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Effect of some bioproducts on the growth, yield and fruit quality of apple trees

Walid Fediala Abd El-Gleel Mosa[1, 2*], Lidia Sas Paszt[1], Mateusz Frąc[1], Paweł Trzciński[1], Michał Przybył[1], Waldemar Treder[1], Krzysztof Klamkowski[1]

[1]*Research Institute of Horticulture, Skierniewice, Poland*

[2]*Plant Production Department, Faculty of Agriculture (Saba Basha), Alexandria University, Alexandria, Egypt*

**Corresponding author: walidbreeder@yahoo.com*

Abstract

Mosa W.F.A.E-G., Sas Paszt L., Frąc M., Trzciński P., Przybył M., Treder W., Klamkowski K. (2018): Effect of some bioproducts on the growth, yield and fruit quality of apple trees. Hort. Sci. (Prague), 45: 111–118.

These experiments began with the planting of maiden apple trees of cv. 'Topaz' in 2011. In springtime in 2012–2016, chemical fertilisation (NPK) and various natural bioproducts, namely Fertigo, Micosat, Humus UP, Humus Active + Aktywit PM, Aktywit PM, BioFeed Quality, BioFeed Amin, Vinassa, Florovit Natura and Florovit Eko were applied to the apple trees alone or enriched with *Pantoea* sp., *Pseudomonas fluorescens, Klebsiella oxytoca* and *Rhizobium* bacterial species. Growth, yield and fruit quality parameters were then evaluated. Our results reveal that the trunk cross-sectional area was greatly increased by the addition of the beneficial bacteria to Humus UP, Yeast, Vinassa and Micosat, as compared to NPK chemical fertilisation. Yeast, Vinassa, Micosat, Humus UP and BioFeed Amin enriched with the beneficial bacteria significantly increased fruit weight in kg and the number of fruits compared to the NPK control in 2015 and 2016.

Keywords: vinassa; manure; bacteria; humus up; growth; yield

Mineral fertilisers commonly used in agricultural production not only have harmful effects on the environment, but can also alter the composition of fruits, vegetables and root crops. They also decrease the amounts of vitamins, minerals and other useful compounds and may persist as harmful residues in food (Bogatyre 2000). Vessey (2003) defined a bio-fertiliser as a substance which contains living microorganisms which, when applied to seeds, plant surfaces or soil, colonise the rhizosphere or the interior of the plant and promote growth by increasing the supply or availability of primary nutrients to the host plant. The same author added that the development and application of sustainable agricultural techniques and bio-fertilisation are vital for alleviating environmental pollution. Additionally, the use of bio-fertilisers can improve productivity per unit area in a relatively short time, promote the consumption of smaller amounts of energy, mitigate contamination of soil and water and increase soil fertility (Chirinos et al. 2006). Von-Bennewitz and Hlusek (2006) reported that bio-fertilisation is beneficial in stimulating the growth and fruiting of pome and stone fruits. In addition, bio-fertilisers are low-cost, effective and renewable sources of plant nutrients that can be used as supplements to chemical fertilisers (Boraste et al. 2009). The present study was conducted to compare the impact of min-

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eral fertilisation (NPK) with the impact of selected bio-fertilisers, used alone or in combination with beneficial bacteria, on the growth, yield and fruit quality of apple trees cv. 'Topaz'.

MATERIAL AND METHODS

The experiment was initiated in the autumn of 2011. Maiden apple trees cv. 'Topaz' were planted at a spacing of 2 m in a row and 4 m between rows, with a total of approximately 1,250 trees/ha. The experiment consisted of twenty-two treatments, and each treatment was repeated twice with four trees/replicates. In the spring of 2012–2016, NPK, Fertigo, Micosat, Yeast, Florovit Natura and Florovit Eko (PK) were added to the soil on two occasions: at the end of April and in the middle of June. Humus UP, Humus Active + Aktywit PM, BioFeed Quality, BioFeed Amin and Vinassa were applied to the soil at the end of May and then again in the middle of July in the period 2012–2016.

