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Effect of biofertilizers on yield and morphological parameters of onion cultivars

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ABSTRACT

The present study evaluated the effect of different organic fertilizers on the morphological parameters and yield in two different onion cultivars. Proper use of organic fertilizers in appropriate amounts could be helpful to growers from the economic point of view. Field experiments were conducted to study the effect of three different organic biofertilizers on yield and morphological parameters of two onion cultivars 'Stuttgarter Riesen' and 'Rote Laaer' during 2016 and 2017. The investigated treatments included: B-Stimul® – a mixture of bacterial and algal extracts, EkoBooster 2® – organic matter and NPK, and VermiFit A® – an extract of compost produced by Californian earthworms, peat, nutrients, plant hormones, enzymes, amino acids, and sugars. The following parameters of onion plants were evaluated: number of leaves, bulb diameter, bulb weight, marketable and total yields. The study showed that all the results were affected by the growing season (higher values were recorded in 2016). In 'Stuttgarter Riesen', EkoBooster 2® application resulted in the highest bulb weight in 2016 (67.16 g) and in 2017 (55.17 g) and in the highest number of leaves in 2016 (6.66) and in 2017 (6.30), which led to the highest marketable bulb yield in 2016 (3.47 kg m^{-2}) and in 2017 (2.53 kg m^{-2}). In 'Rote Laaer' in 2016, EkoBooster 2® application resulted in the highest number of leaves (7.06), bulb diameter (54.32 mm) and bulb weight (79.30 g). In 2017, the largest bulb diameter (54.13 mm) and the highest bulb weight (71.79 g) and marketable bulb yield (2.39 kg m^{-2}) were determined after VermiFit A® application. EkoBooster 2® showed the best effect on parameters such as the number of leaves, bulb weight, and marketable bulb yield of the cultivar 'Stuttgarter Riesen' and positively affected the parameters of 'Rote Laaer' during 2016, while in 2017 VermiFit A® showed better results as compared to the other treatments.

Key words: *Allium cepa*, bulb diameter, bulb weight, number of leaves

INTRODUCTION

Modern agriculture tends to use organic fertilizers instead of chemical preparations and ensures the production of quality vegetables in this way. Organic manures can serve as an alternative to mineral fertilizers and also as soil structure improvers (Dauda et al., 2008). The onion plant has a shallow and unbranched root system and because of that it is more susceptible to nutrient deficiencies than most crop plants. Proper soil fertility is very important in onion production. Nutrient requirements vary with location, genotype and soil type. Yassen and Khalid (2009) showed that all organic fertilizer treatments involving the use of a mixture of farmyard and chicken manures improved vegetative growth characteristics of onion plants, some of the main constituents of essential oil and NPK content. Excess nitrogen also causes onion bulbs to be more susceptible to storage pathogens. Adequate potassium levels are

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especially important in improving bulb quality and storage life. According to Fawzy et al. (2016), the positive economic effect of liquid organic fertilizers on agriculture may be a factor in extending their use over larger areas. Organic fertilizers produced from earthworm-digested organic waste are rich in NPK, micronutrients, beneficial soil microbes, nitrogen fixing and phosphate solubilizing bacteria and *Actinomycetes* (Sharma and Agarwal, 2014). Additions of compost have increased microbial activity and biomass of onion plants (Verma and Marschner, 2013). Inoculants containing microorganisms or plant growth promoting rhizobacteria (*Bacillus* spp.) have helped to reduce the use of inorganic fertilizers and contributed to improving soil fertility (Adesemoye et al., 2009). Čolo et al. (2014) showed that by using *Azotobacter chroococcum*, *Bacillus subtilis* and a mixture of these inoculants, bulb weight and the yield of onion bulbs significantly increased compared to variants with two strains of *Pseudomonas fluorescens* and the control. According to Compant et al. (2010), PGPB produce vitamins and other biologically active compounds which stimulate plant growth. Many studies have shown a positive effect of farmyard manure (Yoldas et al., 2011; Gadelrab and Elamin, 2013; Adeyeye et al., 2017) and also a positive influence of combinations of organic and inorganic manures on the growth and yielding of onion and tomato plants (Kokobe et al., 2013; Ilupeju et al., 2015; Islam et al., 2017), but there is still a lack of information on how organic fertilizers with a mixture of bacterial and algal cultures as well as earthworm-digested compost and organic matter influence plant growth and yield.

