Journal of Elementology ISSN 1644-2296

Franczuk J., Rosa R., Zaniewicz-Bajkowska A., Słonecka D. 2019.
Effects of boron application and treatment with effective microorganisms on the growth, yield and some quality attributes of broccoli.
J. Elem., 24(4): 1335-1348. DOI: 10.5601/jelem.2019.24.2.1787

RECEIVED: 19 December 2018
ACCEPTED: 23 May 2019

ORIGINAL PAPER

EFFECTS OF BORON APPLICATION AND TREATMENT WITH EFFECTIVE MICROORGANISMS ON THE GROWTH, YIELD AND SOME QUALITY ATTRIBUTES OF BROCCOLI*

Jolanta Franczuk, Robert Rosa, Anna Zaniewicz-Bajkowska, Dominika Słonecka

Department of Vegetable Crops
Siedlce University of Natural Sciences and Humanities, Siedlce, Poland

Abstract

The paper deals with the effects of boron topdressing and Effective Microorganism (EM) treatments on the growth, yield and quality of broccoli harvested in summer. EM is a microbial inoculant promoted to stimulate plant growth and soil fertility in agriculture. Boron (B) is one of eight micronutrients needed for proper plant growth. Different combinations of Effective Microorganism were applied: added to the nursery substrate before planting seeds (EM1); added to the nursery substrate before planting seeds and as topdressing in a form of spray after seedlings were planted out (EM2); as pre-planting treatment in the field, just before the seedlings were transplanted (EM3); as pre-planting treatment in the field, followed by topdressing as a spray (EM4); control (without EM). Boron was applied as mineral fertilizer three weeks after broccoli seedlings had been planted out in the field. The experiment was carried out between 2014 and 2015, at the Experimental Station of Siedlce University of Natural Sciences and Humanities, located in central-eastern Poland. Compared to the control, each method of Effective Microorganisms application to broccoli significantly increased its marketable curd yield, average curd weight and leaf greenness index (SPAD). Plants had the longest arc of curd and the largest L-Ascorbic acid content when EM were added to the substrate and then applied in the field in the form of spray. Effective Microorganisms applied as EM1, EM2, and EM3 combinations increased the potassium and calcium content in broccoli. However, there was no significant effect of EM application on dry matter, sugar and protein content in broccoli curds. Boron application to broccoli resulted in an increase in the marketable curd yield, the weight of marketable curds, the length of arc of curd, and dry matter, phosphorus and potassium content.

Keywords: bio-stimulators, *Brassica oleracea* L. var. *italica*, mineral fertilization, nutritional value, yield.

dr hab. inż. Robert Rosa, Department of Vegetable Crops, Siedlce University of Natural Sciences and Humanities, Prusa 14 st., 08-110 Siedlce, Poland; phone: +48 25 643 12 76, e-mail: robert.rosa@uph.edu.pl

* The research carried out under research project No 226/06/S was financed from a science grant awarded by the Ministry of Science and Higher Education.