Pi22C *Pantoea* sp. at 0.9×10^9 CFU/ml, Ps49A *Pseudomonas fluorescens* at 0.5×10^9 CFU/ml, NAzot2 *Klebsiella oxytoca* at 2.8×10^9 CFU/ml and N65AB *Rhizobium* sp. at 0.3×10^9 CFU/ml were bred in a nutrient broth which was composed of 5 g peptone, 3 g beef extract, 1,000 ml distilled water supplemented with glucose (1 g/l) and incubated at 28°C on a horizontal shaker at 100 RPM (revolutions per minute) for 48 hours. The bacterial biomass was separated from the nutrient broth in a centrifuge at 6,000 rpm and then suspended in sterile tap water. These strains were added together in a mixture of the three species to the soil using an irrigation system on two occasions: in May and in July in the period 2012–2016.

The following fertilisation combinations were used in the experimental orchard in Dąbrowice in the period 2012–2016.

1. Chemical NPK (control): 17.64 g/m^2 NH_4NO_3, 6.52 g/m^2 triple super phosphate and 16.0 g/m^2 K_2SO_4. It was applied as 60 kg/ha N, 30 kg/ha P and 80 kg/ha K.

2. Fertigo (manure) (Ferm-O-Feed, The Netherlands): Granulated bovine manure containing 55% C, 1% N, 0.3% P, 1% K and microelements. The product was applied at 150 g/m^2 (1.5 kg/ha).

3. Micosat (CCS Aosta Srl, Italy): Microbial inoculum containing mycorrhizal fungi (*Glomus mosseae* and *G. intraradices*), and plant growth-promoting bacteria (*Pseudomonas fluorescens* and *Bacillus subtilis*). The product contains 40% C, 0.15% N, 43.1% P and 0.956% K. Micosat F12 WP was applied to the soil at planting at 10 g/m^2 (100 kg/ha), and again in mid-June in liquid form in an amount of 1 g/m^2 (10 kg/ha).

4. Humus UP (Ekodarpol, Poland): An extract from vermicomposts containing 0.65% C, 0.03% N, 3.08% P and 0.453% K. It was applied to the soil as a 2% solution at 2 g/m^2 (20 l/ha).

5. Humus Active + Aktywit PM (Ekodarpol, Poland): An extract from vermicomposts based on a product derived from molasses. Humus Active is a soil improver and contains 0.78% C, 0.03% N, 0.105% P and 0.412% K. The Aktywit PM soil improver contains 20.5% C, 0.92% N, 8.12% P and 4.30% K. Humus Active was applied to the soil as a 2% solution at 2 ml/m^2 (20 l/ha), and Aktywit PM was applied to the soil as a 1% solution at 1 ml/m^2 (10 l/ha).

6. BioFeed Quality (Agrobio Products B.V., the Netherlands): An extract from several seaweed species reinforced with humic and fulvic acids, containing 0.6% C, 0.07% N, 3.26% P. It was applied to the soil as a 0.5% solution at 0.5 ml/m^2 (5 l/ha).

7. BioFeed Amin (Agrobio Products B.V., the Netherlands): An extract reinforced with vegetal amino acids that contains 1.12% C, 0.14% N, and 34.7% P. The product was applied to the soil as a 0.5% solution at 0.5 ml/m^2 (5 l/ha).

8. Loose yeast (Biopuls Start-up of Micro Life Company) was applied to the soil at 112.5 kg/ha.

9. Vinassa (Józefów Sp. z o.o., Poland): molasses residue from yeast production containing 12.0% C, 1.86% N, 949 mg/kg P, 17.615 mg/kg K. The product was applied to soil as a 0.5% solution at 0.5 ml/m^2 (5 l/ha).

10. Florovit Natura (NPK): This bioproduct is composed of 5% N, 3% P_2O_5, 2% K_2O and 30% organic matter. The product was applied at a dose of 468.75 kg/ha.

11. Florovit Eko (PK): This bioproduct is composed of 3% P_2O_5, 5% K_2O and 30% organic matter. It was applied at a dose of 468.75 kg/ha.

Each one of the treatments described above was applied both alone and in combination with beneficial bacteria. In total, the experimental design consisted of twenty-two combinations. The effect of the treatments was studied by evaluating their influence on the following parameters:

Gas exchange measurements. Net photosynthesis, transpiration and stomatal conductance were

https://doi: 10.17221/75/2017-HORTSCI

recorded using the LCpro + (ADC BioScientific, UK) portable system. The measurements of gas exchange were performed in the morning between 10.00 and 12.00, in July and August 2015 and 2016, during the vegetative period.

Trunk cross-sectional area (TCSA). The TCSA was measured on two occasions, in July and in November 2015, during the vegetative period, using a Vernier calliper.

