ASSESSMENT OF SELECTED QUALITY AND QUANTITY PARAMETERS IN VARIOUS WATERMELON CULTIVARS

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Summary

Watermelon is a popularly consumed vegetable well known for its health and nutritional value. It is rich in vitamins, especially vitamin C, and other bioactive compounds with high antioxidant properties. The quality and productivity of the watermelon can be enhanced by using the right cultivars and production techniques.
The objective of this study was to determine the selected quantity and quality parameters between the most popular watermelon cultivars (Farao F1, Constellation F1, Red Star F1, and Bonanza F1) in Bosnia and Herzegovina. The research was conducted during the growing season of 2021 in the region of Sarajevo in Bosnia and Herzegovina. The examined parameters were: fruit number and weight, rind thickness, total soluble solids (TSS), and vitamin C content in marketable fruits. All examined parameters showed significant differences between cultivars. Farao F1 exhibited the highest fruit weight (12.43 ± 0.91 kg fruit^{-1}), TSS content (11.70 ± 0.91 Brix), and vitamin C content (6.47 ± 0.75 mg/100 g). On the other hand, Bonanza F1, a mini cultivar, exhibited the lowest fruit weight (2.26 ± 0.52 fruit^{-1}), rind thickness (0.55 ± 0.19 cm), and TSS content (8.55 ± 1.44 mg/100 g).

Keywords: *watermelon, cultivars, fruit characteristics, vitamin C*

INTRODUCTION

Watermelon (*Citrullus vulgaris* L.) is a highly esteemed plant in human nutrition, belonging to the *Cucurbitaceae* family. Renowned for its delicious and edible fruit, this sprawling plant boasts over 1000 distinct varieties, making it a globally cherished and extensively cultivated vegetable (Nadeem *et al*., 2022; Jeffrey, 2001; Čivić *et al*., 2017). Also, it is well known for its health and nutritional value. Watermelon is rich in bioactive compounds with high antioxidant properties (Amin *et al*., 2014; Kyriacou *et al*., 2018). The content of vitamin C in watermelon depends on the variety of watermelon, weather conditions, and the stage in which the fruits are found. Furthermore, color, weight, and shape are also important parameters for consumers. Watermelons range in shape from round to oblong. Rind colors range from light to dark

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green, with or without stripes. Flesh colors can be dark red, red, or yellow (Vukašinović *et al*., 2005). Recently, mini watermelons have become more popular. This type of watermelon is often seedless, while the extra-large has seeds. Various types of watermelon, along with their apparent differences, are also different according to their composition. Flavor, aroma, color, and texture of watermelon are associated with differential expression of stage-specific genes (Kyriacou *et al*., 2018). So, for any nutritional formulation, the nutritional composition of each type should be considered. Fertilization also has an important effect on the chemical content of watermelon. Too much nitrogen, especially with excessive water during fruit set, can encourage bland flavor (Maynard and Hopkins, 1999). Using organic fertilizers in watermelon production affects the quality of watermelon, and productivity is closely related to chemical fertilizer (Massari and Labban, 2014). On the other hand, organic fertilizer can reduce the harmful effects of chemical fertilizers on the environment and human health (Chandini *et al*., 2019). The main goals of modern watermelon cultivars are to satisfy the particular tastes of consumers and to achieve a high yield for producers. Rind color, size, freshness, sweetness, crispness, and juiciness of the watermelon are the most important attributes for consumers when selecting a whole watermelon (Vukašinović *et al*., 2005). In addition to the inner part of the fruit, the peel can also be used for cooking sweets, and very tasty and high-quality young fruits could be pickled (Ramirez *et al*., 2021).

Nowadays, watermelon production in Bosnia and Herzegovina is usually based on grafted seedlings. Grafted plants grow much quicker; they're more robust, so they need fewer plants per square meter – even 50% fewer compared to usual vegetable production without grafting (Behmen *et al*., 2021). Despite the smaller number of plants per square meter, grafted plants produce larger and higher-quality fruits, thereby achieving a bigger yield and higher market value for the product. With a large scope of research, it was concluded that the grafting of fruitful vegetables on a substrate with a strong root system resistant to soil pathogens and pronounced absorption of food and water represents one of the environmentally acceptable methods for increasing crop yields (Fallik and Ilić, 2014; Petropoulos *et al*., 2012; Behmen *et al*., 2021; Toth *et al*., 2021).

The objective of this study was to determine the selected quality and quantity parameters of fruit between the most popular grafted watermelon cultivars in a moderate continental climate.

