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# QUANTITATIVE TRAITS OF WHITE CABBAGE CULTIVARS IN ASSOCIATION WITH TWO BIOFERTILISERS

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## ABSTRACT

Cabbage is one of the most important vegetables from the Brassicaceae family to which biofertilisers are increasingly applied following the current trend in cabbage organic farming. The main goal of our study was to examine whether solely applicated biofertilisers enhance head weight and other morphological parameters in cabbage. Experiment with three Bejo Zaden cultivars ('Farao' $F_1$, 'Tiara' $F_1$, and 'Excalibur' $F_1$) were conducted under the open field conditions from April to June 2019. Two different microbiological fertilisers, Organic balance and FitoHelp, were applied foliar, six times during the vegetation period, with a battery sprayer. After harvest, several parameters were estimated: head weight, width and height, number of leaves, internal core height and width. The results showed the highest value of head weight (1264.89 g), head width (15.06 cm), head height (15.57 cm), number of leaves (22.56), internal core height (8.01 cm) and internal core width (3.51 cm) in cultivar 'Excalibur' $F_1$ compared to other two cultivars for fresh market. Application of both fertilisers led to increased levels of all tested parameters compared to the control. Furthermore, fertiliser Organic balance showed the highest impact on all tested parameters, resulting in an increasing value of head weight by 78.6%. This study revealed that mixed culture fertiliser showed a greater impact in terms of head weight, number of leaves, and internal core width compared to fertiliser containing a single strain of bacteria. Accordingly, with an exception in head and internal core height, all examined factors showed a statistically significant impact on tested parameters, including their interaction.

**Keywords**: *Cabbage*, *Biofertilisers*, *Head weight*, *Number of leaves*, *Internal core height.*

## INTRODUCTION

Cabbage (*Brassica oleracea var. capitata)* is one of the most important vegetables from the Brassicaceae family. The average production of cabbage in the EU was 4.11 million tons between 2019-2021, with leading countries of Poland, Germany and Romania, which contributed by 50.86% in the total production of all EU countries (FAOSTAT, 2021). It is rich in minerals, dietary fibers, with low caloric value (Haque *et al*., 2006). Beside using it in different cooking recipes, as a fresh vegetable or processed (boiled, stir-fried, fermented), cabbage stands out as a plant with potential functional properties in human health (Vij *et al*., 2022). This crop can be grown all year round, as an early leafy vegetable during spring or in summer, with favorable cooler temperatures and humid conditions in temperate climate (Červenski *et al*., 2022). Optimal temperatures for cabbage head formation are up to 20 °C, while temperatures above 24 °C can cause heat stress.

During the green revolution, breeders selected new genotypes of different crops with potentially high yield, appropriate morphological characteristics, tolerance to diseases and pests, with extended shelf life, but usually accomplished with the application of high doses of mineral fertilisers and pesticides (Dorais et al., 2008). In recent decades, many studies have been conducted regarding the chemical pollution of the soil, water, and air. Combined application of organic and mineral fertilisers showed the potential impact to increase yield in cabbage, reducing the usage of inorganic fertilisers (Islam *et al*., 2017). The application of biofertilisers can be a cost-benefit and ecological solution to maintain crop productivity and sustainable strategy in regular agriculture practice, especially in terms of reducing the amount of applied mineral fertilisers and synthetic pesticides.

Biofertilisers are liquid or powder formulations which consist of different groups of effective microorganisms: photosynthetic bacteria, lactic acid bacteria, yeasts, actinomycetes, and fungi (Wołejko *et al*., 2016). Beneficial microorganisms can contribute to the fixation of atmospheric nitrogen, mobilisation of macro and micronutrients and their translocation, produce plant growth-promoting compounds, protect plants against diseases and pests, improve soil physical, chemical and biological properties, help improve yield and quality characteristics (Mankar *et al*., 2015). Different bacterial genera are considered as plant growth promoting bacteria: *Azoarcus*, *Azotobacter*, *Acetobacter*, *Azospirillum*, *Arthrobacter*, *Bacillus*, *Beijerinckia*, *Bradyrhizobium*, *Burkholderia*, *Diazotrophicus*, *Enterobacter*, *Erwinia*, *Gluconacetobacter*, *Mesorhizobium*, *Microbacterium*, *Pseudomonas*, *Rhizobium*, *Flavobacterium*, *Frankia*, *Rhodococcus*, and *Serratia* (Prasad *et al*., 2019). The positive effects of different microbiological fertilisers on cabbage quantitative traits were previously reported (Steffen *et al*., 2021; Vij *et al*., 2022).

