universal land on which wheat grew for fourteen days watered with distilled water). In the case of the substrate with acid peat and the horticultural substrate for sowing and quilting used for growing wheat, little or no effect on the increase in the metal content after the application of the EM preparation was observed.

In all types of soils used for the cultivation of rapeseed, in which the EM preparation was applied, a decrease in the content of seven to nine elements out of ten was observed. The observations also show that in all types of soils used for rapeseed cultivation, in 100% of the objects where the EM preparation was applied, the content of the elements As, Al and V decreased. The decrease in the content of Cd, La, Cr, and Ni was recorded in 75% of the

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objects, for fourteen days, the rapeseed grew, watered with a 1% solution of EM Naturally Active. In 50% of the sites where rapeseed watered with 1% Naturally Active EM solution grew for fourteen days, a decrease in the content of Pb, Co and Na was noted.

Table 1. Metal content in the soil

Object	Element									
	As	Cd	La	Pb	Al	V	Cr	Co	Ni	Na
	µg/g dry weight									mg/g dry weight
G1	0.78	0.26	1.33	9.92	1315.38	11.14	10.59	0.68	4.91	0.42
G2	1.09	0.25	1.53	10.24	1484.48	12.34	10.61	0.78	5.35	0.46
G3	0.40	0.09	0.40	3.57	555.14	1.15	6,00	0.26	3.98	0.08
G4	0.57	0.09	0.43	3.22	570.94	1.15	6.03	0.58	4.72	0.11
G5	1.46	0.19	3.59	10.68	1209.82	2.99	7.27	0.68	5.13	0.17
G6	1.16	0.16	3.15	8.24	940.00	2.15	6.45	0.52	4.36	0.16
G7	0.79	0.09	1.22	8.16	771.49	1.78	6.23	0.45	4.00	0.13
G8	0.61	0.12	1.07	6.75	737.10	1.56	5.95	0.45	4.02	0.14
G9	0.83	0.24	1.59	10.84	1475.15	12.75	10.40	0.73	5.55	0.48
G10	0.80	0.30	1.49	11.67	1416.95	12.53	11.01	0.75	6.26	0.47
G11	0.47	0.08	0.42	3.36	600.80	1.18	6.10	0.25	3.88	0.09
G12	0.45	0.06	0.44	3.13	538.02	1.07	5.62	0.27	3.81	0.11
G13	1.88	0.25	6.13	19.16	1663.16	4.08	7.78	0.87	4.89	0.30
G14	1.19	0.19	3.97	10.04	993.14	2.38	6.53	0.53	4.41	0.18
G15	0.71	0.15	1.12	8.15	749.35	2.33	5.78	0.46	3.76	0.13
G16	0.47	0.11	0.90	6.59	597.76	1.36	5.57	0.41	3.64	0.15

It was observed that the content of aluminium was higher in all rapeseed seedlings, which were watered with the EM preparation in relation to rapeseed seedlings which were watered with water. The aluminum content in wheat in the control objects watered with water ranged from 176.46 to 442.31 µg/g dry weight, while in the objects watered with the EM prepara-

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tion, it ranged from 189.75 to 632.84 μg/g dry weight. The aluminum content in rapeseed in the control objects watered with water ranged from 262.08 to 461.39 μg/g dry weight, while in the objects watered with the EM preparation, it ranged from 284.21 to 595.59 μg/g dry weight.

Diversified soils, which were used for the research, to a small extent, influenced the content of lanthanum in wheat and rapeseed. The lanthanum content in wheat in the control objects watered with water ranged from 0.09 to 0.34 μg/g dry weight, while in the objects watered with the EM preparation, it ranged from 0.15 to 0.33 μg/g dry weight. The lanthanum content in rapeseed in the control objects watered with water ranged from 0.20 to 0.28 μg/g dry weight, while in the objects watered with the EM preparation, it ranged from 0.15 to 0.49 μg/g dry weight.