MATERIALS AND METHODS

Scion:

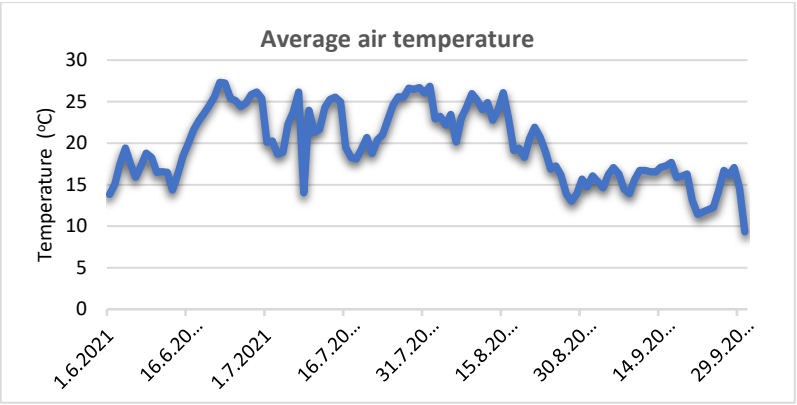
'Farao F1' (Syngenta, South Africa) is a high-yielding, medium-early watermelon with excellent uniformity and high interior quality fruit. It produces large, elongated, blocky-shaped fruits of medium-green color with broad, medium-dark-green stripes. The shape of the fruit is extended.

'Constellation F1' (Syngenta, India) is a high-yielding watermelon with large, oval fruits. The rind is dark with light green stripes. This is a cultivar with strong growth (vigor) and large leaves.
'Red star F1' (Nunhems, Germany) is a vigorous and strong plant with a long harvesting period. The fruit is large and round, with a uniform dark green skin color and sweet, intense red flesh.
'Bonanza F1' (Syngenta, India) is a uniform round-shape fruit with a thin but thick rind that is light green with thin, dark green stripes. Flesh is bright red in color without fibers, crisp, and very sweet. The most important characteristic is the high yield of marketable products due to the homogeneity of the shape and size of the fruits.

Rootstock:
The rootstock 'Tetsukabato' F1 (Kitazawa seed, Japan) (*Cucurbita maxima x Cucurbita moschata*) was used for grafting by the splice grafting method. Its distinctive parentage imparts resistance and tolerance to key diseases, insects, humid conditions, and significant droughts. It is a very popular rootstock for watermelon, melon, and cucumber.

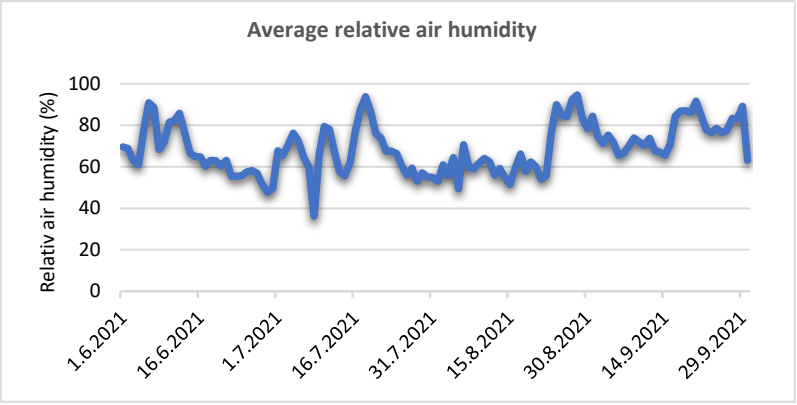
Experiment set up:
The research was conducted during the growing season from June to September 2021 in the region of Sarajevo in Bosnia and Herzegovina (43 °49' 9" N, 18 ° 19' 34" E and altitude 500 m). The experiment was set up in a randomized block design with three repetitions. Seedlings were planted in prepared mounds at a distance of 100 cm in a row and 150 cm between rows. Fertilization was carried out before planting with 2 kg of manure per mound. Seven days after planting, when most of the plants had adapted to the new growth conditions, fertigation with Yara Tera crystallon (NPK 13-40-13) was performed. This procedure was repeated fifteen days after planting. In addition to the manure, it is necessary to introduce 400-500 kg ha^{-1} of NPK mineral fertilizer in the ratio 1:2:1. Top dressing with KAN was carried out in the amount of 150-170 kg/ha in two repetitions. During the experiment, until the plants closed the rows with stems and leaves, cultivation was carried out alternately. All other agrotechnical measures necessary for optimal watermelon growth (irrigation, protection against diseases and pests) were carried out until the end of the growing season (September 30, 2021).