This study aimed to examine the influence of cultivar and microbiological fertilisers on different morphological traits in different white cabbage cultivars. Chosen cultivars were grown in early spring production for fresh market and represent a competitive salad crop among other leafy vegetables by adopting

cleaner and cost-effective crop production practices to ensure both resource use efficiency and food safety.

## MATERIALS AND METHODS

Three cabbage Bejo Zaden cultivars were examined ('Farao' $F_1$, 'Tiara' $F_1$, 'Excalibur' $F_1$). 'Farao' $F_1$ has a solid, round-shaped head, resistant to cracking, weight up to 2.5 kg, suitable for spring-autumn production, and used for fresh market. 'Tiara' F1 is a very early, head-rounded cabbage with a strong ability against cracking, also used for fresh market. 'Excalibur' $F_1$ has medium- sized, round head, with a short core, resistant to various stress factors, suitable for processing and fresh market. Cabbage seeds were grown in plastic containers filled out with the substrate Potgrond H (Klasmann-Deilmann, Germany) in a glasshouse condition in the company Grow Rasad (Irig, Serbia). Seeds were sown on February 20 and the seedlings production lasted for 39 days.

An open field experiment was conducted during April-June 2019 in the company Iceberg Salat Centar (Surčin, Serbia). Cabbage plants were transplanted on April 5, mechanically, in black marsh soil. Randomised soil samples were collected at 0-30 cm depth, before starting the experiment. Chemical analysis of the soil showed sufficient levels of macronutrients and humus (total nitrogen-0.18%; readily available phosphorus-26.7 mg/100 g; readily available potassium-19.3 mg/100 g; and humus-4.3%). Regular cultivation practices were applied during the vegetation period (irrigation, weed hoeing, protection against diseases and pests). The experiment was organised in a complete block design with 3 treatments (control-without fertilisation, a fertiliser Organic balance-OB, and a fertiliser FitoHelp-FH). The dimension of the plots was 1 × 8 m, in each 50 plants, in three replications. The distance between plants in the row was *35 cm, while the* distance between rows was 65 cm.

Organic balance (OB; BTU Center, Ukraine) is a liquid preparation containing a mixture of different effective microorganisms (> $2 \times 10^9$ CFU/ml *Bacillus subtilis* 221, > $2 \times 10^{10}$ CFU/ml *Azotobacter chroococcum polymyxa* 3094, > $1 \times 10^8$ CFU/ml *Paenibacillus polymyxa* 1718, $2 \times 10^9$ CFU/ml *Enterococcus faecium* LK-50, $2 \times 10^9$ CFU/ml *Lactobacillus delbrueckii* sp. *buldaricus* 9702*). FitoHelp* (FH; BTU Center, Ukraine) *is a liquid formulation which consists of* > $4 \times 10^9$ CFU/ml *Bacillus subtilis* 221. Microbiological fertilisers were applied foliar, six times during the vegetation period, with a battery sprayer. A foliar application included 25 ml OB and 50 ml FH, dissolved in 6 l of water. Before the experiment, microbiological fertilisers had not been applied.

During the vegetation period air temperature, air relative humidity, and precipitation were collected using RC-4HC Data Logger and rain gauge. Climatic parameters were measured for 24 hours during the growing period. Average air temperature, average air relative humidity, and total precipitation are presented in Table 1.

Table 1. Climate conditions during cabbage vegetation period

| | Average air temperature (°C) | Maximum air temperature (°C) | Minimum air temperature (°C) | Average air humidity (%) | Total precipitation (mm) |
|---|---|---|---|---|---|
| April 2019 | 15.6 | 30.5 | 8.3 | 62.9 | 48.2 |
| May 2019 | 16.1 | 28.1 | 4.6 | 72.0 | 140.3 |
| June 2019 | 25.0 | 38.1 | 14.4 | 64.6 | 65.7 |

Cabbage heads were harvested 75 days after transplanting, when fully matured. For morphological analysis, we used 3 plants per treatment. All morphological traits were measured using a scale, digital caliper, and ruler.

