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THE EFFECT OF BIOPREPARATIONS ON ROOT GROWTH AND MICROBIOL ACTIVITY IN THE RHIZOSPHERE OF APPLE TREES

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Abstract. The aim of the study was to determine the effect of various biopreparations on the growth of the apple root system, the number of spores of AMF, the total number of bacteria and microscopic fungi in the rhizosphere soil, and the degree of mycorrhizal association in the roots of two apple tree cultivars. The experiment was established in the spring of 2009 in the Experimental Orchard of the Institute of Horticulture in Dąbrowice. The research objects were one-year-old maidens of the apple cultivars 'Topaz' and 'Ariva' grafted on M26 rootstock. The trees were treated with the following biopreparations: control, control NPK (standard NPK fertilization), manure, Micosat F + manure, Humus UP, Humus Active + Aktywit PM, BioFeed Amin + manure, BioFeed Quality + manure, Tytanit + manure, Vinassa + manure, Florovit Eko, and Florovit Pro Natura. Treatment of 'Topaz' and 'Ariva' apple trees with the biopreparations Micosat F, Humus UP, Humus Active + Aktywit PM, BioFeed Amin, Vinassa, Florovit Eko and Florovit Pro Natura produced positive effects on the growth of apple roots and their mycorrhizal frequency, and the size of the populations of microorganisms in the rhizosphere soil.

Key words: bioproducts, filamentous fungi, AM fungi, rhizosphere bacteria, *Malus* Mill., number of spores

INTRODUCTION

The current principle of balanced fertilization in modern agriculture ensures an optimum supply of nutrients to crop plants and maintenance of soils at adequate fertility levels. Such fertilization is provided by, among others, the use of organo-mineral fertilizers and proper agrotechnical practices [Sas Paszt et al. 2011]. This also applies to organic nursery production of fruit plants [Bielicki et al. 2002]. However, the rules adopted for growing plants organically do not allow the use of traditional means for improving soil fertility and condition [Grzyb et al. 2013]. Limited availability of natural

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fertilizers, i.e. manure, bedding materials, compost, as well as bioproducts of organic origin (plant extracts enriched with beneficial microorganisms) is the reason why the interest in and demand for such products are increasing [Malusa et al. 2007]. Our knowledge of the mechanisms of action and methods of application of bioproducts in different environmental conditions is insufficient. For this reason, intense research work has been conducted in this field [Sas Paszt and Żurawicz 2005, Skupień and Oszmański 2007, Meszka and Bielenin 2009]. There is a need for better utilization of the organic matter contained in organic bedding materials and in brown coal as plant cultivation means which are safe, effective and environmentally friendly, and which do not endanger human health [Sas Paszt et al. 2011]. Increasing soil organic matter content and restoring the dominance of beneficial soil microflora are ways to increase the mechanical stability of soil, improve its sorption capacity, and ensure better nutrient uptake by plants [Zachariakis et al. 2001, Lizarazo et al. 2005]. Introduction of organic microbially-enriched bioproducts into horticultural and agricultural practice will help to reduce the use of mineral fertilizers, and thus to protect the natural environment and human health. Normal development of plants in all natural communities as well as in orchards and berry crop plantations is determined by the proper development of the root system and the activity of the processes occurring in the rhizosphere, including those involving symbiotic mycorrhizal fungi and rhizosphere bacteria [Sas Paszt and Żurawicz 2005, Sas Paszt et al. 2011].

The aim of the study was to assess the effects of various bioproducts on root growth characteristics, the number of spores of arbuscular mycorrhizal fungi, the total number of bacteria in the rhizosphere soil, and the degree of mycorrhizal association in the roots of apple trees of the cultivars 'Topaz' and 'Ariva'.