The aim of the study was to evaluate the effect of three different organic fertilizers on related parameters and yield of two different onion cultivars.

MATERIAL AND METHODS

The experiments were done during 2016 and 2017 in the experimental field of the Faculty of Horticulture in Lednice, Mendel University in Brno, the Czech Republic, (48°47'36"N, 16°47'48"E). Seeds of two onion cultivars, 'Stuttgarter Riesen' and 'Rote Laaer', produced by Permaland (Czech Republic) were used in the trials. The experimental treatments involved the application of three organic fertilizers: B-Stimul®, EkoBooster 2® and VermiFit A®. B-Stimul® (Rawat, Czech Republic) contains a mixture of the following bacterial and algal cultures: *Azospirillum*, *Azotobacter*, *Bacillus*, *Chlorella vulgaris* and *Herbaspirillum* at a concentration of 107 cfu g^{-1}. EkoBooster 2® (Ekopatent, Serbia) contains organic matter – 7.8%, N – 9%, P – 1%, K – 4%. VermiFit A® (Primrose, Czech Republic) is an extract of compost produced by Californian earthworms (*Eisenia foetida*), peat, nutrients in available forms, plant hormones, enzymes, amino acids and sugars. The composition is as follows: pH (H_2O) – 8.2, total N – 1.9%, total K as K_2O – 35.6%, total P as P_2O_5 – 2.8%, dry matter – 0.95%. The trials were conducted according to the Latin square system in four repetitions. Sowing was done on 15th March (in both years), into containers in a greenhouse. The substrate for sowing was ProfiMix, produced by Agro CS (Czech Republic). The seeded containers were kept in the greenhouse under optimal temperature and were provided with an irrigation system for plant germination and growth. Sticky tapes were used for the protection against insects. The seedlings, when they were nearly fifty days old and about 25 cm in height, were moved to the experimental field for transplanting on 4th May 2016 and 10th May 2017. According to the fertilizer producers' instructions, the fertilizer VermiFit A® was applied four times during the vegetation period, while B-Stimul® and EkoBooster 2® three times. In both years, the treatments involved foliar spraying with the following doses per 1 m^2: VermiFit A® – 0.4 ml in 39.6 ml of water, B-Stimul® – 3.38 g in 3.38 l of water, EkoBooster 2® – 0.125 ml in 25 ml of water. During 2016, each cultivar covered 16 plots with a size of 4 m² each. The spacing was 0.3 × 0.035 m (270 plants per plot). For the protection against diseases, the fungicide Flowbrix (AgroProtec, Czech Republic) was used at a dose of 2.5 L ha^{-1} in 400 L of water. It was applied twice: on 22nd June 2016 and on 7th July 2016. Harvesting was done manually on 6th August 2016. During 2017, the total size of the experiment was 115.2 m², 32 plots at 2 × 1.8 m each. The spacing was 0.3 × 0.035 m (210 plants per plot). In 2017, there were no symptoms of diseases or pests on the onion plants in the field. Harvesting was done manually on 12th August 2017. During 2016 and 2017, before transplanting, samples of soil were taken for the determination of the levels of N, P, K, Ca, Mg and pH (Tab. 1). The samples for agrochemical analyses were taken from a depth of 0.3-0.6 m on 22nd March 2016 and 2017. The samples were taken from 3 different places in the field. Meteorological data, such as the amount of precipitation (mm), sunshine duration, defined as the number of sunny hours (Fig. 1), and