INTRODUCTION

Effective microorganisms (EM) are applied increasingly often to stimulate nutrient cycling and plant growth. They are not nutrients, and they can only help plants to take in nutrients and stimulate their resistance to stress factors (Sabeti et al. 2017). They are beneficial microorganisms of natural origin. Apart from photosynthetic bacteria, effective microorganisms include milk bacteria, yeast, selected species of fungi and actinomycetes. The main species included in EM preparations are lactic acid bacteria *Lactobacillus plantarum*, *Lactobacillus casei*, *Streptococcus lactis*, photosynthetic bacteria *Rhodopseudomonas palustris* and *Rhodobacter sphaeroides*, the yeasts *Saccharomyces cerevisiae* and *Candida utilis*, the *Actinomycetes Streptomyces albus* and *Streptomyces griseus*, and finally the fungi *Aspergillus oryzae* and *Mucor hiemalis* (Xu 2001, Wielgosz et al. 2010). EMs also affect soil physical and chemical properties and its biological activity. There are other positive results of their application such as improvement of soil structure and fertility, elimination of putrefactive processes, acceleration of organic compound mineralization and improvement of the availability of such nutrients as N and P (Lack et al. 2013). Among others, Hussein and Joo (2011), Satekge et al. (2016), Shaheen et al. (2017) and Smith (2016) found that the use of EM increased crop productivity. Marschner (2007) reported that the stimulating effect of microorganisms on plant growth could be caused by the fact that they produce secondary metabolites, growth hormones, phytochelatin, organic acids and B vitamins. Xu Hui-Lian et al. (2001) observed that EM stimulated photosynthetic processes and increased the weight of plants. Effective Microorganisms also positively affect plant resistance to external factors and pathogens, which is why they are used in fruit and vegetable growing. They can be used for seed conditioning, seedling soaking, plant foliar spraying and watering. They can be applied throughout the growing season, and their use does not require a withdrawal period (Sabeti et al. 2017).

Boron (B) is one of the eight essential micronutrients, also called trace elements, required for the normal growth of most plants (Weisany et al. 2013). It enhances the growth and yield of plants because it stimulates division and elongation of the cell and development of its walls. Goldbach and Wimmer (2007) and Miwa et al. (2007) underline that boron plays an important role in the metabolism of carbohydrates and proteins. Boron deficiency causes many anatomical, physiological and biological disorders (Brown et al. 2002).

The natural content of boron in the soil depends mainly on the type of material from which it has developed. Clay soils are generally rich in boron in contrast to sandy ones, in which boron may be present in small amounts. Boron concentrations in soils vary from 2 to 200 mg B kg^{-1}, but generally its forms available to plants constitute less than 5 to 10% (Diana

2006). In Poland, sandy soils dominate and the content of this chemical element is insufficient, which necessitates supplementation of boron with mineral fertilizers either to soil or as a foliar spray (SZULC, RUTKOWSKA 2013). One of the vegetable species with the greatest demand for boron is broccoli.

A representative of the *Brassicaceae* family, broccoli (*Brassica oleracea* L. var. *Italica* Plank) is a common vegetable plant of the Mediterranean origin. It is tasty and more nutritious than any other vegetables of the same genus. It is considered to be a valuable source of vitamins, antioxidants, glucosinolates and other anti-carcinogenic compounds.

The experiment dealt with the effects of Effective Microorganisms (EM) applied in different combinations and of boron topdressing on the broccoli yield and selected nutrient content.

MATERIAL AND METHODS

Experimental site

The experiment was carried out between 2014 and 2015, at the Experimental Station of Siedlce University of Natural Sciences and Humanities, located in central-eastern Poland (52°03′N, 22°33′E). The soil was classified as Luvisol, with the average organic carbon content of 0.97%, the humus layer reaching the depth of 30-40 cm, and pH_{KCl} of 6.0. The content of available forms of nutrients in the soil (mg kg^{-1}) was as follows: 4.7 NO_3-N, 2.5 NH_4-N, 12 P, 27 K, 10.8 Mg, 87.5 Ca, 0.11 B.

Experimental design

The experiment was established as a split-plot design with three replicates and two factors: factor I – mineral fertilisation (MF), factor II – different methods of using Effective Microorganisms (EM) – Table 1.

The Effective Microorganisms used in the experiment are a mixture of beneficial microorganisms, composed of five families, ten genera and more than 80 types of aerobic and anaerobic microbes, including photosynthetic bacteria, lactic acid bacteria, yeast, *Actinomycetes*, fungi and so on.

Boron was used in the form of Nitrabor fertilizer. It contains calcium nitrate with 15.4% N (including 14.1% NO_3-N and 1.3% NH_4-N), 25.6% CaO and 0.3% boron. It is recommended to apply to vegetables, especially to species that require increased doses of boron.