Fruit yield per tree. Yield was estimated by measuring the weight in kg and the number of all fruits per tree/replicate in each treatment at harvest time (third week in October).

Fruit quality. The apples were stored in a cold storage room in a normal atmosphere at 1°C and 80% air humidity for one month. They were assessed one day after their removal them from cold storage. The following quality parameters were measured: the weight of individual fruits, percentage of blush, flesh firmness (FF), total soluble solids content (TSS) and titratable acidity (TA).

Fruit weight was measured using a WPS 2100/C/2 balance (Radwag, Poland). Flesh firmness (FF) was determined using the penetrometer method on two opposing sides of each fruit (on blush and on background colour) using an EPT-1R Pressure Tester (Kelowna, Canada) equipped with a Magness-Taylor 11-mm diameter probe. The results were expressed in kg. The total soluble solids content (TSS) and titratable acidity (TA) were measured in freshly prepared juice. TSS was determined using an ATAGO PR-101 digital refractometer (ATAGO, Japan). The results were expressed as %. Titratable acidity (TA) was determined using the standard titration method with an automatic titrator DL 50 Graphix (Mettler Toledo, Switzerland), by titrating the juice with 0.1 N NaOH to the end point at pH = 8.1. The results were expressed as a percentage of malic acid.

The obtained data were subjected to analysis of variance (ANOVA) using Statistica 13.1.336.0 64-bit (PL). The least significant difference (LSD) at the 0.05% level of significance was used to compare the treatment means.

RESULTS

The data in Table 1 show that the trunk cross-sectional area was significantly increased by the addition of beneficial bacteria to Humus UP, Yeast, Vinassa and Micosat compared to NPK chemical fertilisation.

The results shown in Table 2 demonstrate that the photosynthetic rate was markedly increased in July 2015 by the addition of the beneficial bacterial strains to Micosat, Vinassa, Humus Active + Aktywit PM, Humus UP and Florovit Eko, while in July 2016, it was markedly raised by the combination of Fertigo, BioFeed Amin, Vinassa, Yeast and BioFeed Quality with the beneficial bacteria compared to NPK chemical fertilisation. Moreover, it was also appreciably raised by Micosat, Vinassa and Humus UP combined with the beneficial bacteria in August 2015, and by the addition of the beneficial bacteria to Yeast, Humus UP, Micosat and Humus Active + Aktywit PM in August 2016, in comparison with the NPK control.

The results in Table 2 show that stomatal conductance was statistically enhanced by the addition of the beneficial bacteria to Vinassa and Humus UP in August 2015, and to Micosat and Humus Active + Aktywit PM in August 2016 compared with NPK. Yeast combined with the beneficial bacteria clearly increased stomatal conductance in July 2015, and in July 2016 this parameter was substantially enhanced by the addition of beneficial bacterial strains to BioFeed Quality, Vinassa and Yeast, compared with the NPK control.

The data in Table 3 indicate that Yeast, Vinassa, Micosat, Humus UP and BioFeed Amin, when each one was combined with the beneficial bacteria, elicited a remarkable increase in fruit yield, expressed as fruit weight in kg and the number of fruits, in comparison with NPK chemical fertilisation.

According to the results presented in Table 4, fruit weight (g) was markedly enhanced by the addition of the beneficial bacteria to Humus UP, Yeast, Micosat, Vinassa, BioFeed Amin and Humus Active + Aktywit PM, compared with the NPK control. The percentage of blush in 2015 was slightly increased with Micosat, Florovit Eko, Humus Active + Aktywit PM, Fertigo and Yeast combined with the beneficial bacterial strains, and also, in response to the treatments with Humus UP, BioFeed Amin and Humus Active + Aktywit PM, as compared to the NPK control. In 2016, the percentage of blush was appreciably improved with BioFeed Amin, Humus UP, Yeast, Florovit Natura, Fertigo and Humus Active + Aktywit PM. The total soluble solids content exhibited a statistically significant increase in response to the addition of the beneficial bacteria to Humus Active + Aktywit PM, BioFeed Quality, Florovit Natura, Vinassa, Yeast, NPK, Florovit Eko and BioFeed Amin,

https://doi: 10.17221/75/2017-HORTSCI

Table 1. The effect of NPK and bioproducts, used alone or enriched with beneficial bacteria, on trunk cross-sectional area of cv. 'Topaz' apple trees grown in an experimental orchard in Dąbrowice in 2015 and 2016