Table 2. Metal content in plants

Object	Element									
	As	Cd	La	Pb	Al	V	Cr	Co	Ni	Na
	μg/g dry weight									mg/g dry weight
R1	0.54	0.27	0.32	8.29	442.31	0.79	49.55	0.40	32.26	0.19
R2	0.21	0.20	0.15	5.53	632.84	0.57	59.54	0.44	35.87	0.23
R3	0.13	0.19	0.09	4.51	233.15	0.24	28.16	0.22	16.61	0.20
R4	0.06	0.17	0.21	4.62	435.56	0.34	46.21	0.36	25.80	0.21
R5	0.80	0.26	0.19	6.21	197.25	0.32	52.73	0.41	33.28	0.23
R6	1.34	0.36	0.33	4.46	327.81	0.49	47.97	0.37	32.69	0.21
R7	0.24	0.54	0.20	13.67	176.46	0.81	215.57	1.55	132.71	0.62
R8	0.18	0.34	0.22	8.13	189.75	0.75	133.90	1.29	80.03	0.25
R9	0.17	0.36	0.28	7.76	461.39	0.88	110.44	1.02	65.10	3.37
R10	0.71	0.47	0.43	21.29	387.54	1.37	147.59	1.29	87.10	2.14
R11	0.10	0.52	0.20	9.62	262.08	0.81	159.42	1.25	95.20	2.04
R12	0.53	0.59	0.15	9.89	284.21	0.64	105.69	0.94	63.37	1.36
R13	0.47	1.45	0.26	17.64	439.79	0.84	115.91	0.96	68.84	1.93
R14	0.90	0.87	0.49	20.61	595.59	1.65	287.97	2.25	174.82	2.47

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The study showed that the content of arsenic in the wheat watered with water was from 0.13 to 0.80 μg/g of dry weight, and thus it was higher than the content of arsenic in the rapeseed watered with water, which was from 0.10 to 0.47 μg/g of dry weight. A higher arsenic content was also noted in wheat watered with EM preparation, amounting to 0.06 to 1.34 μg/g dry weight, than the content of arsenic in the in EM-watered rapeseed, amounting to 0.53 to 90 μg/g of dry weight.

The use of EM preparation resulted in a decrease in nickel content in wheat in relation to objects watered with water, while in rapeseed, this action had the opposite effect. In wheat in the control objects watered with water, the content ranged from 16.61 to 132.71 μg/g of dry weight, while in the objects watered with the EM preparation, it ranged from 25.80 to 80.03 μg/g of dry weight. The nickel content in rapeseed in the control objects watered with water ranged from 65.10 to 95.84 μg/g of dry weight, while in the objects watered with the EM preparation, it ranged from 63.37 to 174.82 μg/g of dry weight.

In rapeseed objects watered with water, higher contents of cadmium, vanadium, lead, aluminum and sodium were observed than in wheat objects watered with water. In wheat objects watered with water, higher amounts of arsenic, chromium, lanthanum, nickel and cobalt were observed than in rapeseed objects watered with water. The rapeseed objects watered with the EM preparation were characterised by a higher content of arsenic, cadmium, vanadium, chromium, cobalt, lanthanum, lead, nickel and sodium than in wheat objects watered with the EM preparation.

It was observed that 87.5% of micro- and macroelements (potassium, calcium, phosphorus, zinc, boron, manganese and copper) increased in the G4 object (universal soil where wheat grew for fourteen days with 1% Naturally Active EM solution) in relation to the object G3 of the control unit. An increase of 75% of micro- and macroelements (magnesium, potassium, calcium, boron, manganese and copper) was observed in the G8 object (acid peat, where wheat grew for fourteen days, watered with 1% Naturally Active EM solution) in relation to the control G7 (acid peat, where wheat grew for fourteen days, watered with distilled water). Object G2 showed an increase of 62.5% of micro- and macroelements (magnesium, potassium, phosphorus, boron and manganese) in relation to the control object G1. On the horticultural substrate for sowing and quilting, on which wheat grew for fourteen days, watered with 1% EM Naturally Active solution, a 62.5% decrease of micro- and macronutrients (magnesium, potassium, calcium, phosphorus and manganese) was observed in relation to the horticultural substrate for sowing and picking, where wheat was grown for fourteen days and watered with distilled water.