Seedling preparation

Broccoli seedlings of cv. Wiarus were grown in a non-heated greenhouse. Seeds were sown in the successive study years on the 17 and 20 of March to multi-trays of the size of 400 × 600 mm, with 54 cells and the cell diameter of 54 mm. 60% of seedlings were produced without the addition of EM

Table 1

Factors of the experiment

Factor I: Two mineral fertiliser combinations	
MF1	basic pre-planting treatment NPK (206 kg N, 146 kg P_2O_5, 273 kg K_2O ha^{-1} – in the form of ammonium nitrate, granular superphosphate and 60% potassium chloride, respectively) + nitrogen topdressing to the soil (62 kg ha^{-1} – in the form of ammonium nitrate)
MF2	basic pre-planting treatment NPK (206 kg N, 146 kg P_2O_5, 273 kg K_2O ha^{-1} – in the form of ammonium nitrate, granular superphosphate and 60% potassium chloride, respectively + Nitrabor topdressing to the soil (400 kg ha^{-1}).
Factor II: Five combinations with Effective Microorganisms (EM)	
EM0	control without EM.
EM1	EM added to the substrate during seedling production (1 litre of 10% EM water solution to 1 m^3 of substrate)
EM2	EM added to the substrate during seedling production (1 litre of 10% EM water solution to 1 m^3 of substrate) + topdressing with 10% EM solution as a foliar spray
EM3	EM applied to seedlings planted out in the field (each seedling watered with 1 litre of 10% EM solution)
EM4	EM applied to seedlings planted out in the field (each seedling watered with 1 litre of 10% EM solution) + topdressing with 10% EM solution as a foliar spray

and 40% on substrate mixed with 10% EM water solution. EM was applied: 1 dm^3 of the solution in 1 m^3 of the substrate. The substrate used for the production of seedlings was made of de-acidified "highmoor" peat, pH 5.5-6.5 and salinity no greater than 2 g NaCl l^{-1}. The substrate was enriched with mineral fertiliser containing NPK (14-16-18%) and Mg (5%). On average, the nutrient content in the substrate was as follows (mg dm^{-3}): 238 NO_3-N, 18 NH_4-N, 70 P, 207 K, 1016 Ca and 158 Mg.

Field work

Broccoli was preceded by triticale, and the field was cultivated and ploughed in the autumn. In the spring, disc harrowing was used two weeks before seedlings were planted out. After that, mineral fertilizers were applied at the doses of 206 kg N, 146 kg P_2O_5, 273 kg K_2O ha^{-1} to supplement the nutrient content to the optimal level for broccoli. The seedlings were planted on 18 or 22 of April in the two successive years, at a spacing of 50 × 50 cm. Directly after planting, each seedling on the EM3 unit was watered with 1 litre of 10% solution of Effective Microorganisms. Then, for three weeks the soil was mulched with polypropylene fibre in an amount of 17 g m^{-2}. After removing the fibre, the plants were topdressed with mineral fertilizers. 62 kg ha^{-1} of nitrogen was applied to plants in the MF1 treatment (the same amount of nitrogen as on MF2, where it was supplied with Nitrabor). A Nitrabor dose of 400 kg ha^{-1} was used together with 1.2 kg ha^{-1} B in the MF2 combination. Finally, EM2 and EM4 plants were sprayed with 10% EM solution.

Sample collection and laboratory analysis

Broccoli was harvested by hand on 12 June 2014, and on 11 June 2015. Afterwards, the following parameters were determined: marketable yield, weight of marketable curds, length of the curd arc and stalk diameter. From each plot, a sample was taken for chemical analyses to determine dry mass (by drying to constant weight at 105°C), L-ascorbic acid (Tillmans method), monosaccharide (Luff-Schoorl method), protein content (Kjeldahl method, using a factor of 6.25) and selected mineral components. The phosphorus content was measured via colorimetry on a SPEKOL 221 spectrophotometer. Potassium and calcium were determined with a FLAPHO 41 flame photometer. Magnesium was determined on a SOLAR 929 ATI UNICAM atomic absorption spectrophotometer. Before harvetsing the broccoli curd, the leaf greenness index (SPAD) was measured (with a SPAD-502 Plus Konica Minolta®).