Treatment	Tree trunk cross-sectional area (mm)			
	2015		2016	
	May	November	May	November
NPK	35.8[cd]	39.2[cd]	40.9[cd]	45.1[de]
NPK + bacteria	33.6[d]	36.4[d]	37.9[d]	41.2[e]
Fertigo	36.0[cd]	39.0[cd]	41.3[cd]	45.5[de]
Fertigo + bacteria	35.7[cd]	39.0[cd]	41.4[cd]	44.3[de]
Micosat	37.1[cd]	40.2[cd]	42.7[cd]	46.3[de]
Micosat + bacteria	53.6[a]	56.7[a]	58.8[a]	61.2[a]
Humus UP	40.0[cd]	43.1[cd]	45.3[cd]	49.7[de]
Humus UP + bacteria	51.2[ab]	54.5[ab]	56.3[ab]	59.3[a-c]
Humus Active + Aktywit PM	38.8[cd]	42.1[cd]	43.8[cd]	47.4[de]
Humus Active + Aktywit PM+ bacteria	41.2[cd]	43.9[cd]	46.1[cd]	49.6[de]
BioFeed Quality	39.0[cd]	42.0[cd]	44.1[cd]	48.5[de]
BioFeed Quality + bacteria	36.3[cd]	39.6[cd]	41.4[cd]	44.8[de]
BioFeed Amin	37.0[cd]	40.4[cd]	42.0[cd]	45.9[de]
BioFeed Amin + bacteria	41.5[cd]	44.8[cd]	46.8[c]	50.6[cd]
Yeast	34.7[cd]	38.4[cd]	40.3[cd]	43.5[de]
Yeast + bacteria	52.6[a]	56.0[a]	57.7[a]	60.5[ab]
Vinassa	40.2[cd]	43.6[cd]	45.7[cd]	49.0[de]
Vinassa + bacteria	53.2[a]	56.5[a]	58.1[a]	61.6[a]
Florovit Natura	36.8[cd]	39.9[cd]	41.4[cd]	45.3[de]
Florovit Natura + bacteria	42.9[bc]	46.3[bc]	48.3[bc]	51.6[b-d]
Florovit Eko	37.0[cd]	40.2[cd]	41.7[cd]	46.2[de]
Florovit Eko + bacteria	38.3[cd]	42.0[cd]	43.9[cd]	48.0[de]

means not sharing the same letter(s) within each column are significantly different at the 0.05 level of probability

and also in response to Humus Active + Aktywit PM, Florovit Eko, Yeast, Vinassa, BioFeed Quality and Humus UP, compared with the NPK control in 2015. In 2016, the TSS was improved by the application of BioFeed Quality, Micosat, Humus UP and NPK enriched with the beneficial bacteria, but the differences were not significant when compared with the NPK control. Flesh firmness was enhanced by the addition of the beneficial bacterial strains to Humus Active + Aktywit PM, BioFeed Amin, BioFeed Quality, Yeast, Humus UP and Vinassa in comparison with the NPK control, but the differences were not significant. Titratable acidity (% malic acid) was markedly increased by Yeast, Humus Active + Aktywit PM, Florovit Eko, BioFeed Amin, Vinassa and BioFeed Quality combined with bacterial strains, and also by the treatments with Humus UP, BioFeed Quality, Vinassa and Yeast in 2015, while it was significantly increased in response to Micosat + beneficial bacteria in 2016.

DISCUSSION

Our obtained results showed that the addition of bacterial strains to Vinassa, Micosat and Humus

https://doi: 10.17221/75/2017-HORTSCI

Table 2. The effect of NPK and bioproducts, used alone or enriched with beneficial bacteria, on the rate of photosynthesis and stomatal conductance in the leaves of cv. 'Topaz' apple trees grown in an experimental orchard in Dąbrowice in 2015 and 2016