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Table 3. Contents of macro and micronutrients in soil

Object	Element							
	Mg	K	Ca	P	Zn	B	Mn	Cu
	mg/g dry weight				µg/g dry weight			
G1	1.47	1.05	35.88	0.90	33.52	0.53	122.14	20.46
G2	1.56	1.36	20.06	1.17	29.31	2.14	124.48	14.60
G3	1.05	0.14	17.85	0.48	12.51	2.27	22.63	9.37
G4	1.00	0.22	25.42	0.50	16.60	2.54	26.56	13.72
G5	1.82	0.56	28.37	0.59	26.16	0.53	65.53	5.94
G6	1.63	0.46	19.38	0.45	30.44	0.80	62.09	6.73
G7	0.94	0.23	3.35	0.27	19.44	0.40	24.71	5.48
G8	0.96	0.25	4.04	0.26	18.50	0.80	24.93	5.50
G9	1.61	1.68	22.40	1,00	49.72	3.74	140.17	21.20
G10	1.75	2.02	28.11	1.12	42.34	3.21	129.70	19.73
G11	1.12	0.44	18.02	0.54	20.04	3.07	21.48	21.76
G12	1.07	0.56	18.62	0.57	11.10	2.94	22.72	8.06
G13	1.04	1.23	29.42	1.56	84.39	1.47	100.59	14.03
G14	1.75	1.03	22.90	0.57	19.83	0.67	69.97	8.41
G15	1.08	0.24	4.42	0.26	22.30	0.27	23.92	7.23
G16	0.88	0.24	5.42	0.26	13.71	0.20	22.46	4.55

In the object G10 (the universal top-quality substrate, on which rapeseed watered with 1% Naturally Active EM solution grew for fourteen days), an increase in all macronutrients and a decrease in all tested microelements was observed in relation to the control object G9 (universal substrate of the highest quality, on which for fourteen days rapeseed grew watered with distilled water).

An increase in 75% of macronutrients (potassium, calcium, phosphorus) was observed in the object G12 (universal soil on which, for fourteen days, rapeseed watered with 1% Naturally Active EM solution grew), with a simultaneous decrease in microelements (zinc, boron, copper) in relation to the object control G11 (universal soil on which rapeseed watered with distilled water grew for fourteen days).

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Object G14 (horticultural substrate for sowing and quilting, on which rapeseed watered with the Naturally Active EM solution grew for fourteen days) showed a decrease in all the tested microelements compared to the control object G13 (horticultural substrate for sowing and quilting, on which rapeseed watered with distilled water was growing for fourteen days). Moreover, object G16 (acid peat, on which rapeseed watered with 1% Naturally Active EM solution grew for fourteen days) showed a decrease in all micronutrients (zinc, boron, manganese and copper) compared to the control object G15.

When analysing the content of micro- and macroelements in the horticultural substrate for sowing and quilting after the cultivation of wheat and rapeseed watered with the Naturally Active EM solution, different trends in the changes of individual elements were observed. In object G6, where wheat was growing for fourteen days, the content of all tested macroelements decreased, while in the same substrate where rapeseed grew (object G14), a decrease in all tested microelements was observed.

A study by Iriti et al. (2019) reports that the application of EM in common bean cultivation increased the magnesium, manganese, phosphorus and sodium content of beans. According to Sawicka et al. (2021), the use of innovative technology of potato cultivation with the application of EM will allow us to obtain better quality products ennobled to potato processing.

According to Mohamed et al. (2021), the application of EM as an additive to sweet bell pepper cultivation through foliar applications enhanced sweet bell pepper development traits and biochemical components (mineral elements and some biocomponents).