Statistical analysis

The results were statistically analysed with ANOVA, following the model for the split-plot design. The significance of differences was determined with the Tukey's test at the significance level of $P \leq 0.05$. All the calculations were performed with Statistica 10.0 software.

Weather conditions

Air temperatures and rainfall, especially during the planting of broccoli seedlings, were higher in 2014 than in 2015 (Figure 1). However, more favourable weather conditions for broccoli growth and development were in 2015. In May 2014, high air temperatures contributed to weaker growth. In the same year, unfavourable distribution of rainfall during the first three weeks of June depressed the yield of curds.

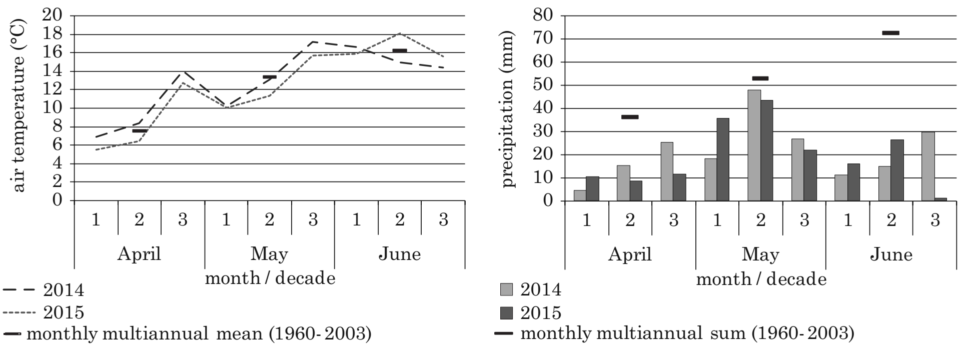

Fig. 1. Weather conditions during the broccoli growing period according to the Zawady Meteorological Station, Poland

RESULTS AND DISCUSSION

The two-year average marketable yield of broccoli curds was 11.6 t ha^{-1} (Table 2). In 2015, with more favourable weather conditions, the yield was

Table 2

The yield of broccoli

Treatments	Year		Mineral fertilization		Mean
	2014	2015	MF1	MF2	
Marketable yield (t ha^{-1})					
EM0	9.0*a**	10.4*a*	8.7	11.1	9.9*a*
EM1	12.0*b*	11.4*a*	11.2	12.1	11.6*b*
EM2	13.0*c*	15.1*c*	12.9	14.7	13.8*c*
EM3	11.0*a*	12.0*b*	10.1	12.6	11.4*b*
EM4	12.0*b*	11.1*a*	10.3	12.6	11.4*b*
Mean	11.0*A*	12.0*B*	10.6*A*	12.6*B*	11.6
Weight of marketable curd (g)					
EM0	236.5	269.8	229.9*a*	276.4*a*	253.1*a*
EM1	330.3	390.8	352.5*b*	368.7*b*	360.6*b*
EM2	391.8	441.3	412.5*d*	420.7*c*	416.6*d*
EM3	368.5	423.3	383.5*c*	408.3*c*	395.9*c*
EM4	377.8	420.2	378.0*c*	420.0*c*	399.0*c*
Mean	341.0*A*	389.1*B*	351.3*A*	378.8*B*	365.0

* Values followed by different lowercase letters in columns and different uppercase letters in rows differ significantly at $P \leq 0.05$

about 6.5% higher than in 2014. EM application also contributed to its substantial growth, and compared to the control the average yields increased by 1.5 t ha^{-1} (EM3, EM4), 1.7 t ha^{-1} (EM1) and 3.9 t ha^{-1} (EM2), i.e. by 15.2%, 17.2 and 39.4%, respectively. During the research, the highest statistically significant yield was on harvested from the plots where EM had been applied to seedlings and to plants in the field as topdressing (EM2). A significant increase in marketable yield, compared to the control, was noted after EM1 and EM4 application in 2014, and after EM3 treatment in 2015.