Treatment	Photosynthesis (μmol CO_2/m^2 s)				Stomatal conductance (mol/$m^{/2}$ s)			
	2015		2016		2015		2016	
	July	August	July	August	July	August	July	August
NPK	7.00^{gh}	6.26^{c-f}	10.65^{c}	7.99^{ef}	0.12^{ab}	0.09^{b-f}	0.18^{d}	0.12^{c-f}
NPK + bacteria	7.08^{gh}	7.06^{b-e}	12.15^{a-c}	8.40^{d-f}	0.10^{ab}	0.10^{b-e}	0.21^{d}	0.11^{d-f}
Fertigo	11.38^{a-e}	5.36^{d-f}	10.90^{c}	8.58^{d-f}	0.14^{ab}	0.08^{c-f}	0.21^{d}	0.13^{b-e}
Fertigo + bacteria	6.22h	7.09^{b-e}	13.23^{ab}	9.88^{a-f}	0.10^{b}	0.11^{b-d}	0.20^{d}	0.13^{a-e}
Micosat	8.79^{d-h}	6.86^{b-f}	11.80^{a-c}	10.07^{a-e}	0.13^{ab}	0.10^{b-e}	0.23^{b-d}	0.15^{a-c}
Micosat + bacteria	10.56^{b-f}	9.37^{ab}	12.71^{abc}	11.56^{ab}	0.10^{ab}	0.11^{bc}	0.23^{b-d}	0.17^{ab}
Humus UP	8.33^{e-h}	6.92^{b-e}	11.42^{bc}	10.50^{a-d}	0.11^{ab}	0.09^{b-f}	0.20^{d}	0.12^{c-f}
Humus UP + bacteria	13.70^{ab}	11.81^{a}	12.86^{a-c}	11.54^{ab}	0.21^{ab}	0.17^{a}	0.23^{b-d}	0.15^{a-c}
Humus Active + Aktywit PM	8.24^{e-h}	6.64^{c-f}	12.26^{a-c}	8.75^{d-f}	0.12^{ab}	0.09^{b-f}	0.19^{d}	0.13^{b-e}
Humus Active + Aktywit PM+ bacteria	12.62^{a-c}	7.82^{b-d}	12.75^{a-c}	11.83^{a}	0.18^{ab}	0.11^{b}	0.20^{d}	0.17^{a}
BioFeed Quality	7.98^{f-h}	4.357^{f}	11.16^{bc}	8.75^{d-f}	0.14^{ab}	0.07^{ef}	0.19^{d}	0.14^{a-d}
BioFeed Quality + bacteria	8.52^{d-h}	5.48^{d-f}	13.88^{a}	9.64^{a-f}	0.14^{ab}	0.08^{d-f}	0.27^{a-c}	0.15^{a-c}
BioFeed Amin	7.45^{f-h}	6.51^{c-f}	12.73^{a-c}	8.87^{d-f}	0.11^{ab}	0.08^{d-f}	0.19^{d}	0.15^{a-d}
BioFeed Amin + bacteria	8.29^{e-h}	8.67^{bc}	13.25^{ab}	9.30^{b-f}	0.09^{b}	0.10^{b-e}	0.23^{b-d}	0.13^{b-e}
Yeast	7.91^{f-h}	4.85^{ef}	12.12^{a-c}	9.77^{a-f}	0.12^{ab}	0.07^{f}	0.23^{b-d}	0.12^{c-f}
Yeast + bacteria	9.73^{c-g}	6.97^{b-e}	13.70^{a}	11.36^{a-c}	0.29^{a}	0.08^{c-f}	0.31^{a}	0.14^{a-d}
Vinassa	9.28^{d-h}	6.70^{c-f}	12.61^{a-c}	9.01^{c-f}	0.14^{ab}	0.08^{c-f}	0.22^{cd}	0.13^{c-e}
Vinassa + bacteria	11.79^{a-d}	11.71^{a}	13.69^{a}	10.39^{a-e}	0.19^{ab}	0.15^{a}	0.28^{ab}	0.12^{c-f}
Florovit Natura	8.79^{d-h}	6.91^{b-f}	12.20^{a-c}	7.98^{ef}	0.12^{ab}	0.08^{c-f}	0.20^{d}	0.11^{c-f}
Florovit Natura + bacteria	8.99^{d-h}	7.05^{b-e}	11.91^{a-c}	8.25^{d-f}	0.15^{ab}	0.11^{bcd}	0.20^{d}	0.12^{c-f}
Florovit Eko	7.59^{f-h}	6.18^{c-f}	12.46^{a-c}	7.58^{f}	0.11^{ab}	0.09^{b-f}	0.18^{d}	0.09^{f}
Florovit Eko + bacteria	14.06^{a}	7.54^{b-d}	12.30^{a-c}	8.08^{d-f}	0.23^{ab}	0.10^{b-e}	0.20^{d}	0.10^{ef}

means not sharing the same letter(s) within each column are significantly different at the 0.05 level of probability