Study area:



Graph 1. Average daily air temperatures for the experimental field in Butmir area
Grafikon 1. *Prosječne vrijednosti temperatura zraka na eksperimentlanom polju u Butmiru*

The year 2021 was quite warm, and it had fewer rainless days than rainy ones. Considering the vegetation period for watermelon, the coldest month was September, with an average daily air temperature of 15.2 °C and a minimum daily air temperature of 9.3 °C. The warmest month was July, with an average daily air temperature of 22.3 °C and a maximum daily air temperature of 26.7 °C. July also had a few days with an average daily air temperature below 20 °C. June and August were quite similar, with an average daily air temperature of 20.7 °C for both months.
For every outdoor plant production, in addition to outside air temperature, relative air humidity is also important. The average relative air humidity during the watermelon growing season is shown in Graph 2.



Graph 2. Average relative air humidity for the experimental field in Butmir area
Grafikon 2. *Prosječne vrijednosti relativne vlažnosti zraka na eksperimentalnom polju u Butmiru*

The year 2021, during the watermelon vegetation period, was very humid, with the highest average relative air humidity in August (94.6%) and the lowest in July (36.2%). In the beginning of the vegetation (June), the average relative air humidity was 66%, but in the first half of the month it was constantly over 65%, but at the end of the month it was lower than 50%. July and August were quite similar, with an average relative air humidity of around 67%. In September, the humidity increased by an average of 76%.
The basic physical and chemical characteristics of the soil were analyzed by Čadro *et al.* (2022) before the vegetation period. The alluvial type of soil was determined. The physical and chemical characteristics of soil are shown in Table 1.

Table 1. Soil physical and chemical characteristics in Butmir, Sarajevo (05. 01. 2021)
Tabela 1. *Fizičko-hemijske karakteristike zemljišta u Butmiru, Sarajevo (05. 01. 2021)*

Depth (cm)	**Clay (%)**	**Silt (%)**	**Send (%)**	**pH in H_2O**	**pH in KCl**	**Humus (%)**	**P_2O_5 (mg/100g)**	**K_2O (mg/100g)**
0-25	32.9	33.5	33.6	7.5	6.4	2.7	34	48

Based on the physical characteristics of the surface layer of the soil, the soil in Butmir is a clay loam with an approximately equal ratio of clay, silt, and sand. Based on the chemical characteristics, the soil has a neutral pH reaction (7.5 in H_2O and 6.4 in HCl), and the humus level is at medium. The content of easily accessible forms of phosphorus (P_2O_5) and potassium (K_2O) in the soil is very high. Based on that, the soil is suitable for growing watermelon.

Plant sampling
Harvest was carried out on randomly selected 10 plants of each type of watermelon to determine fruit size and marketable yield. The first harvest was on July 20th, and the last one was on September 17th. The fruits were weighed on digital scales immediately after harvesting. The analyses of morphological and quality contributing parameters were performed after the third harvest at the end of August. All examined parameters were analyzed at full watermelon maturity BBCH 89 (Meier, 2018).

Plant analysis
The Brix value of the watermelon was directly obtained by using a device called a refractometer (*MA871, Milwaukee Instruments*) (Milczarek and Sede, 2023).
The content of L-ascorbic acid (mg/100 g FW) was determined using Tillman's method (AOAC, 2002). Three parallel titrations were performed for each sample. The average values of the volumes of three titrations were taken for the calculation of the vitamin C content.

Statistical analysis

The average values of the parameters in the study were statistically processed by a computer using the software SPSS. Data analysis was performed using the Analysis of Variance (ANOVA) and LSD t-test.

RESULTS AND DISCUSSION

Table 2. Yield and quality-contributing characteristics of the selected watermelon cultivars
Tabela 2. *Prinos i osobine koje određuju kvalitet odabranih kultivara lubenice*

Parameters / Cultivars	Fruits weight (kg fruit^{-1})	Number of fruits	Rind thickness (cm)	Content of sugar (Brix)	Content of vitamin C (mg/100 g FW)
Farao F1	12.43±0.92^{a}	1.50±0.53^{a}	1.23 ±0.09^{a}	11.70 ±0.94^{a}	6.47 ± 0.75^{a}
Constellation F1	11.30±0.94^{b}	2.10±0.88^{b}	1.51 ±0.21^{b}	10.80 ±1.03^{a}	5.31 ± 0.60^{b}
Red Star F1	8.54 ±0.65^{c}	1.60±0.84^{c}	0.87 ±0.11^{c}	9.00 ± 3.09^{b}	3.85 ± 0.64^{c}
Bonanza F1	2.26 ±0.52^{d}	4.10±0.19^{d}	0.55 ±0.19^{d}	8.55 ± 1.44^{b}	4.47 ± 0.34^{d}
* Means denoted by the same letter indicate no significant difference at the 0.05 level.					