EM application significantly increased the average weight of marketable broccoli curds. The biggest ones were harvested on plots with the EM2 combination (Table 2), where the difference relative to the control was 163.5 g (64.6%). Curds harvested in 2015 were on average 48.1 g heavier than in 2014. Hussein and Joo (2011) found that EM treatment of Chinese cabbage (*Brassica rapa*) seedlings considerably improved plant growth and increased their weight. Similarly, while examining the effect of EM on the growth and yield of cv. Optima cabbage, Satekge et al. (2016) recorded a 78.7% increase in fresh matter weight of heads in relation to the control. Shaheen et al. (2017) noted an increase in the curd yield and in leaf length and surface after EM application to spinach seeds. Kowalska (2016) noted that foliar and soil application of the EM Farma-Plus fertilizer resulted in the highest yield of potatoes grown in an organic system; in addition, there was a beneficial effect of the use of EM and mineral fertilizer, such as a higher share of marketable potatoes in the whole yield.

In the present experiment, in all EM variants, boron topdressing (MF2) resulted in a significant increase in the marketable yield of curds (on average by 18.9%) and their marketable weight (by about 7.8%) compared to the control (Table 2). A significant increase in the weight of marketable curds after applying boron was also recorded on the control plots without EM (20.2%), in the EM3 combination (by 6.5%), and in the EM4 combination (by 11.1%). A positive effect of boron on the total yield of broccoli curds was also noted by other authors, for example Hussain et al. (2012), Singh et al. (2015), Islam et al. (2015), and Farooq et al. (2018). In addition, Hussain et al. (2012) and Singh et al. (2015) found a significant increase in curd weight. The optimum levels of NPK and boron applied to broccoli positively affect photosynthetic efficiency and improve other processes like enzyme activation, protein and carbohydrate accumulation, and translocation of sugar and starch; because of all that the yield also increases (Shah et al. 2010).

The length of the arc of curds harvested in 2015 was on average about 43 mm bigger than in 2014 (Table 3). Curds with the longest arc (238 mm)

Table 3

Length of broccoli arc and stalk diameter

Treatments	Year		Mineral fertilization		Mean
	2014	2015	MF1	MF2	
Length of curd arc (mm)					
EM0	187*ab**	233*a*	204	216	210*a*
EM1	194*b*	235*a*	215	215	215*a*
EM2	235*c*	240*ab*	232	243	238*b*
EM3	181*a*	248*b*	210	220	215*a*
EM4	190*ab*	245*ab*	214	221	218*a*
Mean	197*A*	240*B*	215*A*	223*B*	219
Stalk diameter (mm)					
EM0	30	33	32	32	34
EM1	34	26	30	36	26
EM2	29	31	30	30	32
EM3	25	26	25	25	27
EM4	30	28	29	30	28
Mean	30	29	29	31	29

* Values followed by different lowercase letters in columns and different uppercase letters in rows differ significantly at $P \leq 0.05$

were collected after EM application to seedlings and as topdressing in the form of spray (EM2). The best effect of EM in 2014 was achieved by their use on seedlings, followed by topdressing in the form of spray (EM2). In 2015, pre-planting application in the field (EM3) was the most effective. In 2014, curds with the smallest arc length were obtained from the EM3 plants, and in 2015 they were produced by the control plants grown without EM.

For all EM combinations, Nitrabor (MF2) significantly increased curd arc length in comparison with plants grown without boron (MF1). Husain et al. (2012) and Singh et al. (2015) recorded doses a significant increase for all boron compared to the control in broccoli curd and stem diameters. In the present experiment, the stalk diameter of broccoli was on average 29 mm, and no significant changes were recorded as a result of the applied factors (Table 3). Satekge et al. (2016) noted a significant increase relative to the control in the diameter of cabbage stems after EM application.

