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YIELD AND QUALITY OF BEETROOT (*Beta vulgaris* ssp. *esculenta* L.) AS A RESULT OF MICROBIAL FERTILIZERS

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Summary: The purpose of this study is to examine the effect of two different types of microbial fertilizers, namely Micro-Vita I (containing several groups of Azotobacter, nitrifying microorganisms and phosphate-solubilizing microorganisms) and Micro-Vita II (containing Azotobacter, nitrifying microorganisms, phosphate-solubilizing microorganisms and iron), on the yield and quality of beetroot (Beta vulgaris ssp. esculenta, cv Kestrel). Beetroots grown in the field without using microbial fertilizers served as the experimental control. The experiments were conducted in a field located in the village of Jurumleri, near Skopje, characterized by a well-drained and sandy soil, in 2013. The purpose of the study is to determine how different microbial fertilizers influence the production and quality of beetroot. The yields obtained were significantly higher in the beetroot grown using Micro-Vita II (69.43 t ha^{-1}) and Micro-Vita I (58.13 t·ha^{-1}) fertilizers, compared to the control yield (54.8 t/ha). The beetroot grown under the Micro-Vita I regime indicated significantly higher contents of vitamin C (6.86%), cellulose (13.79%) and protein (18.18%) compared to the control crops. Furthermore, the beetroot grown under the Micro-Vita II regime indicated significantly higher contents of vitamin C (14.71%), cellulose (27.59%), protein (44.62%), minerals (6.25%) and Fe (100%) compared to the control crops. According to the results obtained, the application of microbiological fertilizers is recommended for beetroot (cv. Kestrel), with regard to the beetroot quality and bioactive compounds, and can be used in organic farming.

Keywords: beetroot, microbial fertilizers, yield, chemical composition

INTRODUCTION

Red beetroot (*Beta vulgaris L. ssp. vulgaris, Chenopodiaceae*) is a very important vegetable crop grown all over the world. From the health perspective, the content of minerals and pigments in beetroot is of paramount importance. These pigments belong to the groups of red-violet betacyanins and yellow betaxantins. They effectively inhibit lipid peroxidation, especially betanine, and exhibit some anticarcinogenic, antibacterial and antiviral activity (Kanner et al., 2001). Red beets are the main source of beta-cyanins, which are used in the food industry as natural food dyes (Szalaty, 2008). Beetroot and other root vegetables feature many beneficial properties important in the human diet, i.e. they are relatively cheap, can be locally produced worldwide and stored for a long period (Ilić and Fallik, 2002). Its cultivation does not cause any problems, and the good storability of beetroots ensures the availability of fresh product throughtout the year, without the need of applying expensive storage equipment. Red beets are also widely used in the food industry.

Beetroot fertilization must meet the ecological requirements, i.e. an overall decrease in fertilization and an increase in plant productivity and protection. Moreover, suitable and optimal fertilization methods and fertilizer types should be used on a bigger scale. Growing foliage needs a lot of nitrogen, whereas root crops necessitate potassium and phosphorus. The method of cultivation had a significant effect on the chemical composition of fresh beetroots (Kosson et al., 2011). The productivity of beetroot, regardless of its cultivars and types, also increases with the application of nitrogen fertilizers (Ugrinović, 1999).

It is recommended that red beetroot be cultivated using the integrated fertilization of 75% biofertilizer/yeast and 25% chemical fertilizer, and harvested in the second stage to achieve considerably high values of growth parameters and bioactive metabolites (Farouk and Sharawy, 2016). Vegetable waste composts and standard organic fertilizer, i.e.

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manure, exerted a minor effect on the yield of plants. However, the aim of organic fertilization is not only to increase yields, but also to enrich the soil with organic matter and improve its physical properties. As argued by Paavola and Rintala, the replacement of fresh natural fertilizers with fermented masses or composts considerably reduces the emission of noxious odors and the spread of pathogens. It also reduces the penetration of nitrates into the soil profile, which results in better quality plant yields. The favorable yield-forming effect of *Trichoderma sp.* isolates, which were applied to the soil in the vegetable waste composts in our study, provides new possibilities of acquiring valuable organic fertilizers for growing red beets.

Under high-fertility soil conditions, the application of ecological foliar fertilizers, containing macro and micro biogenic elements and plant extracts without soil fertilization, results in an average beetroot yield of 68.98 t/ha (Markoski et al., 2015).

The purpose of this study is to determine the differences in the content of basic quality components of red beetroots cultivated using microbial fertilizers.

MATERIAL AND METHODS

The experiments were conducted in the open alluvial field in the village of Jurumleri, near Skopje, in 2013. Hybrid 'Kestrel' beetroots (*Beta vulgaris* ssp. *esculenta*) were used as plant material.

The following two types of microbial fertilizers were used for the treatment of beetroots: Micro-Vita I, containing several groups of *Azotobacter*, nitrifying microorganisms and phosphate-solubilizing microorganisms, and Micro-Vita II, containing several groups of *Azotobacter*, nitrifying microorganisms, phosphate-solubilizing microorganisms and a balanced ratio of iron.

