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EFFECT OF EFFECTIVE MICROORGANISMS (EM) ON NUTRIENT CONTENTS IN SUBSTRATE AND DEVELOPMENT AND YIELDING OF ROSE (*Rosa x hybrida*) AND GERBERA (*Gerbera jamesonii*)

WPŁYW EFEKTYWNYCH MIKROORGANIZMÓW (EM) NA ZAWARTOŚĆ SKŁADNIKÓW POKARMOWYCH W PODŁOŻU ORAZ ROZWÓJ I PLONOWANIE RÓŻY (*Rosa x hybrida*) I GERBERY (*Gerbera jamesonii*)

Abstract: The aim of conducted studies was to assess the effect of the application of Effective Microorganisms (EM) on changes in contents of available and readily soluble forms of nutrients in the peat substrate as well as growth, development and yielding of rose (*Rosa x hybrida)* and gerbera (*Gerbera jamesonii*) grown on the substrate. Effective Microorganisms were applied before the vegetation season in the form inoculum at 3 g preparation·5 dm^{-3} substrate and in foliar application as plant spraying (repeated three times, with an aqueous solution at a concentration of 0.1%). In the conducted studies the effect of EM, applied both to the roots and as foliar application, was found on changes in contents of available nutrients in the substrate, at the simultaneous substrate acidification, in relation to the control combination. The significantly highest yield of flowers in case of both examined species was recorded at the application of the EM inoculum to the roots. This had a positive effect on the number or formed shoots and the diameter of flowers (in case of roses) and the number of formed inflorescences (in case of gerberas). Foliar application of Effective Microorganisms had a positive effect on the diameter of flowers in roses and the number of formed inflorescences and the number of leaves in case of gerberas. Results of conducted analyses indicate that Effective Microorganisms may be useful in the cultivation of roses and gerberas, due to their positive and at the same time significant effect on growth and yielding of these plants.

Keywords: Effective Microorganisms, rose, gerbera, development, yielding, nutrient content, substrate

Several popular species of ornamental plants, such as eg rose, gerbera or pelargonium, are grown in soilless culture systems, ie in substrates being completely isolated from the soil medium. The substrate used most commonly in container culture of these species is peat

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substrate. In the course of plant vegetation the organic matter it contains is mineralized, as a result of which process nutrients are released to the root medium of plants, at the simultaneous deterioration of air and water relations. Mineralization of organic matter is performed by soil microorganisms. Thanks to the intensification and targeting of microbiological processes taking place in the root medium, among other things as a result of enhanced nutrient availability, it is feasible to improve quantitative and qualitative yielding of plants.

One of the microbiological preparations used for this purpose is Effective Microorganisms (EM), being a commercial mixture of photosynthesizing bacteria, Actinomycetes, lactic acid bacteria, yeasts and fermenting fungi (*Apergillus* and *Penicilium*) [1-3]. The microbiological composition of the EM concentrate (population size in 1 cm^3 given in brackets): *Streptomyces albus* (10^5), *Propionibacterium freudenreichil* (10^5), *Streptococcus lactis* (10^5), *Aspergillus oryzae* (10^5), *Mucor hiemalis* (10^5), *Saccharomyces cerevisiae* (10^5) and *Candida utilis* (10^5) [4]. Moreover, EM also contain an unspecified amount of *Lactobacillus* sp., *Rhodopseudomonas* sp. and *Streptomyces griseus*. Effective Microorganisms have a positive effect on the decomposition of organic matter, limiting putrefaction, increasing nitrogen content in the root medium of plants (the role of nitrifying bacteria), phosphorus (the role of Actinomycetes), improving soil fertility and as a result contributing to growth and development of root systems of plants [3, 5, 6]. To date several studies have been conducted on the application of EM in growing of different plant species [7-13]. The use of EM, apart from the improvement of plant yielding, also results in increased counts of beneficial soil microorganisms and enhanced resistance of plants to pathogens [12, 13].

The aim of the presented studies was to assess the effect of the application of Effective Microorganisms on changes in contents of available forms of nutrients in the peat substrate, as well as growth, development and yielding of roses and gerberas grown to produce cut flowers.