air temperature (minimum, maximum and average) (Fig. 2), were recorded with automatic sensors located near the experimental field. Irrigation with sprinkles was applied during the vegetation period according to weather conditions. The parameters which were determined were: bulb diameter (the widest part of a bulb) (mm), bulb weight (g), and the number of leaves, as well as yield (marketable and total). The number of leaves per plant was determined on fifteen selected plants during the vegetation period on 11th July 2016 and 2017, while bulb diameter (mm) and bulb weight (g) as well as yield were determined after harvest on all the plants transplanted from the pots, in the laboratory of the Faculty of Horticulture in Lednice, Mendel University in Brno, the Czech Republic.

Determination of yield (marketable and total)

The economic parameters were determined by evaluating marketable bulb yield per plot, recalculated as yield in kg m^{-2}. Onion bulbs were cleaned of roots and leaves before weighing. The quality of the crop was evaluated according to the Czech quality standards (ČSN 46 3161).

Soil analysis

Soil analysis showed a pH (H_2O) of 7.18 in 2016 and 7.16 in 2017 at the depth of 0.3 m. According to the agrochemical analyses in 2016, the N content was lower than what is usually required by onion

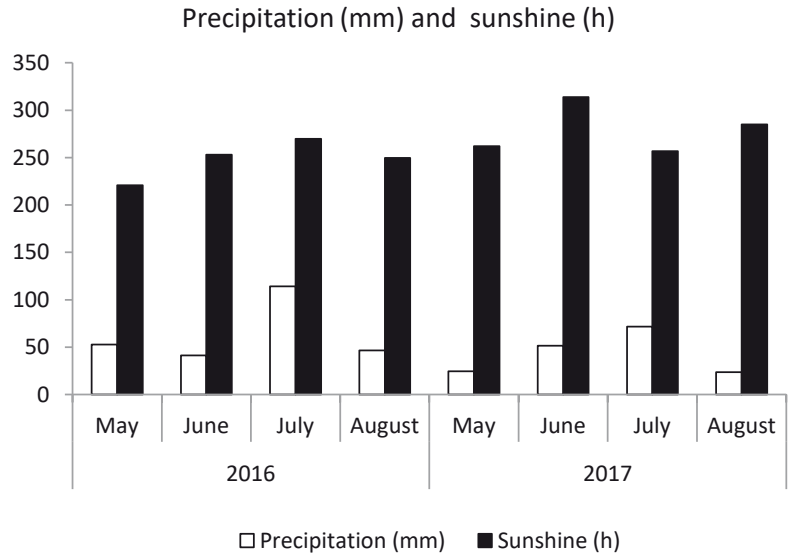

Figure 1. Amount of precipitation (mm) and sunshine duration (h) during the vegetation period in 2016 and 2017

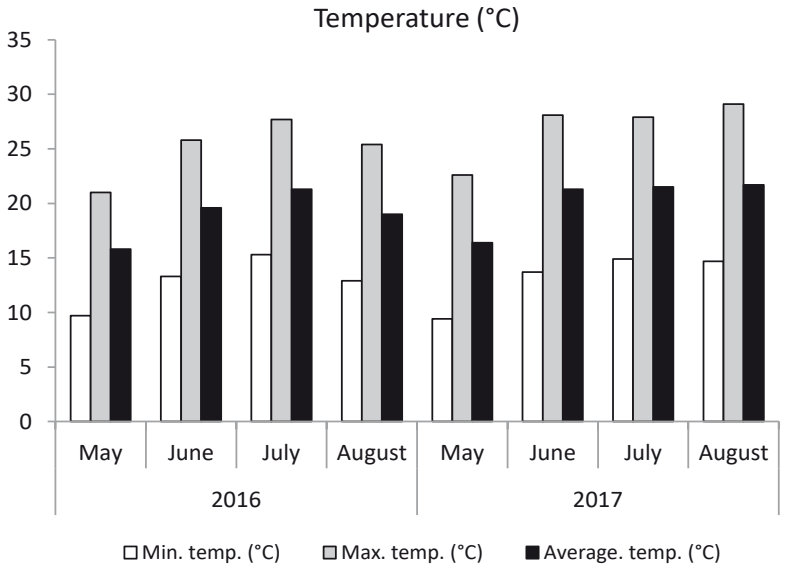

Figure 2. Variations in the average minimum and maximum temperatures (ºC) during the vegetation period in 2016 and 2017