We used two-way ANOVA with Tukey's test for post-hoc comparison. All tests were performed at a significance level α of 0.05. Statistical analysis was performed by using SPSS Statistics for Windows, version 25.0 (SPSS Inc., USA) and Microsoft Office Excel, version 2019 (Microsoft Corp., USA).

## RESULTS AND DISCUSSION

Results for head weight, head width, head height, number of leaves, internal core height, and internal core width are presented in Table 2.

Table 2. Main and interaction factors effects on morphological traits in white cabbage

| | Head weight (g) | Head width (cm) | Head height (cm) | Number of leaves | Internal core height (cm) | Internal core width (cm) |
|---|---|---|---|---|---|---|
| **Main factors** | | | | | | |
| *Cultivar* | | | | | | |
| Farao $F_1$ | 924.67±31.45 **a** | 13.38±0.36 **a** | 14.00±0.34 **a** | 18.00±0.79 **b** | 7.32±2.48 **a** | 3.31±0.79 **b** |
| Tiara $F_1$ | 915.33±37.66 **a** | 13.10±0.54 **a** | 13.54±0.34 **a** | 15.11±0.41 **a** | 6.19±4.64 **b** | 2.92±0.92 **a** |
| Excalibur $F_1$ | 1264.89±71.35 **b** | 15.06±0.40 **b** | 15.57±0.61 **b** | 22.56±0.62 **c** | 8.01±4.48 **b** | 3.51±0.71 **c** |
| | | | | | | |
| *Fertiliser* | | | | | | |
| Control | 723.22±62.44 **a** | 12.22±0.42 **a** | 12.86±0.41 **a** | 16.78±0.69 **a** | 5.82±4.59 **a** | 2.99±1.21 **a** |
| Organic balance | 1291.33±63.83 **c** | 15.00±0.53 **b** | 15.27±0.39 **b** | 20.56±0.44 **c** | 8.29±3.14 **b** | 3.49±0.87 **c** |
| FitoHelp | 1090.33±14.20 **b** | 14.31±0.35 **b** | 14.99±0.49 **b** | 18.33±0.69 **b** | 7.41±3.87 **b** | 3.27±0.33 **b** |
| | | | | | | |
| **Significance** | | | | | | |
| Cultivar (C) | *** | *** | *** | *** | *** | *** |
| Fertiliser (F) | *** | *** | *** | *** | *** | *** |
| | | | | | | |
| **Interaction factors** | | | | | | |
| C × F | ** | * | ns | ** | ns | ** |

The data are the means (n=3) ±SE. Values followed by the same letter are not significantly different at the 0.05% level of probability according to Tukey's test. Asterisks indicate significant differences at ∗P ≤ 0.05; ∗∗ P ≤ 0.01; ∗∗∗ P ≤ 0.001; ns, non-significant.

Cultivar and fertiliser showed a significant influence on the cabbage head weight, as well as their interaction (Table 2). Head weight ranged between 915.33-1264.89 g. Our results were in line with Kołota and Chohura (2015), who stated that cabbage weight 1-2 kg, is the most favorable for the fresh market. Cultivar 'Excalibur' $F_1$ exhibited the highest, while 'Tiara' $F_1$ obtained the lowest head weight. Various studies emphasised the influence of the genotype on cabbage head weight (Singh *et al*., 2013; Bhandari *et al*., 2021). Head weight is one of the most important parameters that affect cabbage yield. Kibar *et al*. (2014) found a very strong positive correlation between head weight and yield indicating that this trait increases total yield. Furthermore, the same study pointed out that head length, diameter, and interior core diameter also represent one of the important yield components in cabbage.

In our study, the average cabbage head weight was increased by 78.6% and 50.8% using fertilisers OB and FH, respectively, compared to the unfertilised control. Similarly, to our results, Salim *et al*. (2018) showed a positive impact of two bacterial species, *Pseudomonas fluorescens* and *Azotobacter chroococcum*, on cabbage head weight. Application of fertiliser Bioaktiv (*Azotobacter* sp., *Bacillus subtilis, Fusarium* sp. and *Penicillium oxalicum*) showed higher lettuce fresh weight and earlier head formation compared to control plants (Tošić *et al*., 2016). The effectiveness of different beneficial microorganisms on plant growth and yield depends on plant species - cultivar, the ability of plant growth-promoting organisms to colonise roots, soil type, fertility, and continual application. Also, the interaction between plants and microorganisms and the different compounds they produce, plays an important role in the expected success in the application of these fertilisers. Positive achievement in head weight could be due to increased nutrient availability and possible nutrient uptake due to enzymes, hormones, vitamins and other plant growth-promoting compounds produced by microorganisms (López-Bucio *et al*., 2015).