Material and methods

The vegetation and laboratory experiments were conducted at the Experimental Station of the Department of the Faculty of Horticulture, the Poznan University of Life Sciences. Analyses were conducted on the effect of Effective Microorganisms (EM) on changes in contents of available nutrient forms in the peat substrate (macro- and microelements as well as sodium, substrate pH and salinity), as well as growth, development and yielding of roses (*Rosa x hybrida)* and gerberas (*Gerbera jamesonii*) grown for cut flowers.

In the experiments highmoor peat was used, coming from deposits in Latvia (Hartmann), with the following chemical composition (in $mg \cdot dm^{-3}$): $N\text{-}NH_4$ 28, $N\text{-}NO_3$ 7, P 37, K 11, Ca 107, Mg 21, $S\text{-}SO_4$ 10, Fe 50.2, Zn 1.3, Mn 1.3, Cu 0.4, B 0.43, Na 11, Cl 27, pH 3.86, EC 0.16 $mS \cdot cm^{-1}$ and bulk density of 460 $g \cdot dm^{-3}$. In order to optimize its reaction peat was limed based on the neutralization curve, applying 7.5 g dolomite$\cdot dm^{-3}$. After liming the chemical composition of peat was as follows (in $mg \cdot dm^{-3}$): $N\text{-}NH_4$ 35, $N\text{-}NO_3$ trace amounts, P 20, K 18, Ca 2045, Mg 164, $S\text{-}SO_4$ 25, Fe 19.8, Zn 1.8, Mn 2.7, Cu 0.4, B 0.50, Na 18, Cl 29, pH 6.31, EC 0.49 $mS \cdot cm^{-1}$. At 14 days after liming the following fertilizers and technical salts were applied: ammonium saltpetre (34% N), monobasic potassium phosphate (22.3% P, 28.2% K), magnesium sulfate (9.5% Mg,

12.7% S-SO_4), iron chelate Librel FeDP7 (7% Fe), manganese sulfate ($MnSO_4 \cdot H_2O$, 32.3% Mn), zinc sulfate ($ZnSO_4 \cdot 7H_2O$, 22.0% Zn), copper sulfate ($CuSO_4 \cdot 5H_2O$, 25.6% Cu) and borax ($Na_2B_4O_7 \cdot 10H_2O$, 11.3% B), providing the contents of nutrients conforming to the standard levels, recommended for growing the analyzed plant species, amounting in case of roses to (in $mg \cdot dm^{-3}$): N-NH_4 35, N-NO_3 220, P 220, K 260, Ca 2045, Mg 220, Fe 50, Zn 20, Mn 20, Cu 5, B 0.50, pH 6.0 - 6.5, while in case of gerberas it was (in $mg \cdot dm^{-3}$) N-NH_4 35, N-NO_3 230, P 220, K 250, Ca 2045, Mg 240, Fe 50, Zn 20, Mn 20, Cu 5, B 0.50 and pH 6.0÷6.5, respectively.

The experiments were established in the systematic design in 10 replications. The following application methods of Effective Microorganisms (EM): root and foliar applications (described in the text as EM-substrate and EM-spraying) were used. The control was not treated with EM. In case of the combination in which EM was applied to the substrate, its inoculation at a dose of 3 g preparation per 5 dm^3 substrate was performed 10 days before planting to a permanent location. In turn, plants were sprayed 3 times in the vegetation season in June at 10-day intervals, with spray liquid at a concentration of 0.1%. Both roses and gerberas were growing at a standard stocking of 3 plants$\cdot m^2$. Throughout the vegetation period cultivation measures for investigated species were performed following current recommendations.

During the vegetation period at 3- to 4-day intervals the following biometric measurements of plants were taken: the length of the peduncle, the number of cut flowers, diameters of the flower head, the number of inflorescences, the number of leaves, the number of removed leaves (for gerberas), the number and length of shoots, the number of cut flowers and their diameters (for roses).