All examined parameters showed statistically significant differences between cultivars. The highest fruit weight was achieved by the Farao F1 cultivar (12.43 ± 0.92 kg fruit^{-1}) which also had the highest total soluble solids content (11.70 ± 0.94 Brix). The lowest fruit weight (2.26 ± 0.52 kg fruit^{-1}) and Brix values (8.55 ± 1.44 Brix) were obtained with Bonanza F1, which is a mini watermelon cultivar. On the other side, cultivar Bonanza F1 had the greatest number of fruits (4.10 ± 0.19).
Morales *et al*. (2023) reported that the yield and quality of watermelon are affected by cultivar and rootstock. Amin *et al*. (2014) state that the sugar content depends on the type of watermelon, and the green type has the highest content among all others.
Comparing four cultivars of watermelon, the highest content of vitamin C (6.47 ± 0.75 mg/100 g FW) was found in Farao F1 and the lowest in Red Star F1 (3.85 ± 0.64 mg/100 g FW). Watermelon cultivars with a higher content of vitamin C could be a good source of antioxidants. Significant differences in vitamin C content among watermelon cultivars were found by Tlili *et al*. (2011); Tarazona-Díaz *et al*. (2010), and Choo and Yong (2001). The difference in vitamin C content could be induced by watermelon genotype (Perkins-Veazie *et al*., 2007; Lenucci *et al*., 2006).
The thickness of the watermelon rind in our experiment ranged from 0.55 to 1.51 cm. The Constellation F1 cultivar had the largest rind thickness, while Bonanza F1 had the smallest. In Bosnia and Herzegovina, watermelon rind is not used in human nutrition and industry. On the other side, in the US, home-owners and small industries use the

leftover watermelon crop, especially from cultivars with thick and crisp rinds, to produce pickles (Gusmini *et al*., 2004). Rind thickness in the watermelon cultivars tested in their experiment ranged from 0.7 to 2.4 cm, with an average of 18 mm. The same authors state that the most suitable cultivars for rind pickle production had rinds ranging from 2.0 to 2.4 cm thick; however, cultivars with a rind thickness of 1.0 to 1.9 cm might also be suitable for rind pickle production. If the rind thickness was <1.0 cm, it is too thin to be used in the production of rind pickles. According to Tarazona-Díaz *et al*. (2010), watermelon rind, particularly from a dark-skinned, seedless cultivar, is a quantitatively valuable natural source of amino acids like citrulline and phenols, which possess antioxidant properties.

CONCLUSIONS

In summary, our study revealed significant differences among watermelon cultivars, with Farao F1 exhibiting the highest fruit weight and sugar content and Bonanza F1 displaying the lowest fruit weight and Brix values. Vitamin C content varied, with Farao F1 having the highest and Red Star F1 the lowest.

The thickness of the watermelon rind varies among different cultivars. While it is not used in Bosnia and Herzegovina, it is widely used as a pickled product in the US, highlighting its potential uses beyond traditional consumption.

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OCJENA ODABRANIH KVALITATIVNIH I KVANTITATIVNIH PARAMETARA RAZLIČITIH KULTIVARA LUBENICE

Rezime

Lubenica je popularno povrće dobro poznato po svojoj zdravstvenoj i nutritivnoj vrijednosti. Bogata je vitaminima, posebice vitaminom C, te drugim bioaktivnim spojevima s visokim antioksidativnim djelovanjem. Kvaliteta i produktivnost lubenice mogu se poboljšati odabirom pravih kultivara i proizvodnih tehnika. Cilj ovog rada bio je utvrditi odabrane parametre kvaliteta i prinosa između najpopularnijih kultivara lubenice (Farao F1, Constellation F1, Red Star F1 i Bonanza F1) u Bosni i Hercegovini. Istraživanje je provedeno tijekom vegetacijske sezone 2021. godine na području Sarajeva u Bosni i Hercegovini. Ispitivani parametri su: broj i masa plodova, debljina kore, ukupna topljiva suha tvar (TSS) i sadržaj vitamina C u plodovima. Svi ispitivani parametri pokazali su značajne razlike između ispitivanih kultivara. Farao F1 pokazao je najveću masu ploda (12,43 ± 0,91 kg plod^{-1}), sadržaj TSS (11,70 ± 0,91 Brix) i sadržaj vitamina C (6,47 ± 0,75 mg/100 g). S druge strane, najmanju masu ploda (2,26 ± 0,52 plod^{-1}), debljinu kore (0,55 ± 0,19 cm) i sadržaj TSS-a (8,55 ± 1,44 mg/100 g) pokazala je mini sorta Bonanza F1.

Ključne riječi: *lubenica, kultivari, osobine ploda, vitamin C*