The experiments were based on the type of microbiological fertilizer:

1. Ø Control - without fertilization
2. Experiment 1 - a treatment with the Micro-Vita I microbial fertilizer
3. Experiment 2 - a treatment with the Micro-Vita II microbial fertilizer

The application of the fertilizers was foliar (using a sprinkler) in the vegetation period. The solution (100 ml of fertilizers in 10 L of water) was made every 7 days. The application of both fertilizers began on 25 May, and the last application was performed on 24 August.

The effect of microbial fertilizer application on beetroots was determined on the basis of the following parameters:

- Yield (t/ha),
- Water and dry matter content determined by drying the fresh plant material at a temperature of 105ºC to constant weight,
- Content of vitamin C determined by using the Mury method (Vracar, 2001),
- Protein content converted into the percentage of total nitrogen x 6.25 (Jekić et al., 1988),
- Cellulose content determined by using the Hoffman method (Jekić et al., 1988),
- Determination of the total minerals with the combustion of air dry materials at a temperature of 500 to 550°C to constant weight (Sarić, 1986),
- Iron content using the atomic absorption spectrophotometry.

The results obtained were analyzed using the appropriate descriptive statistical methods, the analysis of variance and the R statistical software.

RESULTS AND DISCUSSION

Microbiological fertilizers (Micro-Vita) stimulate the development of the root system, improve blooming, and facilitate photosynthesis and fertility. They significantly improve the utilization of cations and anions from the soil, as well as the fertility, microbiological composition and water-air regime of the soil. Moreover, microbiological fertilizers improve the resistance of plants to bacterial and fungal diseases, thus reducing the need for chemical agents.

Beets can be removed from the soil with large breaks from one harvest to another, depending on the size of the root and its purpose. During harvest delays, the root continues to grow and thus increases the total yield. Early planted beetroot usually comes out in 80 to 110 days and can produce yields from 15 to 25 t/ha. Beets for processing and storage with a vegetation period of 110 to 150 days can produce yields from 30 to 50 t/ha (Černe, 1981). Table 1 shows the beetroot yields obtained in the two experiments conducted relative to the control yields.

Table 1. Yields (*t ha*$^{-1}$) of beetroot based on the application of microbial fertilizers

	Control	Micro-Vita I	Micro-Vita II
Average yield	54.80	58.13	69.43
Difference between the control and the experiments		3.33	14.63*
Difference between Experiment 1 and 2			11.30*
Index (%)	100.00	106.07	126.70
Standard deviation	3.96	6.73	3.92
Coefficient of variation (%)	7.22	11.57	5.65
	$LSD_{0,05}$= 8.07		

According to the data in Table 1, the control crops indicated the lowest average yield of 54.80 *t ha*$^{-1}$, followed by the crops treated with Micro-Vita I (with a yield of 58.13 *t ha*$^{-1}$), whereas the highest yield was recorded in the crops treated with Micro-Vita II totaling 69.43 *t/ha*$^{-1}$. The yield obtained with Micro-Vita I was 6.07% higher than the control yield, whereas the yield obtained in Experiment 2 was 26.70% higher than the control yield. The coefficient of variation was the lowest (5.65%) for Experiment 2, followed by the control coefficient of variation (7.22%), whereas the highest coefficient of variation (1.57%) was computed for Experiment 1.

Table. 2. Chemical composition of the control and experimental beetroots

Experiment / Component	Control	Experiment 1	Experiment 2
Water (%)	91.70	91.02	90.89
Index (%)	100.00	99.26	99.12
Dry matter (%)	8.30	8.98	9.11
Index %	100.00	108.19	109.76
Vitamin C (mg/100 g)	10.20	10.90	11.70
Index %	100.00	106.86	114.71
Cellulose (%)	0.29	0.33	0.37
Index %	100.00	113.79	127.59
Proteins (%)	0.55	0.65	0.94
Index %	100.00	118.18	144.62
Mineral matters (%)	0.96	0.99	1.02
Index %	100.00	103.13	106.25
Fe (mg/100 g)	0.2	0.2	0.4
Index (%)	100.00	100.00	200

Owing to its chemical composition, beetroot is much appreciated and widely used in the human diet. The following constituents are found in 100 g of beetroot: 82.9 to 91.7% water, 0.11 to 2.0% crude protein, 0.1-0.3% crude fat, from 4 to 14.4% carbohydrates, 4.3% sugar, 0.9-1.1% fiber and from 0.77 to 1.1% minerals. The following minerals are found in 100 g of fresh beetroot: 43-100 mg of sodium, 230-370 mg of potassium, 2-28 mg of magnesium, 30-66 mg of phosphorus, 0.5-1.73 mg of iron and 18 mg of sulfur. With regard to the beetroot vitamin content, vitamin C amounts to 8-36 mg/100 g, followed by carotene (0.01 to 0.12 mg/100 g), vitamin B_1 (0.02-0.11 mg/100 g), vitamin B_2 (0.02-0.12 mg/100 g), vitamin B_3 (0.04-0.4 mg/100 g), and vitamin B_6 (0.05 mg/100 g) (Lešić et al. 2002).