MATERIALS AND METHODS

One-year-old maiden trees of the apple cultivars 'Topaz' and 'Ariva' grafted on M26 rootstock were planted in the spring of 2009 in the Experimental Orchard of the Institute of Horticulture in Dąbrowice. The experiment was conducted in 4 replications (with 3 trees per replication). Spacing between the trees was 4 m × 2.5 m, with a 2.5-meter isolation strip between the plots. The experiment included control trees (not fertilized with NPK, nor with any bioproducts), trees fertilized in the spring of each year with NPK (at a rate of 70 kg $N \cdot ha^{-1}$ as NH_4NO_3, 60 kg $P \cdot ha^{-1}$ as P_2O_5, 120 kg $K_2O \cdot ha^{-1}$ as K_2SO_4), and manure (at 1500 $kg \cdot ha^{-1}$). Mycorrhizal preparations were applied at two times: first Micosat F12 was applied to the root zone at 100 $kg \cdot ha^{-1}$, and later Micosat F MS 200 was applied to the root zone at 10 $kg \cdot ha^{-1}$). Preparation Humus UP at a concentration of 2% was applied to the soil at 20 $l \cdot ha^{-1}$. Humus Active at a conc. of 2% was applied to the soil at 20 $l \cdot ha^{-1}$ + Aktywit PM at a conc. of 1% also to the soil at 10 $l \cdot ha^{-1}$. Biostimulator BioFeed Amin at a conc. of 0.5% was applied to the soil at 5 $l \cdot ha^{-1}$, and the preparation BioFeed Quality at a conc. of 0.5% also to the soil at 5 $l \cdot ha^{-1}$. Tytanit as a 0.05% spray solution was applied to the leaves at 0.5 $l \cdot ha^{-1}$. Vinassa was applied to the soil at a conc. of 0.5% at 5 $l \cdot ha^{-1}$. Biofertilizer Florovit Eko was applied to the soil at 150 $g \cdot m^{-2}$ – 1500 $kg \cdot ha^{-1}$, and Florovit Pro Natura was applied to the soil at 150 $g \cdot m^{-2}$ – 1500 $kg \cdot ha^{-1}$).

The following combinations were used in the experiment in a randomized block design:

1. **Control** (non fertilized with NPK, without application of bioproducts, nutrient levels (in mg per 100 g of soil): P – 10.3, K – 11.0, Mg – 8.79, B – 5.53, Cu – 6.98, Fe – 870, Mn – 121, Zn – 4.78).
2. **Control NPK** (NPK fertilization at doses of 70 kg N·ha^{-1}, 60 kg P·ha^{-1}, 120 kg K_2O·ha^{-1}).
3. 'Fertigo' granulated **manure** (product of the Dutch company Ferm-O-Feed).
4. **Micosat F** (Micosat F12 and Micosat F MS 200 – preparations of the Italian company CCS Aosta, containing a microbial inoculum with mycorrhizal fungi and beneficial bacterial strains).
5. **Humus UP** (product of Ekodarpol, an extract produced on the basis of organic manure processed by Californian earthworms).
6. **Humus Active + Aktywit PM** (products of Ekodarpol, Humus Active – an extract from organic manure processed by Californian earthworms, Aktywit PM – an activator of microbial life produced on the basis of molasses).
7. **BioFeed Amin** (product of Koppert, an extract containing plant amino acids).
8. **BioFeed Quality** (product of Koppert, a seaweed extract containing humic and fulvic acids).
9. **Tytanit** (mineral product of Intermag, contains titanium).
10. **Vinassa** (produced by Mazowiecka Fabryka Drożdży Józefów, a waste from the production of baker's yeast).
11. **Florovit Eko** (product of Inco-Veritas, contains lignite, potassium sulphate, phosphate, dolomite, bentonite and molasses).
12. **Florovit Pro Natura** (product of Inco-Veritas, contains lignite, urea, potassium sulphate, ammonium phosphate, dolomite and molasses).

In addition to the biopreparations Micosat F, BioFeed Amin, BioFeed Quality, Tytanit and Vinassa, fertilization with manure was applied in the amount of 750 kg per ha (0.5 dose). The experiment lasted until 2013.

Determination of root growth characteristics. To determine the growth characteristics of apple tree roots, root samples were collected in July 2013. Roots together with soil were collected using a 0.5 l cork borer from an area a ten centimeters away from the trunk of the apple trees. The sample of the root system obtained in this way was placed on a sieve and cleaned by washing the soil out and drying. Root growth characteristics were determined by scanning the root sample with an EPSON EXPRESSION 10 000 XL root scanner powered by WinRhizo software [Arsenault et al. 1995]. The following parameters were determined: root length, root surface area, root diameter, root volume, and the number of root tips (tabs 1 and 2).

Microbiological analysis of growth substrates. In July 2013, rhizosfere soil samples (50 g each) were collected from the field experiment for analysis of the size of microbial populations. Each soil sample was thoroughly mixed and 5 g portions were suspended in 45 g of sterile distilled water. The suspensions were stirred for 45 min on a shaker (at 160 swings per min), and then used to prepare a series of ten-fold dilutions (10^{-2}, 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6}), which were afterwards plated on suitable growth media.