UP resulted in a greatly increased photosynthetic rate compared to NPK chemical fertilisation. These results are consistent with the findings of HAMEL (2004), who reported that the network of extraradical mycorrhizal hyphae facilitated nutrient acquisition and the transport of many ions to the roots, particularly less mobile ions such as P, N, K, S, Ca and Zn. Moreover, Malusa et al. (2007) found that inoculation of the roots of strawberry plants with the Micosat preparation significantly increased the number of spores in the rhizosphere of the strawberry cultivars. According to Khan et al. (2010), phosphorus plays an important role in photosynthesis, energy transfer, signal transduction and respiration in the plant. In addition, phosphorus is known to play an indispensable biochemical role in photosynthesis, respiration and energy storage in the living plant (Sagervanshi et al. 2012). Fe takes part in various important biological processes, such as photosynthesis, respiration and chlorophyll biosynthesis (Kobayashi, Nishizawa 2012). Derkowska et al. (2015) re-

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Table 3. The effect of NPK and bioproducts, used alone or enriched with beneficial bacteria, on the number of fruits and fruit weight of cv. 'Topaz' apple trees grown in an experimental orchard in Dąbrowice in 2015 and 2016

Treatment	Fruit yield/tree			
	2015		2016	
	number	weight (kg)	number	weight (kg)
NPK	117.7[f]	14.7[bc]	77.6[e]	14.3[ef]
NPK+ bacteria	123.0[ef]	12.5[c]	74.6[e]	12.5[f]
Fertigo	160.5[a–f]	21.6[a]	86.8[c–e]	15.5[d–f]
Fertigo + bacteria	184.5[a–d]	23.2[a]	105.6[c–e]	16.6[d–f]
Micosat	158.5[a–f]	21.7[a]	77.8[de]	14.0[ef]
Micosat + bacteria	189.2[a–c]	23.6[a]	124.6[a–c]	25.1[ab]
Humus UP	172.5[a–d]	22.1[a]	153.0[ab]	19.7[b–e]
Humus UP + bacteria	179.7[a–d]	23.2[a]	156.8[a]	26.3[a]
Humus Active + Aktywit PM	155.7[b–f]	20.2[ab]	99.6[c–e]	17.3[d–f]
Humus Active + Aktywit PM + bacteria	152.7[b–f]	22.4[a]	87.4[c–e]	15.8[d–f]
BioFeed Quality	145.5[c–f]	20.4[ab]	103.0[c–e]	18.4[d–f]
BioFeed Quality + bacteria	159.7[a–f]	20.6[ab]	110.4[b–e]	18.7[c–f]
BioFeed Amin	152.2[b–f]	19.6[ab]	99.8[c–e]	17.9[d–f]
BioFeed Amin + bacteria	180.7[a–d]	22.5[a]	155.0[ab]	25.9[ab]
Yeast	139.7[d–f]	21.4[a]	117.2[a–e]	20.0[b–e]
Yeast + bacteria	203.2[a]	24.2[a]	157.4[a]	24.9[a–c]
Vinassa	166.2[a–e]	21.4[a]	103.6[c–e]	17.5[d–f]
Vinassa + bacteria	191.7[ab]	23.9[a]	123.2[a–d]	20.9[a–d]
Florovit Natura	171.5[a–d]	22.2[a]	114.0[a–e]	20.1[a–e]
Florovit Natura + bacteria	183.5[a–d]	23.6[a]	113.4[a–e]	19.9[b–e]
Florovit Eko	162.5[a–f]	21.4[a]	83.2[c–e]	16.6[d–f]
Florovit Eko + bacteria	165.7[a–e]	20.7[ab]	92.8[c–e]	16.1[d–f]

means not sharing the same letter(s) within each column are significantly different at the 0.05 level of probability

ported that the application of Humus UP doubled the total number of bacteria and filamentous fungi in the rhizosphere soil of 'Elsanta' and 'Elkat' strawberry cultivars in comparison with NPK fertilisation. Furthermore, Sas Paszt et al. (2015) found that the application of Micosat, Humus UP and Vinassa resulted in a statistically significant increase in mycorrhizal frequency in the roots of 'Honeoye' strawberry plants.