Head width and head height were significantly influenced by cultivar and fertiliser, while the interaction between the two factors was only found in head width (Table 2). Cultivar 'Excalibur' $F_1$ showed the highest value of head width (15.06 cm) and head height (15.57 cm), compared to 'Tiara' $F_1$ that showed the lowest value (13.10; 13.54, respectively). Our results support the findings of Bhandari *et al*. (2021) which showed a significant influence of different cabbage cultivars on the head width and height in spring and autumn production. Cultivar 'Excalibur' $F_1$ with the highest head weight, also showed the highest head width and height, probably due to the enhanced nutrient availability of this cultivar improved by biofertilisation, which supports higher absorption of nutrients by plants that can positively affect growth and translocation towards the head which enhanced head length. Application of both fertilisers led to significantly higher head width and height compared to the control, even though there was not a significant difference

between the two fertilisers. OB led to increased head width by 22.8% and head height by 18.7% towards non-fertilised plants. Literature data showed a positive contribution of biofertiliser containing *Pseudomonas fluorescens* and humic acid, with a recommended dosage of mineral fertiliser to the highest head height and diameter (Verma *et al*., 2014).

Number of leaves was significantly influenced by cultivar and fertiliser, as well as the interaction between two main factors (Table 2). Cultivar 'Excalibur' $F_1$ showed the highest number of leaves (22.56), while 'Tiara' $F_1$ showed the lowest number (15.11). Previous study supports our findings that genotype has a significant impact on the number of leaves (Olaniyi and Ojetayo, 2011). Application of both fertilisers led to a significantly higher number of leaves compared to the control, by 22.5% and 9.2% with OB and FH, respectively. Similarly, a study with the application of an integrated plant nutrition system together with cow manure, contributed to a significantly increased number of leaves (Hossain *et al*., 2015).

Internal core height and internal core width were statistically influenced by cultivar and fertiliser, while interaction between the two factors was only significant in core width (Table 2). Cultivar 'Excalibur' $F_1$ showed the highest core width (3.51 cm) and core height (8.01 cm), compared to 'Tiara' $F_1$ that showed the lowest value (2.92; 6.19 cm, respectively). The results of Kleinhenz and Wszelaki (2003) reported a significant impact of the cabbage genotype on core width and length. Application of OB led to significantly higher core height by 42.4%, while in parameter core width both fertilisers contributed to the statistically increased measure of it by 16.7% with OB and 9.4% with FH. Different studies measuring stem parameters, with the application of combined mineral and organic fertilisers, cow manure, confirmed our findings (Hossain *et al*., 2015; Islam *et al*., 2017).

Our study revealed that the application of both microbiological fertilisers led to an increased level of morphological traits. Probably their application led to increased nutrient availability and transport, which at the end of the vegetation period led to higher head weight compared to non-fertilised plants. Especially, formulation with multiple bacteria genera fertiliser gave better results in head weight due to the possibly synergistic effect of these strains compared to a single one. During the experiment, temperatures were mostly favorable to head formation, with the exception of higher temperatures above 25 °C in May and June, which lasted for several hours during the day (Table 1). Further investigations should include different seasons and interactions between cultivar, fertiliser, and season, which could explain more briefly the contribution of each factor to cabbage quantitative traits.

## CONCLUSION

The presented study showed that cultivar and microbiological fertiliser influenced all tested parameters, while the conjoint effect of these factors was observed in head weight, head width, number of leaves, and internal core width. Application of cultivar 'Excalibur' and fertiliser Organic balance showed the highest increase in all tested morphological parameters. Formulation of mixed culture fertiliser obtained significantly higher head weight compared to single bacterial strain fertiliser,

indicating that the selected combination of cultivar and fertiliser can be an efficient way of improving the morphological attributes of cabbage.

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