Chemical analyses. Towards the end of the vegetation period substrate samples were collected in order to conduct chemical analyses for the contents of soluble nutrients and sodium. One mixed sample comprised 8-10 individual samples collected from each combination. Collected samples were analyzed chemically using the universal method according to Nowosielski [14]. Macroelements (N-NH_4, N-NO_3, P, K, Ca, Mg, S-SO_4), Cl and Na were extracted in 0.03 M CH_3COOH, at a substrate: extraction solution ratio of 1:10. After extraction the following parameters were determined: N-NH_4, N-NO_3 - by microdistillation according to Bremner as modified by Starck, P - by colorimetry with ammonium vanadium molybdate, K, Ca, Na - by photometry, Mg - by absorption atomic spectrometry (AAS, a Carl Zeiss Jena apparatus), S-SO_4 - by nephelometry with $BaCl_2$ and Cl - by nephelometry with $AgNO_3$. Microelements (Fe, Mn, Zn and Cu) were extracted from the substrate using Lindsay's solution, containing in 1 dm^3, 5 g EDTA (ethylenediaminetetraacetic acid), 9 cm^3 25% NH_4OH solution, 4 g citric acid and 2 g $Ca(CH_3COO)_2 \cdot 2H_2O$. Microelements were determined by AAS. Salinity was determined using conductometry, as electrolytic conductivity of the substrate (EC in $mS \cdot cm^{-1}$), while pH was determined by potentiometry (substrate:water = 1:2). Results of investigations were analyzed statistically and means were clustered using the Duncan test at the significance level $\alpha = 0.05$.

Results

Multi-faceted changes were observed in the contents of nutrients and sodium in the radical zone of plants (Table 1). In case of substrate inoculation with EM the assayed

contents of ammonium nitrogen, nitrate nitrogen, phosphorus, potassium and magnesium were markedly lower than in the control combination, at a similar content of sulfate sulfur (in case of gerberas) as well as phosphorus, calcium and magnesium (in case of roses). A reduction of nutrient contents may be the effect of their higher uptake by plants, stimulated by the formation of a higher number of flowers. Root application of Effective Microorganisms in case of both species resulted in a slight acidification of substrate. The highest contents of nitrate nitrogen, phosphorus, potassium, magnesium and sulfur were shown for substrates sampled from under gerbera plants, while those of nitrate nitrogen in case of roses, sprayed with Effective Microorganisms. The application of EM as a microbiological inoculum of the substrate resulted in a slight increase in its salinity.

Table 1

The effect of Effective Microorganisms on contents of ammonium nitrogen, nitrate nitrogen, phosphorus, potassium, calcium, magnesium, sulfate sulfur (in mg·dm^{-3}) as well as pH and salinity (EC) of substrate in growing of gerberas and roses

Combination	N-NH_4 [mg·dm^{-3}]	N-NO_3 [mg·dm^{-3}]	P-PO_4 [mg·dm^{-3}]	K [mg·dm^{-3}]	Ca [mg·dm^{-3}]	Mg [mg·dm^{-3}]	S-SO_4 [mg·dm^{-3}]	pH	EC [mS·cm^{-1}]
Gerbera									
Control	101.5b	150.5b	169.7a	134.4b	1649.2b	328.3a	454.6a	6.27b	0.09a
EM-substrate	52.5a	73.5a	157.2a	76.8a	1665.8b	287.0a	451.5a	5.57a	0.12ab
EM-spraying	31.5a	518.0c	396.8b	236.8c	1095.3a	689.8b	651.5b	5.46a	0.14b
Rose									
Control	35.0a	59.5a	262.5b	184.3a	2166.2b	412.7a	508.4a	5.97a	0.16a
EM-substrate	49.0b	61.3a	212.0a	155.0a	1989.7ab	361.6a	514.4a	5.69a	0.17a
EM-spraying	42.0a	280.0b	163.1a	365.8b	1626.3a	360.8a	487.5a	6.06a	0.36b

Table 2

The effect of Effective Microorganisms on contents of iron, manganese, zinc, copper, chlorides and sodium (in mg·dm^{-3}) in substrate in growing of gerberas and roses

Combination	Fe [mg · dm^{-3}]	Mn [mg · dm^{-3}]	Zn [mg · dm^{-3}]	Cu [mg · dm^{-3}]	Cl [mg · dm^{-3}]	Na [mg · dm^{-3}]
Gerbera						
Control	17.85a	5.52a	21.40a	2.15ab	87.1a	174.3a
EM-substrate	21.37a	7.90a	17.52a	1.88a	112.3a	179.6a
EM-spraying	26.29b	13.45b	23.11b	2.46b	197.9b	427.9b
Rose						
Control	27.03b	15.21b	27.83b	2.39ab	250.4a	273.5a
EM-substrate	36.25b	19.52c	28.92b	2.44b	257.3a	260.1a
EM-spraying	16.90a	6.74a	17.06a	1.92a	248.0a	230.8a

A marked increase was shown for contents of iron, manganese and chlorides in substrates both in the cultivation of gerberas and roses, in case of application of EM to the radical zone (Table 2). This may have resulted from a reduction of substrate pH, with which metal solubility increased, including that of metallic microelements. In case of gerberas the highest contents of iron, manganese, zinc, copper and chlorides were recorded for substrate sampled from under plants sprayed with Effective Microorganisms, while in roses at the application of these microorganisms to the root zone.

