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The influence of microbial inoculums on yield and yield components of rocket (*Eruca sativa* Mill.)

Zvezda Bogevska[1]*, Olga Najdenovska[1], Marina Stojanova[1], Monika Stojanova[1], Dejan Ristikj[1]

original scientific paper (izvorni znanstveni rad)

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Abstract

The use of microbial inoculums can improve growth and yield of plants without use of agrochemicals which can result in obtaining quality food. Rocket is widely grown for spice and salad in the areas of Mediterranean Sea. Having in mind the importance of rocket in human diet the research was carried out in rocket grown in unheated protected houses. The experiment included four variants as follows: variant 1 control – untreated variant; variant 2 – treated with application of inoculum from the product Uniker into the soil before the sowing of the rocket; variant 3 – treated with application of inoculum from two different products Uniker and Slavol S before sowing of the seeds, whereby Slavol S was applied by immersion of the seeds for five minutes before sowing, and Uniker was applied in the soil before the sowing of the rocket; variant 4 – treated with foliar application of live cells of bacteria *Azotobacter sp*. (10-6 cfu/ml) every fifteen days during vegetation. During the vegetation total yield (t/ha) and yield components were measured. The results showed that the highest average yield (22.30 t/ha) was achieved by variant 4. Also the highest average value for the weight of the whole plant (4.22 g), root weight (0.50 g), rosette weight (3.73 g) and leaves weight (2.50 g) was obtained by variant 4. The highest average value for the number of leaves was measured in variant 3 (6.13) while the root length was highest in control variant (116.70 mm).

Key words: rocket, microbial inoculums, yield, yield components.

Introduction

Rocket is used as salad and spice in human diet. Nutritional value of 100 g fresh rocket is as follows: water 91.7 g, fat 0.66 g, carbohydrates 3.7 g, proteins 2.6 g, fibers 1.6 g (Nyzinska-Wierdak, 2015). Having in mind the nutritional value of rocket nowadays there is a high interest in finding different technologies of production or adequate measures during production in order to increase yields and

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quality of the rocket. In conventional production on soil the average yields of rocket are 2 kg/m^2 (Lešić et al., 2004; Đurovka, 2008). Modern soilless technologies like floating hydroponics showed that the average yields of rocket reached 4.25 kg/m^2 (Geršak et al., 2012). Jakše et al. (2013) found that the best yield was obtained in vermiculite and perlite in the cells of volume 20 ml (2.13 and 1.89 kg/m^2). Microbial fertilizers represent an attractive replacement for chemical fertilizers that are polluting the environment and are used to increase the crop yield in an eco-friendly way while relying on sustainable agriculture principles (Najdenovska and Gjogjevikj, 2009; Najdenovska, 2012; Stamenković et al., 2018). Many authors have confirmed positive effect of inoculation of plants using different microorganisms on yields of different crops (Dobbelaere et al., 2001; Govedarica et al., 2002; Mrkovački et al., 2007; Yazdani et al., 2009; García de Salamone et al., 2012**;** Hajnal-Jafari et al., 2012; Marks et al., 2015). Thus the objective of the research was to determine the influence of microbial inoculums on yield and yield components of rocket.

Material and methods

The experiment was carried out in the village Lisice in Skopje. The rocket (*Eruca sativa* Mill.) was grown for autumn – winter production in unheated plastic tunnel. The rocket was sown on 19th of November in nests with more than 10 seeds per nest with black foil as mulch. The distance between rows was 25 cm and 20 cm between the nests in the row. All variants sprouted on 26th of November. During the vegetation rocket was irrigated without adding additional fertilizers and pesticides. The experiment included four variants, each variant in 3 repetitions in random block system. The variants of the experiment were:

- Variant 1 control – untreated variant;
- Variant 2 – treated with application of inoculum from the product Uniker into the soil before the sowing of the rocket;
- Variant 3 – treated with application of inoculum from two different products Uniker and Slavol S before sowing of the seeds, whereby Slavol S was applied by immersion of the seeds for five minutes before sowing, and Uniker was applied in the soil before the sowing of the rocket;
- Variant 4 – treated with foliar application of live cells of bacteria *Azotobacter sp*. (10^{-6} cfu/ml) every fifteen days during vegetation.

The product Uniker contains effective strains of proteolytic and cellulolytic bacteria that decompose the hardly-soluble compounds of carbon, nitrogen and phosphorus in the soil while the product Slavol S contains bacterial auxin (IAA or indole-3-acetic acid) and rhizobacteria.

The yield was measured after 90 days of sprouting using digital balance in the field. Randomly was selected 30 plants per variant and in the laboratory several yield components (biometrical parameters) were measured: weight of the whole plant (g), root length (mm), root weight (g), weight of the rosette (g), number of the leaves and leaves weight (g).