Table 1. Effect of biopreparations on root growth characteristics of apple cultivar ‘Topaz’

Treatment	Root length ($cm \cdot plant^{-1}$)		Root surface area ($cm \cdot plant^{-1}$)		Root diameter ($mm \cdot plant^{-1}$)	
	‘Topaz’	‘Ariva’	‘Topaz’	‘Ariva’	‘Topaz’	‘Ariva’
Control	143.0 a	178.7 a	128.4 b	73.5 b	2.86 d	1.31 e
Control NPK	199.0 ab	181.0 a	74.9 a	170.8 d	1.20 c	3.00 f
Manure	540.4 e	495.0 d	152.4 c	99.8 b	0.90 b	0.64 ab
Micosat + Manure	1652.2 f	304.2 c	307.9 d	127.9 c	0.59 b	1.34 e
Humus UP	359.7 d	562.3 f	100.9 ab	123.4 c	0.89 b	0.70 c
Humus Active + Aktywit PM	1051.0 ef	562.1 f	152.5 c	106.9 bc	0.46 a	0.61 ab
BF Quality + Manure	219.5 b	543.1 e	83.5 a	99.1 bc	1.21 c	0.58 a
BF Amin + Manure	310.7 d	555.9 ef	125.8 b	180.5 d	1.29 c	1.03 de
Manure + Tytanit	245.8 b	370.5 c	79.1 a	86.6 b	1.02 bc	0.75 c
Vinassa + Manure	296.4 c	612.3 g	97.5 ab	117.0 c	1.05 bc	0.61 ab
Florovit Pro Natura	297.8 c	204.2 b	67.4 a	55.4 a	0.72 b	0.86 d
Florovit Eko	362.1 d	293.6 bc	85.4 a	77.8 b	0.75b	0.84 d

Means in columns marked with the same letter do not differ significantly at p = 0.05 according to Tukey’s multiple test
* – the measurements shown in the table were made in July 2013. Field experiment, Dąbrowice 2009–2013

Table 2. Effect of biopreparations on root growth characteristics of apple cultivar ‘Ariva’

Treatment	Root volume ($cm \cdot plant^{-1}$)		Number of root tips (per plant)	
	‘Topaz’	‘Ariva’	‘Topaz’	‘Ariva’
Control	9.17 e	2.41 c	261 a	509 b
Control NPK	2.24 b	12.82 e	517 bc	445 a
Manure	3.42 c	1.60 b	1325 e	1304 c
Micosat + Manure	4.57 d	4.28 d	3591 f	764 bc
Humus UP	2.25 b	2.16 c	931 d	1452 c
Humus Active + Aktywit PM	1.76 ab	1.62 b	3722 f	1493 c
BF Quality + Manure	2.53 bc	1.44 ab	455 b	1632 d
BF Amin + Manure	4.05 d	4.67 d	1050 e	1350 c
Manure + Tytanit	2.03 b	1.61 b	570 bc	1195 c
Vinassa + Manure	2.55 bc	1.80 b	789 c	1682 d
Florovit Pro Natura	1.21 a	1.20 a	880 cd	761 bc
Florovit Eko	1.60 ab	1.64 b	898 cd	797 bc

* – see Table 1

To estimate the total number of bacteria, 100 μl portions of the soil suspensions were spread with a glass spatula on plates containing the medium Tryptone Soy Agar 20% (TSA) [Vieira and Nahas 2005]. To estimate the total number of spore-producing bacteria, the soil suspension being tested was first pre-incubated at 80°C for 30 min and then 100 μl portions of it were spread with a glass spatula on plates containing the TSA medium. The total number of filamentous fungi was estimated by plating 100 μl portions of the suspension onto plates containing Rose Bengal Chloramphenicol Agar medium [Chang et al. 2007].

The plates with the diluted soil solution plated on the TSA medium were incubated at 28°C for 7 days, and the plates with Rose Bengal Chloramphenicol Agar medium at 25°C for 5–7 days. When calculating the number of bacteria, only those plates on which the number of colonies did not exceed 30–300 were taken into account. In the counting of fungi, plates containing 20–100 colonies were taken into account. The results were converted to colony-forming units per 1 g dry weight of the medium (cfu $\cdot$ g^{-1}), (tab. 4).