The obtained results indicate that tree thickness was significantly increased by the addition of beneficial bacteria to Humus UP, Yeast, Vinassa and Micosat. These results are in agreement with the findings of Esitken et al. (2003). They reported that the application of beneficial bacterial strains belonging to *Pseudomonas, Bacillus, Rhizobium* and *Klebsiella* species was beneficial for plant growth in apricot (*Prunus armeniaca* L. cv. Hacihaliloglu). Grzyb et al. (2012) found that Humus UP, Micosat and Vinassa resulted in increased trunk cross-sectional area in 'Topaz' and 'Ariwa' cultivars of maiden apple trees. Further, Grzyb et al. (2015) also noted that the application of Humus UP, Vinassa and Vinassa + Micosat increased the trunk diameter of maiden trees of apple cv. 'Topaz' and of sour cherry cv. 'Debreceni Bötermö'.

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Table 4. The effect of NPK and bioproducts, used alone or enriched with beneficial bacteria, on the fruit characteristics of cv. 'Topaz' apple trees grown in an experimental orchard in Dąbrowice in 2015

Treatment	Fruit characteristics									
	2015					2016				
	weight (g)	blush (%)	TSS (%)	firmness	acidity (%)	weight (g)	blush (%)	TSS (%)	firmness	acidity (%)
NPK	134.6$^{f–h}$	90.67$^{a–c}$	13.71$^{c–e}$	6.19$^{a–c}$	0.67^{de}	154.5^{ij}	77.67^{c}	13.97$^{a–c}$	8.18$^{a–c}$	0.96^{b}
NPK+ bacteria	115.9^{i}	84.00$^{a–c}$	14.11^{a}	5.81^{c}	0.68$^{c–e}$	151.6^{j}	86.00^{bc}	14.41^{a}	8.10$^{a–c}$	0.86^{jk}
Fertigo	118.8^{hi}	82.67^{bc}	13.41$^{f–h}$	5.82^{c}	0.62^{hi}	170.3$^{f–h}$	91.00^{ab}	14.10^{ab}	8.08$^{a–c}$	0.86$^{i–k}$
Fertigo + bacteria	135.0$^{f–h}$	93.33^{a}	13.54$^{d–f}$	5.83^{c}	0.65$^{e–g}$	181.8$^{c–g}$	94.67^{ab}	13.91$^{a–c}$	8.17$^{a–c}$	0.94$^{b–f}$
Micosat	144.3$^{d–g}$	85.67$^{a–c}$	13.46$^{e–g}$	6.18$^{a–c}$	0.69^{cd}	182.8$^{b–f}$	89.33^{ab}	14.18^{ab}	8.27$^{a–c}$	0.91$^{d–h}$
Micosat + bacteria	162.2$^{a–c}$	92.00^{ab}	13.23^{gh}	6.00^{bc}	0.63$^{g–i}$	189.5$^{a–c}$	90.67^{ab}	14.45^{a}	8.42^{a}	1.01^{a}
Humus UP	143.4$^{d–g}$	93.00^{a}	14.12^{a}	6.14$^{a–c}$	0.74^{b}	182.5$^{b–g}$	91.67^{ab}	14.22^{a}	8.29$^{a–c}$	0.96^{b}
Humus UP + bacteria	157.1$^{a–e}$	85.33$^{a–c}$	13.59$^{c–f}$	6.80^{a}	0.61^{i}	184.0$^{b–e}$	93.00^{ab}	14.39^{a}	8.05$^{a–c}$	0.90$^{e–j}$
Humus Active + Aktywit PM	143.9$^{d–g}$	94.00^{a}	13.71^{cd}	6.07$^{a–c}$	0.67^{e}	169.8^{gh}	88.33^{ab}	14.13^{ab}	7.98$^{a–c}$	0.95$^{b–d}$
Humus Active + Aktywit PM + bacteria	159.0$^{a–d}$	92.67^{ab}	13.99^{ab}	6.39$^{a–c}$	0.71^{c}	196.9^{a}	95.67^{a}	14.19^{ab}	8.50^{a}	0.89$^{g–j}$
BioFeed Quality	143.0$^{d–g}$	85.33$^{a–c}$	14.12^{a}	6.51$^{a–c}$	0.75^{ab}	181.7$^{c–g}$	92.00^{ab}	14.13^{ab}	8.31$^{a–c}$	0.97^{b}
BioFeed Quality + bacteria	172.2^{a}	90.00$^{a–c}$	14.02^{ab}	6.63^{ab}	0.77^{a}	181.4$^{c–g}$	92.00^{ab}	14.23^{a}	8.38^{ab}	0.93$^{b–f}$
BioFeed Amin	146.3$^{c–g}$	93.33^{a}	13.20^{h}	6.03^{bc}	0.64$^{f–h}$	166.4^{hi}	92.33^{ab}	14.11^{ab}	8.06$^{a–c}$	0.86^{jk}
BioFeed Amin + bacteria	172.3^{a}	80.67^{c}	14.17^{a}	6.48$^{a–c}$	0.74^{b}	195.0^{ab}	92.67^{ab}	14.08^{ab}	8.22$^{a–c}$	0.95^{bc}
Yeast	133.5$^{f–h}$	89.00$^{a–c}$	14.03^{ab}	6.05^{bc}	0.75^{ab}	176.4$^{d–h}$	89.00^{ab}	13.56^{bc}	7.70^{c}	0.81l
Yeast + bacteria	169.5^{ab}	94.00^{a}	14.09^{a}	6.64^{ab}	0.70^{c}	188.8$^{a–d}$	93.67^{ab}	14.19^{ab}	8.01$^{a–c}$	0.92$^{c–g}$
Vinassa	153.0$^{b–e}$	88.67$^{a–c}$	14.09^{a}	6.49$^{a–c}$	0.75^{ab}	178.2$^{c–h}$	89.33^{ab}	14.11^{ab}	8.31$^{a–c}$	0.89$^{g–j}$
Vinassa + bacteria	157.6$^{a–d}$	85.33$^{a–c}$	14.04^{ab}	6.81^{a}	0.76^{ab}	190.7$^{a–c}$	92.33^{ab}	14.03^{ab}	7.98$^{a–c}$	0.90$^{f–j}$
Florovit Natura	149.6$^{c–f}$	90.00$^{a–c}$	13.50$^{d–f}$	6.12$^{a–c}$	0.66^{ef}	172.0$^{e–h}$	93.67^{ab}	13.99^{ab}	8.21$^{a–c}$	0.96^{bc}
Florovit Natura + bacteria	140.2$^{e–g}$	90.67$^{a–c}$	14.03^{ab}	6.12$^{a–c}$	0.67^{de}	180.8$^{c–g}$	94.00^{ab}	14.00^{ab}	8.35$^{a–c}$	0.94$^{b–e}$
Florovit Eko	130.4$^{g–i}$	90.00$^{a–c}$	13.83^{bc}	6.17$^{a–c}$	0.63$^{f–i}$	173.7$^{e–h}$	92.33^{ab}	14.09^{ab}	8.09$^{a–c}$	0.88$^{h–j}$
Florovit Eko + bacteria	159.8$^{a–d}$	92.33^{ab}	14.16^{a}	6.47$^{a–c}$	0.71^{c}	182.6$^{b–g}$	89.67^{ab}	13.32^{c}	7.72^{bc}	0.83^{kl}