The results were statistically processed with analysis of variance (ANOVA) using SPSS.

Results and discussion

The yield is a significant indicator of the profitability and economic justification of the cultivation of each agricultural crop. The yield is directly dependent on the biological properties of the variety, the method of cultivation, the agro-ecological conditions as well as the applied agrotechnical measures including the foliar application of nutrients (Vural et al., 2000). The advantage of foliar nutrition is that the utilization of nutrients does not depend on the soil moisture content, the pH of the soil and other chemical and physical properties of the soil (Hanelt, 2001).

From the data in Table 1, the positive effects of the use of different types of microbial inoculums as well as the different ways of application in the production of the rocket can be established. Higher average yield compared to the control variant was achieved in variant 3 (21.80 t/ha) and variant 4 (22.30 t/ha). In variant 2, the achieved average yield of 20.60 t/ha was for 0.4 t/ha lower than control variant (21.70 t/ha). Differences in the obtained average yield also exist among the individual variants. The highest average yield was obtained in variant 4 (22.30 t/ha).

Table 1. Rocket yield t/ha (Ristikj, 2019)
Tablica 1. *Prinos rige t/ha (Ristikj, 2019)*

Repetition	Variant 1 Control	Variant 2 Uniker	Variant 3 Slavol S + Uniker	Variant 4 *Azotobacter* sp.
I	21.40	21.00	22.00	21.90
II	20.90	20.30	22.00	22.20
III	20.70	20.50	21.30	22.80
$\bar{x}$ ± SD	21.0^{a}± 0.36	20.6^{a} ± 0.36	21.8^{b} ± 0.43	22.3^{b} ± 0.45

[a, b] – the values marked with different letters have a statistically significant difference between the examined variants ($p<0.05$)

Higher yield in the treated variants is due to the activity of the used microbial inoculums that influence the intensified adoption of the nutrient elements of the soil, resulting in better nutrition of the plants which allows greater production of organic matter that eventually affects the increase in yield.

Statistically significant differences ($p < 0.05$) were found in variant 3 and variant 4 compared to the control variant. Variant 2 does not differ statistically from the control variant.

The application of bio-products leads to higher plant productivity and improvement of their quality. Bio-products are characterized by a wide range of effects, and their greatest efficacy is manifested in vegetable and fodder crops (Đukić et al., 2006).The highest yield obtained in variant 4 is due to the action of the applied microbial inoculum *Azotobacter chroococcum*. This is explained by the fact that this bacteria has the ability to synthesize many biologically active compounds – nicotine and pantothenic acid, pyridoxine, biotin, heteroauxin, *gibberellins* and a variety of other compounds. The complex of these substances influences the stimulation and acceleration of the growth and development of plants under favorable environmental conditions (Đukić et al., 2007). Mrkovački *et al.* (2007) found out that the application of *Azotobacter chroococcum* increase sugar beet yield by 7 % and crystal sugar yield by 6 %. Our findings are similar as in variant 4 foliar application of microbial inoculum *Azotobacter* (10^{-6} cfu/ml) gave 6 % higher yields than control variant. Dursun et al. (2008) examined the influence of various microbial inoculums on the chemical composition, yield, and biometric parameters of the rocket. The highest average yield of 4586.54 g/m^2 was determined in the variant with the use of microbial inoculum *Pseudomonas putidae* BA - 8.

Pimentel et al. (2010) examined the influence of different doses of farmyard manure on the yield of rocket. The highest yields (31.636 t/ha) were found in the variant using 160 N·ha^{-1} by using cow manure.

Barros Júnior et al. (2011) evaluated the effect of nitrogen fertilization on intercropping of lettuce and rocket. The maximum rocket yield (14435.78 kg/ha) was obtained with the combination of 195 kg·ha^{-1} of N for lettuce and 180 kg·ha^{-1} of N for rocket.

Pimpini and Enzo (1997) found that the average yield of rocket in protected areas in Veneto, Italy was 18 t×ha^{-1} while on the other hand Varga et al. (2009) pointed out that the yield of rocket under protected houses varied from 1.68 to 5.14 kg/m^2 at the second harvest 38 days after plant emerge.
The various types of microbial inoculums as well as the different ways of application have shown a positive influence on the yield components (biometric parameters) of the rocket. In most of the examined parameters, better results in treated variants compared to control were achieved (Table 2).
Variant 3 (3.78g) and variant 4 (4.22 g) showed better results for the weight of the whole plant compared to the control variant (3.72 g). The average weight of the whole plant in variant 2 (3.57 g) was lower than the control variant. The highest average weight of the whole plant was achieved in the variant 4.