Determination of the number of spores of arbuscular mycorrhizal fungi in rhizosphere soil. The rhizosphere soil samples taken from the root zone of apple trees in July 2013 were used for further analyses by weighing out 100 g portions. The portions were then placed in containers and made up to 1 l with distilled water. The suspensions were shaken for about 1 h and then placed in a refrigerator (for 24 h, at 4°C). After storage, each soil solution was filtered through a column of sieves (0.5 mm, 0.125 mm, 0.0063 mm, and 0.0045 mm), and then the fractions of soil remaining on the sieves were rinsed into Petri dishes (120 mm) with distilled water, to which sucrose (5 g per dish) was subsequently added. The resulting specimens were examined with a Nikon SMZ 800 stereoscopic microscope, under which the spores of AMF present were fished out and counted [Błaszkowski 2003, 2008], (tab. 3).

Assessment of the degree of colonization of roots by arbuscular mycorrhizal fungi. Fragments of the roots of apple trees in the samples collected in July 2013 (10 ml portions from each replication) were stained by the method developed at the Rhizosphere Laboratory of the Agrotechnical Department of the Institute of Horticulture [Derkowska et al. 2013]. The roots to be examined were prepared in the following steps:

1. Maceration of root tissues with 10% sodium hydroxide (NaOH) at 65°C for up to 30 min,
2. Washing out roots from the NaOH solution with water – 5 min,
3. Acidification of roots with 10% lactic acid – 10 min,
4. Staining roots with carbol fuchsin for up to 10 min,
5. Rinsing roots with water to remove excess dye – 10 min,
6. Preservation and storage of roots in glycerol.

The root samples prepared in this way were used to make microscopic specimens by selecting each time 30 root fragments about 1 cm long, which were laid out parallel to one another on a microscope slide containing glycerin and crushed with a cover glass. These histological specimens were examined using a Nikon 50i microscope (with 20×, 40×, 60×, 100× objectives), and photographic records were made of the mycorrhizal structures observed. The degree of root colonization by AMF was assessed by the method of Trouvelot [1986]. The results were used to calculate mycorrhizal frequency

(F%), using a computer program MYCOCALC, available from the website: http://www2.dijon.inra.fr/mychintec/Mycocalc-prg/download.html (tab. 3).

Statistical analysis. The results were statistically analyzed using univariate analysis of variance in the system of random blocks. Multiple comparisons of the means for the combinations were performed with Tukey's test at a significance level of α = 0.05 using STATISTICA v.10 software package [StatSoft, Inc. 2011].

RESULTS

The results of the field experiment revealed positive effects of the applied bioproducts on root growth characteristics and the degree of arbuscular mycorrhizal association in the roots of apple trees of the cultivars 'Topaz' and 'Ariva'. The applied bioproducts contributed to a significant increase in the number of spores of AMF and the total number of soil bacteria.

The biopreparations: Micosat F, Humus Active + Aktywit PM, and Vinassa produced positive effects on the growth of the root system of apple trees compared to control plants fertilized with NPK (tabs 1, 2). Application of the preparations Humus Active + Aktywit PM increased eight-fold the length of roots and quadrupled the surface area of roots, whereas inoculation of the roots of 'Topaz' apple trees with the preparation Micosat F resulted in a seven-fold increase in the number of root tips. The preparation Vinassa increased three-fold the length of roots and the number of root tips in 'Ariva' trees. The cultivar 'Topaz' graft on M26 rootstock was characterized by longer roots which had a larger diameter, volume, surface area and the number of root tips as compared to the roots of 'Ariva' apple trees (tabs 1, 2).

Table 3. Effect of biopreparations on mycorrhizal frequency (F%) in the roots and the number of spores in the rhizosphere soil of apple cultivars 'Topaz' and 'Ariva'

Treatment	Mycorrhizal frequency (F%)		Number of spores	
	'Topaz', %	'Ariva', %	'Topaz'	'Ariva'
Control	12.22 ab	18.89 ab	29 ab	29 b
Control NPK	6.67 a	13.33 a	21 a	19 a
Manure	18.89 bc	48.89 g	41 cd	43 d
Micosat + Manure	53.33 g	64.78 h	23 a	27 b
Humus UP	43.33 f	61.11 h	24 a	41cd
Humus Active + Aktywit PM	31.11 de	30.0 de	58 e	43 d
BF Quality + Manure	35.56 ef	27.78 cd	45 d	56 e
BF Amin + Manure	25.56 cd	24.44 bcd	31b	79 f
Manure + Tytanit	18.89 bc	24.44 bcd	24 a	50 e
Vinassa + Manure	22.22 c	21.11 bc	33 b	32 c
Florovit Pro Natura	35.56 ef	35.56 ef	59 e	21 ab
Florovit Eko	27.78 e	40.0 f	37 bc	22 ab