Table 1. Soil element content (mg kg^{-1}) in the 0-30 cm layer of the experimental field in 2016 and 2017

Year	N	P	K	Ca	Mg	pH
2016	21.8	150	399	2710	312	7.18
2017	151.6	111	483	2520	378	7.16

plants. Because of that, 6.4 kg N universal organic fertilizer 8-3-8 product from the company Rašelina, the Czech Republic, was added to the 128 m^2 field. Agrochemical analyses in 2017 showed that the N content of the soil was higher than that usually required for growing onions (Tab. 1).

Measurements of weather conditions

Meteorological data including air temperature (minimum, maximum and average), precipitation (mm), and sunshine duration, defined as the number of sunny hours, were measured during the vegetation period (May-August). In 2016, the amounts of precipitation (mm) in May (52.6), July (114) and August (46.4) were larger compared to those in the same months in 2017 (24.4, 71.7 and 23.7, respectively) (Fig. 1). During May, June and July, irrigation was applied with sprinkles according to weather conditions. The number of sunshine hours was higher in 2017 compared to 2016. The largest difference was in June; the average number of sunny hours in 2016 was 253, while in the same month in 2017 it was 313.7 (Fig. 1). As regards air temperature, the results showed that there were no significant differences between 2016 and 2017 (Fig. 2). However, in 2016 and 2017 in Lednice, the mean monthly temperatures during the stage of bulb formation (June and July) were 2°C lower than the optimum for that growth stage (22°C).

Statistical analysis

Data were evaluated by two-way analysis of variance (ANOVA) using PC software Statistica CZ v. 12 (StatSoft). Vertical bars denoted SE. Differences among the cultivars and treatments were estimated with Fisher's LSD test at $p < 0.05$.

RESULTS AND DISCUSSION

With respect to the morphological and yield parameters of onion plants, in this research the influence of the different organic fertilizers on the number of leaves, bulb diameter, bulb weight (Figs 3, 4 and 5) and yield (Tab. 2) was determined.

Number of leaves per plant

The results showed that the number of onion leaves was higher in 2016 than in 2017 in both cultivars and in all the treatments. In the cultivar 'Stuttgarter Riesen' in 2016, the highest number of leaves was found in the treatment with EkoBooster 2® (6.66), while there were no significant differences between the control, VermiFit A®, and B-Stimul® (Fig. 3A). In 2017, EkoBooster 2® application also resulted in the highest number of leaves produced by onion plants (6.30), while the lowest number was determined in the control (4.76). In both years, there were no significant differences between the treatments with VermiFit A® and B-Stimul® in the cultivar 'Stuttgarter Riesen'. In the cultivar 'Rote Laaer' (Fig. 3B), EkoBooster 2® and B-Stimul® showed the highest efficiency in terms of the number of leaves per plant, both in 2016 (7.06) and in 2017 (6.60). The results showed that the cultivar 'Rote Laaer' produced a higher number of leaves in both years compared to 'Stuttgarter Riesen', and that the biofertilizer EkoBooster 2® was more effective in this respect compared to the other treatments.