In terms of the parameter length of the root highest average value (116.70 mm) was obtained in control variant. All treated variants showed lower average values in comparison to control variant. Among treated variants, the highest average value (101.10 mm) was determined in rocket plants of variant 4.

Higher average values of root weight were measured in plants of variant 3 (0.46 g) and in variant 4 (0.50 g) compared to the control variant (0.34 g). Lower average value of root weight (0.31 g) was obtained in variant 2 in comparison the control variant.

The highest average value for the weight of the rosette was determined in variant 4 (3.73 g). In variant 2, the obtained average value for weight of the rosette (3.26 g) was lower in relation to the control variant. Positive influence of microbial inoculum for the parameter number of the leaves was found in the plants of variants 3 and 4. The highest average value for the number of leaves was found in variant 3 (6.13). The number of leaves in variant 2 was lower compared to the control variant. The highest average value for the leaves weight was obtained in variant 4 (2.50 g) compared to the control variant. In variant 2, the average leaves weight of 1.87 g was lower than the control variant (1.95 g).

Table 2. Average values for yield components (biometrical parameters) of rocket plants (Ristikj, 2019)
Tablica 2. *Prosječne vrijednosti za prinosne komponente (biometrijski parametri) rige (Ristikj, 2019)*

Variant	Weight of the whole plant (g)	Root length (mm)	Root weight (g)	Weight of rosette (g)	Number of leaves	Weight of leaves (g)
	$\bar{x}$ ± SD	$\bar{x}$ ± SD	$\bar{x}$ ± SD	$\bar{x}$ ± SD	$\bar{x}$ ± SD	$\bar{x}$ ± SD
Variant 1 Control	3.72^{ab} ± 1.58	116.70^{b}± 20.02	0.34^{a} ± 1.76	3.38^{a} ± 1.48	5.97^{ab} ± 1.31	1.95^{a} ± 0.85
Variant 2 Uniker	3.57^{a}± 0.39	88.30^{a}± 10.31	0.31^{a}± 0.09	3.26^{a}±0.49	5.10^{a} ± 0.51	1.87^{a} ± 0.34
Variant 3 Slavol S + Uniker	3.78^{b} ± 1.55	100.67^{b}± 23.45	0.46^{a} ± 1.90	3.53^{ab} ± 1.47	6.13^{b} ± 1.33	2.21^{b} ± 1.70
Variant 4 *Azotobacter sp.*	4.22^{c} ± 1.45	101.10^{ab}± 16.49	0.50^{a} ± 1.75	3.73^{b} ± 1.68	5.90^{b} ± 1.26	2.50^{b} ± 1.21

$^{a, b}$ – the values marked with different letters have a statistically significant difference between the examined variants ($p<0.05$)

Statistically significant difference ($p<0.05$) about the weight of the whole plant had variant 4 in comparison to control variant, variant 2 and variant 3. Also, variant 3 had statistically significant differences ($p<0.05$) in comparison to control, variant 2 and variant 4. In terms of root length, variant 2 statistically significant ($p <0.05$) differs from the control variant and variant 3. For the biometric parameter root weight, no statistically significant differences among the examined variants was found. Variants 3 and 4 statistically significant ($p <0.05$) differ from the control variant with respect to the

parameter weight of the rosette and number of leaves. As for the leaves weight, variants 3 and 4 differ significantly ($p < 0.05$) from the control variant, as well from variant 2.

Jakše et al. (2013) examined the influence of NPK fertilizers in combination with biostimulators on the yield and biometric parameters of the rocket, and found that the average height of the plant in the first harvest was 11,6 cm, while the second harvest was 13.7 cm and in the third harvest 11.3 cm. The weight of the leaves was 2.4 g in the first harvest, 2.3 g in the second harvest, and 1.7 g in the third harvest which is similar to our findings. Dursun et al. (2008) examined the influence of various microbial inoculums on the chemical composition, yield and biometric parameters of the rocket. The highest average weight of leaves (1.63 g), the length of the leaf (27.48 cm), the surface of the leaf (93.57 cm^2) and the root weight (0.60 g) were obtained from *Pseudomonas putidae* BA - 8. In a research of Cavarianni et al. (2008) tested rocket varieties "Selvatica", "Folhalarga" and "Cultivada" developed an average 8.83, 10.47 and 11.45 leaves which are higher in comparison to current findings.

Conclusion

According to the results of the research it can be concluded that the application of different types and ways of application of microbial inoculums can be applicable in the production of rocket. In practice for further use, can be recommended variant 4 (foliar application of living cell isolate from the *Azotobacter* (10^{-6} cfu/ml) every 15 days during vegetation).

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