means not sharing the same letter(s) within each column are significantly different at the 0.05 level of probability

The addition of bacteria to both Yeast and Humus UP resulted in the highest yield in terms of fruit weight and the number of fruit. These results are consistent with the findings of Hegab et al. (2010) who reported that the use of yeast in different fruit crops was accompanied by enhanced yield and fruit quality. Moreover, Mansour et al. (2011) also found that applying yeast through soil, foliage or both these methods, at different concentrations to 'Kelsey' plum trees significantly improved yield and fruit quality in terms of fruit weight. Soil yeasts have an active stimulating effect on plant growth and on plant productivity (Pérez-Montaño et al. 2014). Rozpara et al. (2014) reported that the largest and highest amounts of 'Ariwa' apples were harvested from trees fertilised with Humus UP. Furthermore, the addition of *Pantoea* sp., *Pseudomonas fluorescens*, *Klebsiella oxytoca* and *Rhizobium* sp. to Micosat, Humus UP, Yeast, Vinassa and BioFeed Amin resulted in an increased number of fruits and enhanced fruit weight in the apple cultivar 'Topaz' (Mosa et al. 2016).

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CONCLUSION

– Trunk cross-sectional area was significantly increased by the addition of beneficial bacteria to Humus UP, Yeast, Vinassa and Micosat.
– Florovit Eko, Vinassa, Yeast and Biofeed Quality enriched with bacteria increased photosynthetic rate
– Yeast + bacteria and Humus UP + bacteria were the best treatments in increasing the yield in terms of fruit weight and the number of fruits.

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