In 2016, the application of EkoBooster 2® in the cultivar 'Stuttgarter Riesen' resulted in a higher number of leaves: by 25.8%, 19.1% and 20.6 % compared with the control, VermiFit A® and B-Stimul®, respectively. In 2017, spraying of 'Stuttgarter Riesen' onions with EkoBooster 2® resulted in the number of leaves being 32.1% higher than in the control, and 20.5% higher than for VermiFit A® and B-Stimul®. The application of EkoBooster 2® in 'Rote Laaer' in 2016 resulted in a higher number of leaves: by 4.0% compared to the control, and by 9.3% compared to VermiFit A®. In 2017, the number of leaves was by 4.8% higher than in the control and by 2.0% higher than for VermiFit A®, while no significant differences were noted between EkoBooster 2® and B-Stimul® in either year. The improvement in the vegetative growth of onion plants resulting from the application of the liquid organic fertilizer EkoBooster 2® may have been due to its composition consisting of organic matter and NPK in available forms, which led to the optimal nutritional status of onion plants. Most compound fertilizers will contain three elements essential for plant growth: NPK, which stands for nitrogen (promotes leaf growth), phosphorus (root, flower, and fruit), and potassium (stem and root growth and protein analysis) (Yagoub et al.,

Table 2. Marketable and total yields of onion in 2016 and 2017

Cultivar	Treatment	Marketable yield (kg m^{-2})	Total yield (kg m^{-2})	Marketable yield (% of total yield)
		2016		
Stuttgarter Riesen	Control	3.04 b*	3.14 a	96.8
	B-Stimul®	3.15 ab	3.17 a	99.3
	EkoBooster 2®	3.47 a	3.48 a	99.7
	VermiFit A®	3.00 b	3.31 a	90.6
	Mean	3.16	3.27	96.6
		2017		
Stuttgarter Riesen	Control	2.32 c	2.57 b	90.3
	B-Stimul®	2.26 c	2.48 b	91.1
	EkoBooster 2®	2.53 c	2.67 b	94.8
	VermiFit A®	2.16 c	2.32 b	93.1
	Mean	2.31	2.51	92.3
		2016		
Rote Laaer	Control	3.12 a	3.37 a	92.6
	B-Stimul®	2.51 abc	2.88 ab	87.2
	EkoBooster 2®	2.66 abc	2.92 ab	91.1
	VermiFit A®	2.98 ab	3.39 a	87.9
	Mean	2.81	3.14	89.7
		2017		
Rote Laaer	Control	2.30 c	3.21 ab	71.7
	B-Stimul®	2.28 c	2.68 ab	85.1
	EkoBooster 2®	2.23 c	2.60 ab	85.8
	VermiFit A®	2.39 bc	2.40 b	99.6
	Mean	2.30	2.72	85.6

*The letters indicate a significant difference between the treatments and cultivars according to Fisher's LSD test at $p < 0.05$

2012). Green manure as well as poultry and animal manures are good sources of organic NPK. Results similar to ours had been reported by Yohannes et al. (2013), who showed that the use of organic manure with increased N content positively affected the number of leaves of onion. Singh et al. (2004) reported that a combination of 120 kg N ha^{-1} with green manure gave the tallest onion plants and the maximum number of leaves per plant.

Bulb diameter

Plant growth parameters such as bulb diameter relate to the yield of onion (Nasreen et al., 2007). The application of different organic fertilizers significantly affected the bulb diameter depending on the cultivar and year. In 2016, 'Stuttgarter Riesen' showed the largest bulb diameter as a result of treatment with VermiFit A® (54.45 mm), while there were no significant differences between EkoBooster 2®, B-Stimul® and the control (Fig. 4A).

The bulb diameter was larger in 2016 than in 2017, when no significant differences between all the treatments, including the control, were noted. In 2016, transplanting was earlier, which resulted in a larger diameter of bulbs. This may have been due to the favourable weather conditions for the growth of onion plants, which had a positive influence on bulb diameter. The cultivar 'Rote Laaer', in 2016, reached the largest bulb diameter after EkoBooster 2® (54.32 mm) and VermiFit A® (52.22 mm) applications, while the smallest bulb diameter was recorded for the control (45.06 mm) (Fig. 4B). In 'Rote Laaer' in 2017, VermiFit A® showed the highest results regarding bulb diameter (54.13 mm), which was not significantly different from those obtained for the control and B-Stimul® (Fig. 4B). Although EkoBooster 2® gave the best results in 2016, the same treatment produced the lowest values in 2017. EkoBooster 2® contains N; according to the agrochemical analysis in 2017, the N content in the soil was higher than the level recommended for onion. For integrated onion production, the proper total N amount is 60-70 kg ha^{-1}. In 2017, the agrochemical analysis showed