The application of Effective Microorganisms in the growing of **roses** for cut flowers had a positive effect on growth and development of plants. In the conducted analyses

a significant effect on the number of shoots was shown for EM supplied to the roots (an increase by 32.9%) (Fig. 1). Significant differences were found towards the end of the vegetation period (August) in terms of the length of formed shoots. The longest shoots were recorded for plants in the control combination (37.7 cm), while significantly shorter (33.5 cm) were observed in case of plants grown in the substrate inoculated with EM. This dependence was confirmed for the mean value from the analyzed combinations. A significant positive effect connected with the application of Effective Microorganisms to the radical zone was shown on quantitative yielding of roses. This measure, similarly as spraying of plants with EM, had a significant effect on an increase in diameters of rose flowers.

A positive effect of spraying plants with EM, as well as EM being supplied to the radical zone was shown on the number of formed inflorescences in **gerberas**, which is confirmed by the number of cut inflorescences in case of plants sprayed with EM (an increase by 31%), and for plants grown in the substrate inoculated with EM (an increase by 62.1%) in comparison with the control combination. The length of peduncles was similar in case of all tested combinations. No effect of the application of Effective Microorganisms was shown on the diameter of flower heads in the inflorescences.

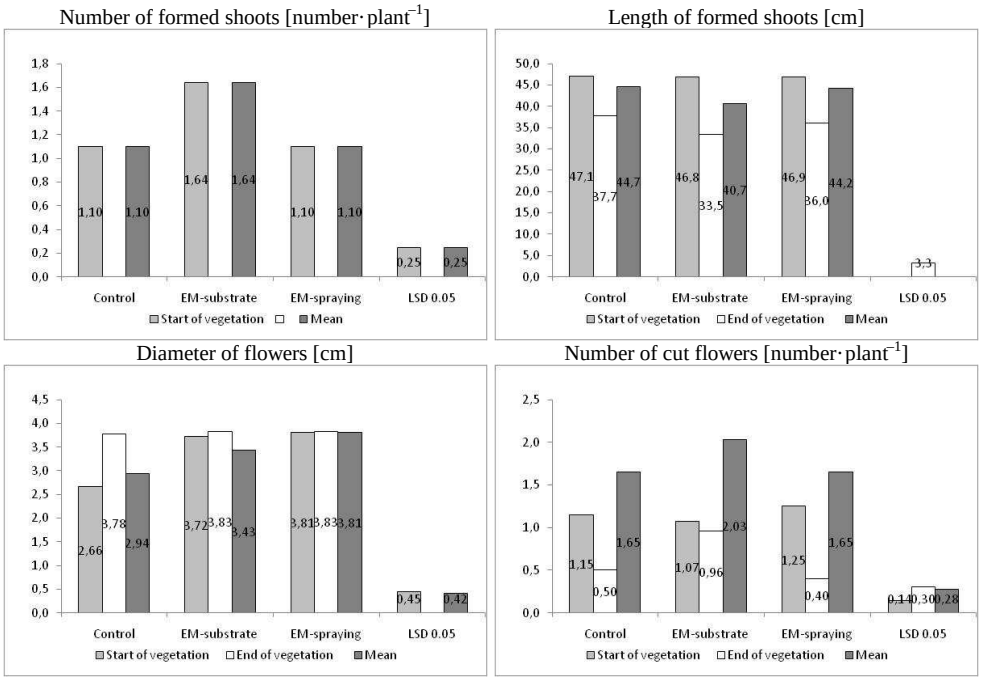

Fig. 1. The effect of Effective Microorganisms on selected biometric parameters of roses; number of formed shoots [number·plant^{-1}]; length of formed shoots [cm]; diameter of flowers [cm]; number of cut flowers [number·plant^{-1}]

Significantly the highest number of leaves was formed by plants sprayed with EM (30.5 leaves·plant^{-1}) in comparison with the control combination (25 leaves·plant^{-1}) and to

plants grown in the substrate inoculated with EM (27.3 leaves·plant^{-1}). Similar trends were recorded in case of the number of leaves removed as a result of cultivation measures.