As a result of all the methods of treatment, Effective Microorganisms raised the index of leaf greenness, SPAD, in relation to the control (Table 4).

Table 4

Leaf greenness index (SPAD) of broccoli

Treatments	Year		Mineral fertilization		Mean
	2014	2015	MF1	MF2	
EM0	74.5*a**	79.1	74.7	78.9	76.8*a*
EM1	83.2*b*	82.3	82.9	82.6	82.8*b*
EM2	84.2*b*	82.1	82.2	84.2	83.2*b*
EM3	82.4*b*	80.1	79.9	82.7	81.3*b*
EM4	80.9*b*	83.3	78.3	85.9	82.1*b*
Mean	81.1	81.4	79.6	82.9	81.2

* Values followed by different letters in columns differ significantly at $P \leq 0.05$

The effect of EM was particularly visible in 2014. These results were consistent with the ones obtained by other authors, like Hussein and Joo (2011), who noted that EM treatment of Chinese cabbage seedlings resulted in an increase in the index compared to plants cultivated without EM. Satekge et al. (2016) recorded a significant increase in the chlorophyll content in cabbage leaves when EM were applied.

In broccoli leaves topdressed with boron (MF2), an increase of the greenness index SPAD was also noted for all treatment combinations, but the difference was not statistically significant. Chatterjee and Bandyopadhyay (2017) found a significant increase in SPAD in cowpea after boron application. The increase was directly proportional to the applied doses of boron.

Dry matter content in broccoli curds throughout the research remained similar and amounted to an average of 11.61%. Its smallest content (11.45%)

was found in curds from the EM3 combination, and was the highest (12.26%) in the EM2 combination (Table 5). The differences, however, were not statistically significant.

Nitrabor application (MF2) contributed to a growth of dry matter content by 1.31%, compared to units without it (MF1). A significant increase in dry

Table 5

The content of selected components of nutritive value of broccoli

Treatments	Year		Mineral fertilization		Mean
	2014	2015	MF1	MF2	
Dry matter (%)					
EM0	12.18	11.18	11.15	12.21	11.68
EM1	11.47	11.73	10.81	12.38	11.60
EM2	11.94	12.64	11.76	12.83	12.29
EM3	11.19	11.72	10.78	12.13	11.45
EM4	12.16	12.36	11.52	13.01	12.26
Mean	11.79	11.93	11.20*A*	12.51*B*	11.86
Protein (g kg^{-1} FM)					
EM0	42.6	38.4	41.5	39.4	40.5
EM1	40.7	39.8	40.1	40.3	40.2
EM2	39.1	41.7	39.7	41.1	40.4
EM3	39.7	41.2	39.7	41.2	40.5
EM4	38.7	42.5	40.8	40.5	40.6
Mean	40.2	40.7	40.4	40.5	40.4
Monosaccharides (g kg^{-1} FM)					
EM0	16.8*ab**	15.9	16.0	16.8	16.4*ab*
EM1	17.0*b*	16.2	17.2	16.0	16.6*ab*
EM2	16.7*ab*	15.5	16.1	16.1	16.1*ab*
EM3	15.1*a*	15.7	15.3	15.5	15.4*a*
EM4	17.7*b*	15.9	16.9	16.7	16.8*b*
Mean	16.7*B*	15.9 *A*	16.3	16.2	16.3
Ascorbic acid (mg kg^{-1} FM)					
EM0	675.1	625.1*a*	650.1	650.1*a*	650.1*a*
EM1	682.2	648.8*ab*	684.1*B*	646.9*aA*	665.5*ab*
EM2	684.8	709.5*c*	681.7	712.7*b*	697.2*b*
EM3	663.5	678.8*bc*	671.6	670.7*a*	671.2*ab*
EM4	677.5	657.6*ab*	661.1	674.0*ab*	667.6*ab*
Mean	676.6	664.0	669.7	670.9	670.3

* Mean followed by different lowercase letters in columns and different uppercase letters in rows differ significantly at $P \leq 0.05$; FM – fresh matter

matter content in broccoli curds as a response to boron application was also noted by Islam et al. (2015). Additionally, Ningawale et al. (2016) found an increase in dry matter content in cauliflower curds after borax treatment; however, the increase was not statistically significant.