* – see Table 1

Table 4. Effect of biopreparations on the total number of bacteria and filamentous fungi in the rhizosphere soil of apple cultivars 'Topaz' and 'Ariva'

Treatment	'Topaz'		'Ariva'	
	total number of bacteria × 10^6 cfu · g^{-1}	total number of fungi × 10^4 cfu · g^{-1}	total number of bacteria × 10^6 cfu · g^{-1}	total number of fungi × 10^4 cfu · g^{-1}
Control	62.82 a	50.66 b	100.35 bc	43.40 ab
Control NPK	99.04 ab	49.86 ab	84.75 b	72.89 b
Manure	73.10 ab	33.13 a	163.76 c	57.65 b
Micosat + Manure	256.40 d	51.29 b	53.11 a	28.33 a
Humus UP	220.90 d	23.49 a	477.90 e	42.90 ab
Humus Active + Aktywit PM	65.86 a	51.34 b	88.61 b	98.29 bc
BF Quality + Manure	110.01 b	81.44 c	341.00 d	69.58 b
BF Amin + Manure	179.89 c	66.13 b	303.40 d	68.51 b
Manure + Tytanit	134.15 b	39.78 a	336.30 d	100.87 c
Vinassa + Manure	356.60 e	39.24 a	129.97 c	63.61 b
Florovit Pro Natura	408.20 f	60.73 b	145.55 c	51.57 b
Florovit Eko	120.24 b	48.30 ab	322.90 c	56.58 b

* – see Table 1

Micosat F and Humus UP contributed to the increase in mycorrhizal frequency, and the preparations Micosat F, BioFeed Amin and Florovit Pro Natura positively affected the number of spores of AMF obtained from the root zone of 'Topaz' and 'Ariva' apple trees (tab. 3). The use of the mycorrhizal inoculum in the experiment resulted in an eight-fold increase in mycorrhizal frequency in the roots of the treated apple cultivars. The results of the examination of microscopic specimens of roots showed that the roots of the cultivar 'Ariva' were more frequently colonized by AMF than the roots of the cultivar 'Topaz'. The bioproducts Micosat F, BioFeed Amin and Florovit Pro Natura increased the number of spores in the soil by as much as four times. A larger number of spores of AMF was obtained from the rhizosphere soil of the cultivar 'Ariva' than from the rhizosphere soil of the cultivar 'Topaz'. The applied biopreparations, i.e. Humus UP, BioFeed Amin, Florovit Eko and Florovit Pro Natura, increased the total number of bacteria and filamentous fungi in the rhizosphere soil compared to the soil under mineral (NPK) fertilization (tab. 4). The total number of bacteria after the application of the products was more than four times as high, and the total number of filamentous fungi was twice as high as in the soil from under the control trees fertilized with NPK. The rhizosphere soil collected from under 'Ariva' apple trees contained a higher total number of bacteria and a greater total number of filamentous fungi in comparison with the soil collected from the root zone of 'Topaz' trees.

The results of this field experiment demonstrate positive effects of the treatments with Micosat F, Humus Active + Aktywit PM, Vinassa, BioFeed Amin and Florovit Pro

Natura, and the use of these preparations in the field cultivation of the apple cultivars 'Topaz' and 'Ariva' favourably affected the examined characteristics of roots and the rhizosphere soil.