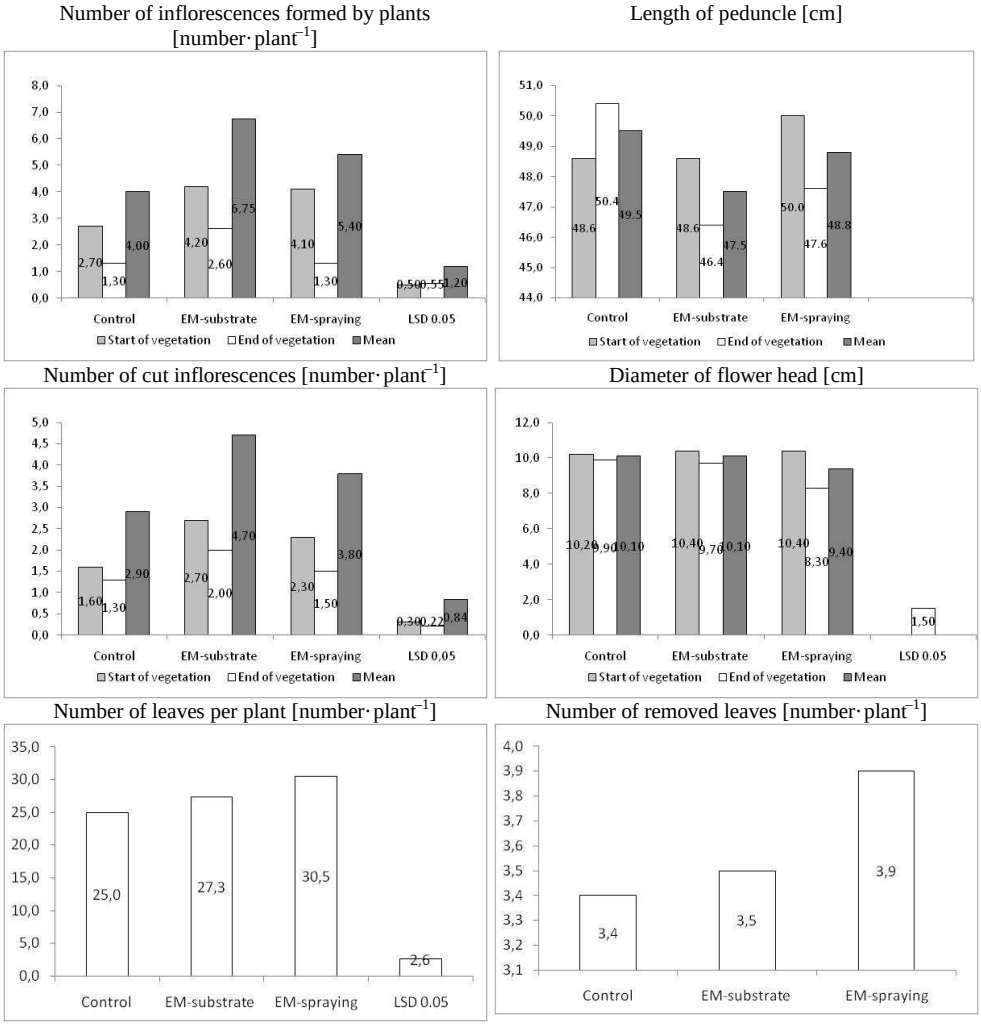

Fig. 2. The effect of Effective Microorganisms on selected biometric parameters of gerberas; number of inflorescences formed by plants [number·plant^{-1}]; length of peduncle [cm]; number of cut inflorescences [number·plant^{-1}]; diameter of flower head [cm]; number of leaves per plant [number·plant^{-1}]; number of removed leaves [number·plant^{-1}]

Discussion

Results of investigations conducted by the authors of this study are positively correlated with literature data. Studies conducted to date indicate an advantageous effect of the application of Effective Microorganisms on plant health, including the protection of

wheat against septoria leaf spot (*Septoria nodorum*) and leaf-spot (*Drechslera tritici-repentis*), winter rape against brown rust (*Puccinia recondita*) [13] and triticale against leaf diseases [15].