In the present experiment the average protein content in broccoli curds was 40.4 g kg^{-1} fresh matter. The experimental factors did not have a significant effect on that content in broccoli (Table 5). However, some authors have reported that EM application to vegetables result in an increase in nitrogen and protein content. Thus, following EM foliar application Frąszczak et al. (2012) reported a significant increase in nitrogen content in basil. A similar increase in onion was reported by Fawzy et al. (2012), and an increase in protein content in spinach was found by Shaheen et al. (2017).

The content of monosaccharides in broccoli curds was, 16.3 g kg^{-1} fresh matter on average. Their mean content in 2014 was significantly greater than in 2015 (Table 5). In 2014, the highest amounts of monosaccharides were in broccoli curds from the EM4 combination (17.7 g kg^{-1} FM), being significantly lower in the EM3 combination. The content of monosaccharides in plants treated with the other combinations was similar to that in EM4. On average for both years of the research, the statistically significantly highest amount of monosaccharides was found in broccoli curds treated with EM4.

Boron application did not affect the content of monosaccharides in broccoli curds. Similarly, Patel et al. (2017) did not observe any changes in the content of sugars in broccoli treated with this element. However, Meena et al. (2015) found greater, compared to control, content of monosaccharides and total sugar in tomato fruits treated with boron.

Ascorbic acid (AA) average content in curds was 670.3 mg kg^{-1} fresh matter. In 2014 it was higher by 12.6 mg kg^{-1} than in 2015, but this difference was not statistically significant (Table 5). In 2015 curds of broccoli treated with EM2 and EM3 combinations contained significantly more AA than control without EM. In addition, broccoli from the EM2 plots had higher content of Ascorbic acid than from the EM1 and EM4 ones. Xu Hui-Lian et al. (2001) found that EM stimulated photosynthesis and affected vitamin C and sugar content in tomato fruits. Shaheen et al. (2017) noted a beneficial effect of their use on vitamin C content in spinach leaves. In the present research an interaction was observed between mineral fertilizer and EM treatments. A combined treatment with boron and EM2 significantly increased the content of Ascorbic acid in broccoli curds compared to control as well as compared to EM1 and EM3 treatments. However, in the combination with EM added to nursery substrate at the time of the seedling production (EM1) boron treatment resulted in a decrease in Ascorbic acid content in plants. Compared with the basic treatment, Patel et al. (2017) in broccoli curds and Meena et al. (2015) in tomato fruits did not note significant changes in the vitamin C content after boron application. However, in an experiment carried out by Islam et al. (2015), boron treatment resulted in a statistically significant higher content of AA in broccoli.

The concentrations of the analyzed macronutrients in broccoli (Table 6) were comparable with those reported by Kałużewicz et al. (2016). Average concentrations of P, K, Ca, Mg were 5.44, 22.8, 3.22 and 1.98 g kg^{-1}. The con-