Table 2 shows the chemical composition obtained in the control and experimental beetroot.

According to the data in Table 2, the highest water content of 91.70% was determined in the control beetroot, followed by the beetroot in Experiment 1 (91.02%), whereas the lowest water content was determined in the Experiment 2 beetroot (90.89%). According to the index indicators, the beetroot water content in Experiment 1 was 0.74% lower than the control beetroot water content, whereas the beetroot water content in Experiment 2 was 0.88% higher than the control beetroot water content.

The highest dry matter content of beetroot was recorded in Experiment 2 (9.11%), followed by Experiment 1 (8.98%), whereas the lowest dry matter content was recorded in the control beetroot (8.30%). According to the index indicators, the beetroot dry matter content in Experiment 1 was 8.19% higher the control beetroot dry matter content, whereas the beetroot dry matter content in Experiment 2 was 9.76% higher than the control beetroot dry matter content. According to Ilić (1995), beetroot contains 9-12% dry matter.

According to the data displayed in Table 2, the highest beetroot vitamin C content was recorded in Experiment 2 (11.70 mg/100 g). The beetroot vitamin C content recorded in Experiment 1 was 10.90 mg/100 g, whereas the control vitamin C content was 10.20 mg/100 g. The index indicators show that the vitamin C content in Experiment 1 was 6.86% higher than the control vitamin C content, whereas the vitamin C content recorded in Experiment 2 was 14.71% higher than the control vitamin C content. The content of beetroot vitamin C in our study is consistent with the previous data, since, according to Đinović (1998), the content of vitamin C in the beetroot is from 4 to 20 mg/100 g (usually 10 mg/100 g), whereas, according to Vraćar (2001), vitamin C in beetroots approximates to 10 mg/100 g.

The highest percentage of beetroot cellulose was recorded in Experiment 2 (0.37%), followed by Experiment 1 (0.33%), whereas the control beetroot indicated the lowest content of cellulose (0.29%). The index indicators show an increase in the content of cellulose compared to the control beetroot by 13.79% in Experiment 1 and 27.59% in Experiment 2. According to Ilić (1995), cellulose is the most abundant polysaccharide in the beetroot (0.9%).

The lowest protein content was recorded in the control beetroot (0.55%). The beetroot protein content recorded in Experiment 1 was 0.65%, which is 18.18% higher than the control beetroot protein content. The highest protein content of 0.94% was observed in Experiment 2, which is 44.62% higher than the control beetroot protein content. According to Vračar (2001), the protein content in the beetroot is 1.3%.

The total beetroot mineral contents obtained were 0.96% (the control), 0.99% (Experiment 1) and 1.02% (Experiment 2). The content of beetroot mineral matters in Experiment 1 was 3.13% higher than the control beetroot mineral content, whereas the beetroot mineral content recorded in Experiment 2 was 6.25% higher than the control beetroot mineral content.

The environment has a great effect on the beetroot micronutrient content. The highest average red beetroot micronutrient content includes 270 mg $Fe \cdot kg^{-1}$ in dry matter, 96 mg $Zn \cdot kg^{-1}$ in dry matter, and 53 mg $Mn \cdot kg^{-1}$ in dry matter). On balance, a general decreasing trend was recorded in the contents of the micronutrients analyzed (iron, manganese and zinc) with the NPK 5-20-30 fertilization (and by the application of high doses of potassium). This was certainly a result of antagonistic activities between the investigated elements and potassium (Petek et al., 2017).

The same amount of iron was recorded in the control and Experiment 1 beetroots (0.2 mg/100 g), whereas in Experiment 2 (where the microbiological fertilizer with the addition of iron was applied) the content of beetroot iron increased by 100%, i.e. the iron content amounted to 0.4% mg/100 g. Vračar (2001) argued that the iron content of beetroot amounts to 0.6 mg/100 g.

CONCLUSION

According to the results obtained, the following conclusions can be drawn: the highest yield of beetroot was obtained using the fertilizer Micro-Vita II, which was 26.70% higher than the control yield. The yield of beetroot obtained using the Micro-Vita I fertilizer was 6.07% higher than the control yield. A statistically significant difference was found between the control and Micro-Vita II beetroot yields (14.63 t ha^{-1}), as well as between the Micro-Vita I and Micro-Vita II beetroot yields (11.30 t ha^{-1}). Significantly higher contents of vitamin C (6.86%), cellulose (13.79%) and protein (18.18%) were recorded in the beetroot treated with the fertilizer Micro-Vita I compared to the control beetroot. Furthermore, significantly higher contents of vitamin C (14.71%), cellulose (27.59%), protein (44.62%), minerals (6.25%) and Fe (100%) were recorded in the beetroot treated with the fertilizer Micro-Vita II compared to the control beetroot. According to the experimental results, the application of microbiological fertilizers leads to a significant increase in beetroot yields and a notable improvement of the beetroot chemical composition.

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