Among the analysed micronutrients in plants, the most frequent increase in the objects watered with EM was recorded for copper. The highest copper content was observed in wheat growing on the highest quality substrate watered with 1% Naturally Active EM solution, the content of which was 201.53 μg/g of dry weight. In the same soil, the lower content of copper was found in rapeseed watered with water, which contained 46.01 μg/g of dry weight and watered with EM preparation, it contained 74.01 μg/g of dry weight.

Among the analysed macroelements, an increase in phosphorus in wheat and rapeseed was recorded in 71.43% of the objects watered with EM. Slightly lower growth in wheat and rapeseed was recorded for the content of calcium, magnesium and potassium, and it occurred in 57.14% of the objects watered with EM.

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Table 4. The content of macro and micronutrients in plants

Object	Element							
	Mg	K	Ca	P	Zn	B	Mn	Cu
	mg/g dry weight				µg/g dry weight			
R1	2.27	103.10	3.51	23.68	247.53	3.83	186.16	131.31
R2	2.66	92.76	3.88	26.46	170.90	9.65	218.82	201.53
R3	2.56	72.84	4.57	24.73	157.89	1.65	147.92	51.61
R4	3.12	78.18	5.93	30.93	129.45	13.41	184.73	126.76
R5	2.82	99.35	5.40	24.95	212.21	1.35	105.71	73.63
R6	2.89	92.68	5.13	24.49	167.51	2.29	117.70	24.09
R7	2.63	10.69	0.79	13.96	332.39	0,00	65.68	64.26
R8	2.09	13.89	0.78	12.99	177.91	0,00	63.24	52.83
R9	7.46	121.89	16.24	15.79	151.84	21.20	304.35	46.01
R10	6.55	128.44	23.18	17.55	250.04	11.22	306.64	74.01
R11	6.46	107.52	26.79	17.62	186.68	53.34	214.64	58.64
R12	5.25	100.82	22.95	18.49	407.85	19.66	196.23	129.42
R13	6.54	104.35	21.70	17.35	146.56	27.5	111.16	20.47
R14	8.85	142.92	37.43	18.03	349.32	26.56	137.99	70.26

The objects R4 (fourteen-day-old wheat grown on universal soil watered with 1% Naturally Active EM solution) and R14 (fourteen-day-old rapeseed growing on a horticultural substrate for sowing and quilting watered with 1% Naturally Active EM solution) were distinguished by an increase in the content of seven out of eight micro- and macroelements. An increase in the content of 75% of micro- and macroelements was observed in the object R2 (fourteen-day-old wheat growing on the highest quality substrate watered with 1% Naturally Active EM solution) and R10 (fourteen-day-old rapeseed growing on the universal top quality substrate watered with 1% Naturally Active EM solution).

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Conclusions

From the practical point of view in agricultural production, obtaining a high yield of good quality depends not only on supplying the crop with macronutrients but also on covering its demand for microelements. They determine the effective use of phosphorus and other macronutrients in the production of biomass. The obtained results indicate that the use of the Naturally Active EM preparation containing beneficial microorganisms influences the creation of habitat favourable to plant growth by facilitating the availability of micro- and macroelements to plants. The concentration of individual elements in the samples was determined by the type of soil, watering with EM preparation and the type of plant. Of the four types of soil on which wheat watered with EM preparation was grown, the greatest increase in the number of micro- and macroelements in wheat was recorded in the R4 object (research sample of 14-day-old wheat growing on all-purpose soil watered with a 1% solution of EM Naturally Active) in relation to the control object watered with water. The application of the EM preparation on the soils where wheat was grown had a significant impact on the content of micro- and macroelements, thanks to which plants have the opportunity to assimilate better nutrients, which can make the plant more valuable from the consumer's point of view. Studies have shown that EM as a representative of biopreparations can be an alternative to artificial fertilisers for not only ecological reasons consistent with the principles of sustainable development. The prices of synthetic fertilizers increased dramatically compared to previous years, making the use of EM economically advantageous as well.

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The contribution of the authors

The article was written in collaboration by all authors.

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