DISCUSSION

Our results coincide with the results of other authors. Grzyb et al. [2012] studied the effects of bioproducts on the growth of M26 apple rootstocks. They found that products such as Micosat and Vinassa, regardless of the location of the experiment or the type of soil, improved the quality of the rootstocks, and also the vegetative growth and the ability to produce lateral shoots by maiden trees in the nursery. The positive influence of fertilization with the biofertilizer Vinassa on the growth of the root system had been demonstrated in the work of Chelariu et al. [2009] and Chelariu and Ionel [2005]. Sumorok et al. [2011] observed in a field experiment that inoculation of roots with a mycorrhizal inoculum resulted in an increase in the degree of mycorrhizal association in the roots of apple trees of the cultivar 'Gold Milenium'. Purin et al. [2006] investigated the activity and diversity of AMF in organic apple orchards and those cultivated by the conventional method. They demonstrated that mycorrhizal frequency in the roots of trees growing in an organic orchard was higher than in the roots of trees grown by the conventional method. The positive effects of inoculation of the roots of apple trees had also been reported by Forge et al. [2001], who studied the effects of mycorrhization of the roots of *Malus domestica* Borkh. apple trees with an inoculum comprising six species of AM fungi (*Glomus aggregatum*, *G. clarum*, *G. etunicatum*, *G. intraradices*, *G. mosseae* and *G. versiforme*). They observed that colonization of the inoculated roots of apple trees by AMF was ten times higher than in the roots of control plants. The results obtained in our experiment are similar to the results of the studies conducted by the above authors and confirm the positive impact of bioproducts on the degree of mycorrhizal association in apple roots. Observations made by Purin et al. [2006], who studied the number of spores AMF in the soil sampled from under apple trees in organic and conventional orchards, showed that in summer the number of spores in the soil collected from an organic orchard was higher in relation to the number of spores in the soil extracted from a conventional orchard. Canbolat et al. [2006] studied the effects of plant growth promoting bacteria (PGPB) and soil compaction on the microflora in the rhizosphere, and on the growth and mineral nutrition status of barley (*Hordeum vulgare*) seedlings. Inoculation with the strain *B.* M-13 more than doubled the total number of bacteria and fungi in relation to the control plants. Gomonova et al. [2007] studied the effects of long-term use of different soil fertilization systems. They demonstrated that the use of manure (preceded in previous years by fertilization with lime) increased more than three times the total number of bacteria compared to the standard NPK fertilization. The authors of this work obtained convergent results, confirming the positive impact of biopreparations on the growth of microorganisms within the root zone and in the rhizosphere soil. The beneficial effects of the applied bioproducts has also been confirmed by Grzyb et al. [2014], who studied the after-effects of the same biopreparations on the vegetative growth and yielding of apple trees. They observed that Humus

Active + Aktywit PM, BioFeed Quality, BioFeed Amin, Vinassa and Tytanit stimulated the growth and yielding of apple trees of the cultivars 'Topaz' and 'Ariva'.

The proven beneficial effects of the tested bioproducts on the growth and yielding of fruit trees [Grzyb et al. 2012, 2014] will contribute to their implementation in fruit-growing practice, reduction in the use of chemical means of production, and consequently to the protection of the natural environment and human health.

CONCLUSIONS

Compared to the NPK-treated control, the applied biopreparations (Micosat F, Humus UP, Humus Active + Aktywit PM, BioFeed Amin, Vinassa, Florovit Eko and Florovit Pro Natura) produced positive effects on root growth, the degree of arbuscular mycorrhizal association, the number of spores of arbuscular mycorrhizal fungi (Micosat F, Humus UP and Florovit Pro Natura), and on the total number of bacteria and fungi in the rhizosphere of the treated apple trees.

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WPŁYW BIOPREPARATÓW NA WZROST SYSTEMU KORZENIOWEGO ORAZ EFEKTYWNOŚĆ MIKROBIOLOGII RYZOSFERY JABŁONI

Streszczenie. Celem badań było określenie wpływu różnych biopreparatów na wzrost systemu korzeniowego, liczbę zarodników grzybów mikoryzowych, ogólną liczbę bakterii i grzybów mikroskopowych w glebie rizosferowej oraz stopień asocjacji mikoryzowej w korzeniach dwóch odmian jabłoni. Doświadczenie założono wiosną 2009 r. w Sadzie Doświadczalnym Instytutu Ogrodnictwa w Dąbrowicach. Obiektem badań były jednoroczne okulanty jabłoni odmian Topaz i Ariva szczepione na podkładce M26. Rośliny traktowano następującymi biopreparatami: kontrola, kontrola NPK, obornik, Micosat F + obornik, Humus UP, Humus Active + Aktywit PM, BioFeed Amin + obornik, BioFeed Quality + obornik, Tytanit + obornik, Vinassa + obornik, Florovit Eco oraz preparat Florovit Pro Nature. Traktowanie drzew jabłoni 'Topaz' i 'Ariva' biopreparatami Micosat F, Humus UP, Humus Active + Aktywit PM, BioFeed Amin, Vinassa, Florovit Eco oraz Florovit Pro Nature wpłynęło korzystnie na wzrost korzeni, stopień frekwencji mikoryzowej i wielkość populacji mikroorganizmów w glebie rizosferowej.

Słowa kluczowe: bioprodukty, grzyby strzępkowe, grzyby AMF, bakterie rizosferowe, jabłoń

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