Numerous authors have confirmed the positive effect of EM on growth and yielding in different plant species. Effective Microorganisms have an advantageous effect on the uptake of nutrients by mung bean, they improve its yielding and the development of the root systems [16]. The application of a mixture of EM and molasses in growing of onion contributed to yielding of this vegetable increased by 29% [4]. In case of pea the increase in yields amounted to 31%, while in sweat corn it was 23%. Moreover, the effect of Effective Microorganisms was shown on yielding of cotton [11] and maize [17].

Studies also confirmed the positive effect of the application of Effective Microorganisms in case of orchard plants, as under their influence yielding of plum was improved [18]. Moreover, a positive effect was shown on growth, development and yielding of apple trees [12]. Trees treated with the above - mentioned microbiological preparation formed more shoots, which were markedly longer and thicker than in case of the control combination. The application of EM had a positive effect on leaf area in apple trees and chlorophyll content in leaves. Application of EM significantly modified nutrient content in leaves, improving nutrient status of plants in terms of nitrogen, phosphorus, potassium, iron, manganese and zinc. Similar changes in nutrient contents in leaves as a result of the application of Effective Microorganisms were also recorded in cotton growing [11].

Conclusions

1. A significant effect was found for the application of Effective Microorganisms, both in the radical zone and foliar applications, on changes in contents of available nutrients in peat substrate.
2. A trend was observed for substrate pH to decrease in case of the combinations with applied Effective Microorganisms in relation to the control combination.
3. Significantly the highest yield of flowers in case of both analyzed species was recorded at the application of Effective Microorganisms inoculum to the radical zone. This method of EM application had a positive effect also on the number of formed shoots and the diameter of flowers (in case of roses) and the number of formed inflorescences (in case of gerberas).
4. Spraying of plants with EM had a positive effect on the diameter of flowers in roses and on the number of formed inflorescences and leaves in case of gerberas.
5. Results of conducted analyses indicate that Effective Microorganisms may be useful in the cultivation of roses and gerberas due to their positive and at the same time significant effect on growth and yielding of these plants.

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WPŁYW EFEKTYWNYCH MIKROORGANIZMÓW (EM) NA ZAWARTOŚĆ SKŁADNIKÓW POKARMOWYCH W PODŁOŻU ORAZ ROZWÓJ I PLONOWANIE RÓŻY (*Rosa x hybrida)* I GERBERY (G*erbera jamesonii)*

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Abstrakt: Celem przeprowadzonych badań była ocena wpływu stosowania Efektywnych Mikroorganizmów (EM) na zmiany zawartości dostępnych i łatwo rozpuszczalnych form składników pokarmowych w substracie torfowym, a także wzrost, rozwój i plonowanie uprawianych w nim róży (*Rosa x hybrida)* i gerbery (*Gerbera jamesonii*). Efektywne Mikroorganizmy zastosowano przedwegetacyjnie w formie szczepionki w dawce 3 g preparatu·5 dm^{-3} podłoża oraz dolistnie w formie opryskiwania roślin (3-krotnie roztworem wodnym o stężeniu 0,1%). W przeprowadzonych badaniach stwierdzono wpływ EM, aplikowanych zarówno w formie dokorzeniowej, jak i dolistnej na zmiany zawartości dostępnych form składników pokarmowych w podłożu, przy jednoczesnym zakwaszeniu podłoża, w stosunku do kombinacji kontrolnej. Istotnie największy plon kwiatów, w przypadku obydwu badanych gatunków, uzyskano przy dokorzeniowym stosowaniu szczepionki EM. Wpływała ona

pozytywnie na ilość wytwarzanych pędów oraz średnicę kwiatów (w przypadku róży) oraz liczbę wytworzonych kwiatostanów (w przypadku gerbery). Aplikowanie dolistne Efektywnych Mikroorganizmów oddziaływało pozytywnie na średnicę kwiatów róży oraz liczbę wytworzonych kwiatostanów oraz liści w przypadku gerbery. Wyniki przeprowadzonych badań wskazują, iż Efektywne Mikroorganizmy mogą być przydatne w uprawie róży i gerbery ze względu na ich pozytywny i zarazem duży wpływ na wzrost i plonowanie tych roślin.

Słowa kluczowe: Efektywne Mikroorganizmy, róża, gerbera, rozwój, plonowanie, zawartość składników pokarmowych, podłoże