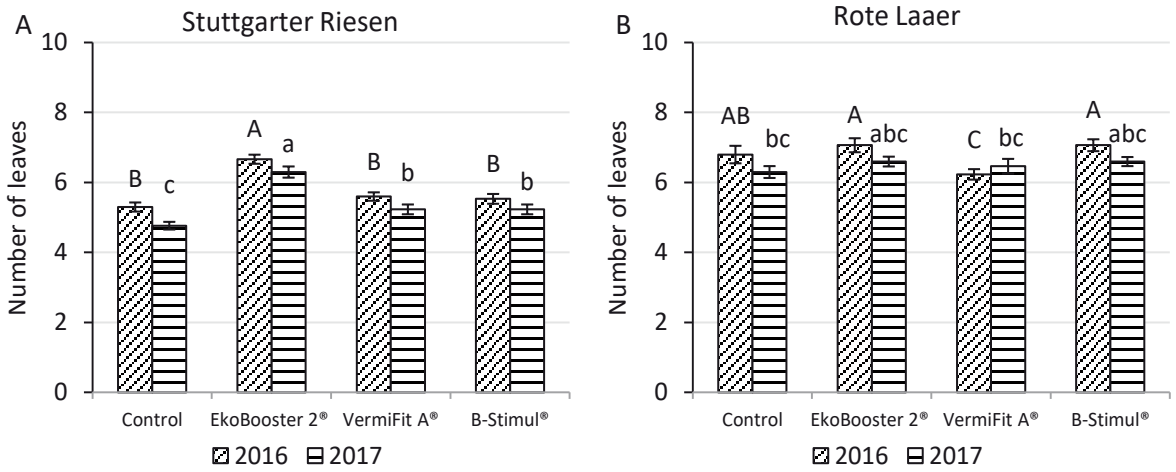

Figure 3. The number of leaves in the cultivars 'Stuttgarter Riesen' (A) and 'Rote Laaer' (B). Capital letters indicate statistical differences according to Fisher's LSD test at $p < 0.05$ between the treatments and cultivars in 2016, while lowercase letters in 2017. Vertical bars show SE

that the N content in the 0-30 cm layer was 151.6 mg kg^{-1} (Tab. 1).

Bulb weight

Bulb weight is an important parameter in influencing the yield of an onion crop. In both cultivars, bulb weight was higher in 2016 than in 2017. 'Stuttgarter Riesen' treated with EkoBooster 2® showed the highest bulb weight in 2016 (67.16 g) as well as in 2017 (55.17 g) (Fig. 5A). Increasing the level of organic nitrogen increased onion bulb weight. Optimum availability of NPK and organic matter increased the rate of metabolism and synthesis of carbohydrates thus increasing the bulb yield. However, the use of organic fertilizers increases the height of the bulb, as reported by Jayathilake et al. (2003) and Akoun (2005). Mohammad and Hassanpour (2012) showed that increasing N-levels up to 150 kg N ha^{-1} had a positive influence on bulb weight and height of plants as well as dry matter yield of onion.

The bulb weight of 'Rote Laaer' was higher than that of 'Stuttgarter Riesen' in both years. In 2016, the treatments with EkoBooster 2® and B-Stimul® resulted in the highest bulb weight (79.30 g) (Fig. 5B). The same treatments in 2017 showed the lowest bulb weight, with VermiFit A® showing the highest results (71.79 g). According to Kandil et al. (2013), the differences between the cultivars studied might be related to different genetic factors. Also, another possible reason may be the differences in weather conditions between 2016 and 2017. According to those results, the increase in the number of sunshine hours during the vegetative growth of onion in 2017 contributed to the reduction in bulb weight.