Table 6

The content of selected minerals of broccoli

Treatments	Year		Mineral fertilization		Mean
	2014	2015	MF1	MF2	
Phosphorus (g kg^{-1} DM)					
EM0	5.41	5.52	5.19	5.74	5.46
EM1	5.46	5.74	5.21	6.00	5.60
EM2	5.64	5.71	5.29	6.06	5.67
EM3	5.64	5.72	5.30	6.06	5.68
EM4	3.91	5.65	4.40	5.16	4.78
Mean	5.21*A*	5.67*B*	5.08*A*	5.80*B*	5.44
Potassium (g kg^{-1} DM)					
EM0	22.1*a**	22.2*a*	21.7	22.6	22.1*a*
EM1	23.5*ab*	22.7*ab*	22.7	23.5	23.1*b*
EM2	24.1*b*	24.0*b*	24.0	24.1	24.0*c*
EM3	23.7*b*	24.1*b*	23.9	23.9	23.9*bc*
EM4	23.0*ab*	22.5*a*	22.4	23.2	22.8*ab*
Mean	23.3*B*	23.1*A*	22.9*A*	23.5*B*	23.2
Calcium (g kg^{-1} DM)					
EM0	3.27*a*	3.14	3.27	3.15	3.21*a*
EM1	3.41*b*	3.12	3.30	3.22	3.26*ab*
EM2	3.46*b*	3.18	3.33	3.31	3.32*b*
EM3	3.43*b*	3.18	3.33	3.28	3.30*b*
EM4	3.24*a*	3.20	3.21	3.23	3.22*a*
Mean	3.36*B*	3.16*A*	3.29	3.24	3.26
Magnesium (g kg^{-1} DM)					
EM0	1.86	2.01	1.97	1.91	1.94
EM1	1.89	2.06	1.99	1.96	1.97
EM2	1.92	2.11	2.06	1.96	2.01
EM3	1.95	2.03	2.06	1.92	1.99
EM4	1.90	2.05	1.99	1.96	1.98
Mean	1.90*A*	2.05*B*	2.01	1.94	1.98

* Mean followed by different lowercase letters in columns and different uppercase letters in rows differ significantly at $P \leq 0.05$; DM – dry matter

tent of potassium and calcium in broccoli curds harvested in 2014 was significantly greater, and that of phosphorus and magnesium was significantly lower than in 2015. Statistical analysis of the results indicated a significant effect of Effective Microorganisms on the content of K and Ca in broccoli curds. Plants treated with EM1 had significantly more potassium, and those treated with EM2 or EM3 had significantly more potassium and calcium than untreated broccoli. Similarly, ABOU-EL-HASSAN and EL-SHINAWY (2015) found that red cabbage grown on soil treated with EM-enriched compost contained significantly more K, Ca, and P than plants treated with compost not enriched with EM. NCUBE et al. (2011) argue that the positive effects of EM may consists in the stimulation of microbiological activity and enhancement of the nutrient uptake by plant roots by solubilizing nutrients. KLEIBER et al. (2013) did not find any significant effects of lettuce seed inoculation on macronutrient content in its leaves.

In the present experiment it was found that broccoli topdressed with a fertilizer with the addition of boron contained significantly more phosphorus and potassium. This is consistent with the research of other authors, e.g. DURSUN et al. (2010), who noted an increase in the content of P and K, but also Fe, Mn, Zn, and Cu in tomato, pepper and cucumber as a response to boron topdressing. Similarly, ESRINGÜ et al. (2011) recorded greater concentration of P and K in strawberry plants treated with this chemical element than in untreated ones. Moreover, DURSUN et al. (2010) noted that vegetables treated with boron contained less Ca and Mg. Similarly, the concentration of these elements in the present experiment tended to be lower in broccoli treated with boron than in untreated plants, but those differences were not statistically significant.

CONCLUSIONS

1. The highest broccoli yield was recorded after the application of Effective Microorganisms to the nursery substrate, supplemented with topdressing in the form of spray after seedlings had been planted out. The increased yield was an effect of greener leaves, which in turn resulted in more efficient photosynthetic processes. EM application increased the content of ascorbic acid, potassium and calcium.

2. Boron application increased the yield of plants used in the experiment. By affecting photosynthesis and carbohydrate transport, boron contributed to a substantial increase in the broccoli's marketable yield (by 15.9%), the weight of the curd (by 16.8%), and in dry matter content, in comparison with that recorded in plants treated with mineral fertilizer only, without boron. Boron addition increased phosphorus and potassium concentrations in broccoli.

3. The application of Effective Microorganisms to nursery substrate, combined with topdressing with mineral fertilizer and boron after seedings have been planted out, can be recommended to broccoli producers.

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