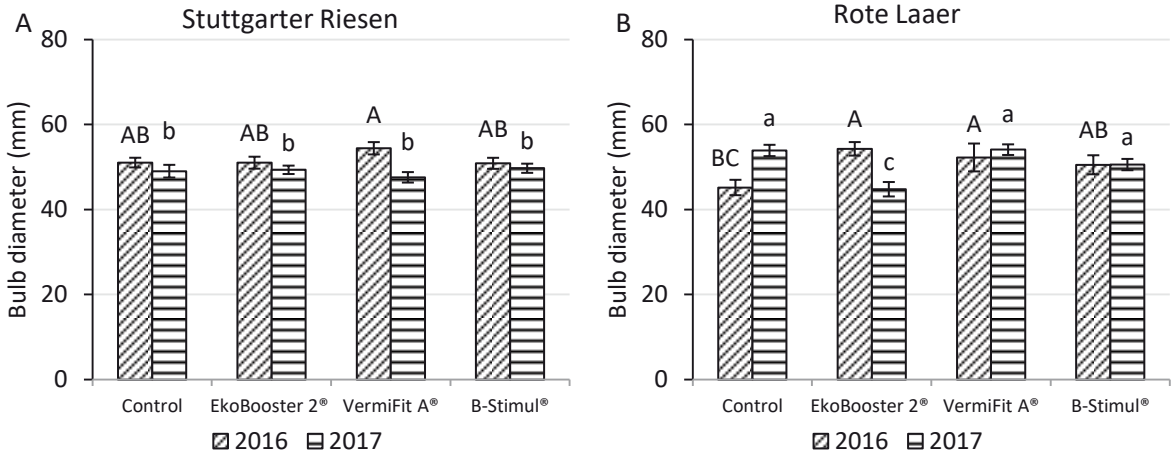

Figure 4. Onion bulb diameter in the cultivars 'Stuttgarter Riesen' (A) and 'Rote Laaer' (B). Capital letters indicate statistical differences according to Fisher's LSD test at $p < 0.05$ between the treatments and cultivars in 2016, while lowercase letters in 2017. Vertical bars show SE

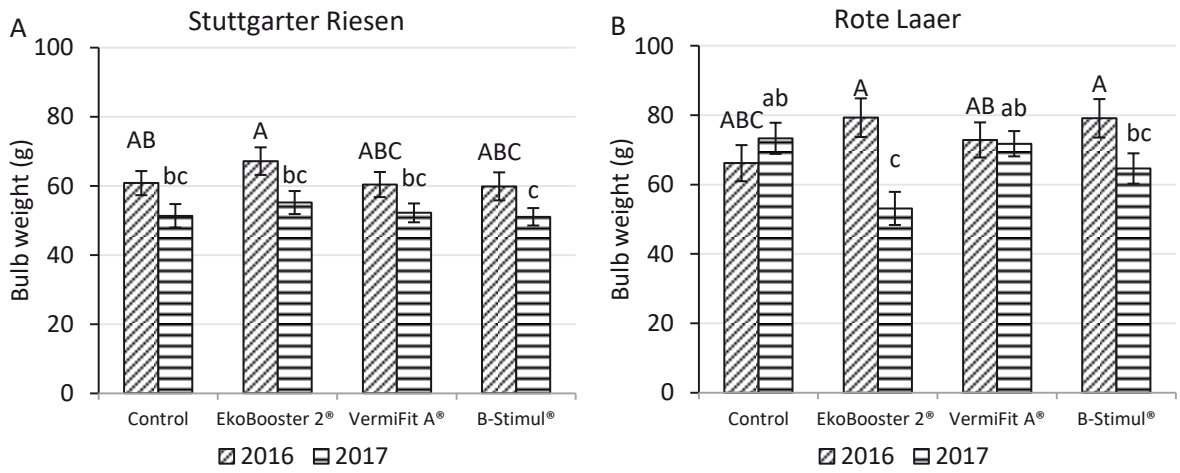

Figure 5. Onion bulb weight in the cultivars 'Stuttgarter Riesen' (A) and 'Rote Laaer' (B). Capital letters indicate statistical differences according to Fisher's LSD test at $p < 0.05$ between the treatments and cultivars in 2016, while lowercase letters in 2017. Vertical bars show SE

Marketable and total yield

'Stuttgarter Riesen' produced a lower yield in 2017 than in 2016; the highest marketable yield resulted from the treatment with EkoBooster 2® (2.53 kg m^{-2}), but there were no significant differences between the other treatments (Tab. 2). Spraying with EkoBooster 2® resulted in the highest marketable yield in 'Stuttgarter Riesen' in 2016 (3.47 kg m^{-2}), which was 15%, 13% and 10% higher than for VermiFit A®, the control and B-Stimul®, respectively.

In 2016, the results indicated a mean marketable yield of 34.8 tonnes per hectare, which is about 90% higher than the FAOSTAT 2014 statistic, while in 2017 the results indicated a marketable yield of 25.3 tonnes per hectare, which is about 37% higher than the FAOSTAT 2014 value. In general, the marketable yield in 2017 was by 27.5% lower than in 2016. The higher yield in 2016 was most likely due to the increase in bulb weight and the number of leaves in that year. Similar results had been reported by Dhaker et al. (2017) and by Shinde and Shinde (2016). One of the possible reasons for higher yields in 2016 may have also been the earlier time of transplanting into the field (6 days earlier than in 2017). Also, other factors, such as climatic conditions in 2017 with a higher number of sunshine hours, may have had an effect on the yield of both cultivars compared to 2016.

In 2017, 'Rote Laaer' showed a marketable yield similar to 'Stuttgarter Riesen'. The highest marketable yield was found for VermiFit A® (2.39 kg m^{-2}), but there were no significant differences between the other treatments. In 2016, the marketable yield of control plants was by 17%, 2.5% and 24.3% higher than the yield produced with EkoBooster 2®, VermiFit A® and B-Stimul®, respectively.

As mentioned above, the total yield was higher in 2016 than in 2017, but in both years there were no significant diferences between the treatments in the cultivar 'Stuttgarter Riesen'. For 'Rote Laaer' in 2016, the highest total yield was found for the treatment with VermiFit A® (3.39 kg m^{-2}) and in the control (3.37 kg m^{-2}). The treatment with VermiFit A®, which is an extract of compost produced by Californian earthworms and peat, gave results 16% and 18% higher than with EkoBooster 2® and B-Stimul®, respectively. Similar results had been reported by Berova et al. (2010) on the yield of pepper treated with biofertilizer Lumbrical produced by Californian earthworms.

CONCLUSIONS

This study showed that onion bulbs could be successfully produced by using organic fertilizers. The economic production of the crop requires efficient application of the correct types and amounts of fertilizers for the supply of nutrients. It can be concluded that EkoBooster 2® showed the best effect on parameters such as the number of leaves, bulb weight, and marketable bulb yield of the cultivar 'Stuttgarter Riesen'. The same biofertilizer positively affected the parameters of 'Rote Laaer' in 2016, while in 2017 VermiFit A® gave better results as compared to the other treatments. The determination of which types of organic fertilizers have the best effect on the morphological parameters and yield of onion could

be helpful in choosing the appropriate amount and form of plant nutritional biopreparations.

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AUTHOR CONTRIBUTIONS

B.P. and T.K. – conducted the experimental work, collected and analyzed the data, wrote the paper; R.P. – gave suggestions and equally contributed to manuscript writing.

CONFLICT OF INTEREST

Authors declare no conflict of interest.

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