

## **Morphological and chemical analysis introduced of the nectarine cultivars in Hercegovina**

Morfološka i kemijska analiza introduciranih sorti nektarine  
u Hercegovini

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### ABSTRACT

A 2-year study was done to compare fruit morphological and chemical composition of three nectarine cultivars grown in south Hercegovina conditions. A high variability among and within cultivars was found and significant differences were observed among them in all properties analyzed. On the basis of evaluated data, the best fruit performance was registered in 'Caldesi 2000' and 'Venus' grown in the condition of this part of the Mediteran. This evaluation may help to select a set of nectarine cultivars with better fruit quality attributes, which in our growing conditions might be indicated in 'Caldesi 2000' and somewhat in 'Venus'. The highest average of fruit width (61.18 mm) and fruit weight (148.24 g) was found in cultivar Caldesi 2000. As for fruit thickness, also cultivar Caldesi 2000 had the highest value (55.39 mm). The results for the highest fruit length (60.48 mm) had Venus cultivar also fruit stone weight length, width and thickness. The contents sugars (glucose, fructose) total soluble dry matter, and total acids in fruits were found in cultivar Venus, but pH and sucrose were found in cultivar Sun Grand.

Key words: nectarine, cultivars, morphological-chemical characteristics of fruit, PCA analysis

### SAŽETAK

Provedeno je dvogodišnje istraživanje kako bi se usporedio morfološki i kemijski sastav plodova tri sorte nektarine uzgojene u južnohercegovačkim uvjetima. Utvrđena je velika varijabilnost između i unutar sorti te su uočene značajne razlike među njima u svim analiziranim svojstvima. Na temelju procijenjenih podataka najbolji učinak ploda zabilježen je kod sorti 'Caldesi 2000' i 'Venus' uzgojenih u uvjetima ovog dijela Mediterana. Ova procjena može pomoći u odabiru niza sorti nektarina s boljim svojstvima kvalitete ploda, što bi u našim uvjetima uzgoja moglo biti označeno kao 'Caldesi 2000' i donekle

'Venus'. Najveći prosjek širine ploda (61,18 mm) i mase ploda (148,24 g) ima sorta Caldesi 2000. Što se tiče debljine ploda, također je sorta Caldesi 2000 imala najveću vrijednost (55,39 mm). Rezultati za najveću duljinu ploda (60,48 mm) imala je sorta Venus kao i težinu, širinu i debljinu koštice ploda. Sadržaj ukupne topljive suhe tvari, šećera (glukoza, fruktoza) i ukupnih kiselina u plodovima utvrđen je kod sorte Venus, a pH i saharoza kod sorte Sun Grand.

Gljučne riječi: nektarina, sorte, morfološko-kemijska svojstva ploda, PCA analiza

## INTRODUCTION

Peaches (*Prunus persica* (L.) Batsch) and nectarines *P. persica* (L.) Batsch, var. Nectarina) belong to the Rosaceae family and are thought to have originated in China. (Salunkhe and Desai 1984). Chinese literature dates cultivation of the peach in China to 1000 b.c. and it was probably carried from China to Persia. Peach, at one time called "Persian apple", quickly spread from there to Europe. In the 16<sup>th</sup> century, it was established in Mexico and in the 18<sup>th</sup> century Spanish missionaries introduced the peach to California, which turned out to be the most important production area after China and Italy (LaRue, 1989). Nectarine is a sub-tropical fruit tree which requires irrigation, thinning and disease protection to be commercially viable (Naor et al. 2001). In recent years, increasing nectarine production in Herzegovina includes new cultivars with different growth and fruiting characteristics, harvest date, more full white fruit colour and better eating quality than the existing old cultivars. A peach and a nectarine are very similar. Genetically there is not much difference between the two. The main difference is that a peach has fuzz on its skin while a nectarine does not. Nectarines also tend to be smaller and more aromatic than peaches and have more red color on the fruit surface. Nectarine fruits may have white, yellow, or red flesh, just as peaches do. Their seeds cannot be distinguished from peach seeds. Like other stonefruit, peaches and nectarines, both closely related Brady (1993), have a characteristic, lignified endocarp (pit or stone) that encloses the seed, a fleshy mesocarp and a thin exocarp (Lill et al. 1989). Research into the phenological and morphological characteristics of the reproductive potential of nectarines in the territory of Herzegovina was conducted by the group of authors Hasanbegović et al. (2017), Aliman et al. (2016), while research into the phenological and pomological characteristics of peaches in the territory of Herzegovina was the subject of research by the author Aliman et al. (2018). The goal of this paper was to determine up to which extent

the introduced nectarine cultivars (Sun Grand, Caldesi 2000 and Venus) have adapted to agro-ecological conditions in Herzegovina as well as do they meet the needs of commercial production by their morphological-chemical characteristics.

## MATERIAL AND METHODS

### Plant material and experimental site

The analyzed nectarine cultivars were selected at the location Hercegovina, Blagaj, in a private orchard in "Jaffa-komerc", near Mostar (42060078 S; longitude 19053961 E) during two trial years in 2014 and 2015, the age of the plantations was 10 years. The plant material included commercial cultivars 'Sun Grand', 'Caldesi 2000' and 'Venus' grafted on rootstock GF677. Trees were trained to the "Fusseto" tree form and planted at a spacing of 4 m x 2,5 m. Trees were grown under standard conditions of summer pruning, fertilization and pest and disease control, except irrigation. Two replicates and five trees per replication were used for each measurement per cultivar.

### Soil conditions

The soil at the Blagaj site belongs to skeletal, carbonate, anthropogenic sandy soil with colluvial sediments, the composition of which depends on the possibility of sedimentation of transported material. Translocated materials that roll and creep from higher ground to lower areas and leveled zones. This soil is water-permeable, well-aerated with stable microaggregates. They have a high Ca CO<sub>3</sub> content and have a basic reaction. They have a low humus content (2% or less), especially the alluvium with a high skeleton content as in this locality.

Soil type: brown carbonate skeletal anthropogenic soil on gravel

These lands belong to the IV b sub-category of land, and in HNK they occupy an area of about 8,816 ha and come together with rent (Use value map HNK/Ž, 2010). The most typical brown soils in HNK were isolated in Mostarsko polje (Bišće polje). These are mostly shallow to medium-deep soils, which come together with rendzin (from the Map of land use value in the area of HNK). These soils are very permeable, airy, and very skeletal. They retain water poorly, so soaking is one of the main agromelioration measures applied in Mostarsko polje.

The results of the analysis of the textural composition of the soil of the sample site Mostar (Blagaj), shown in Table 1, show that this soil belongs to the type of sandy loam.

**Table 1 Textural composition of the soil at the sample site in Blagaj**

**Tablica 1. Teksturni sastav tla na oglednom lokalitetu u Blagaju**

Depth (cm)	Textural composition of the soil %			Textural mark USDA
	sand	Clay	powder	
0-30	70	23	7	Sandy loam (PI) ča (PI)
30-60	69	23	8	

The results show that the content of clay particles (particles <0.002 mm) at two depths (0-30 cm and 30-60 cm) is 23%, which means that it is uniform throughout the root zone and that cation adsorption is good. For the content of powder particles (particles of size 0.002-0.02 mm in %) it can also be considered uniform, as well as for the percentage content of sand particles (particles of size 0.02-2 mm). From the above data, it can be seen that the percentage content of individual textural fractions is uniform in all horizons. Therefore, sandy loam is represented in the soil up to 60 cm deep.

**Table 2 Chemical properties of the soil of the sample site in Blagaj**

**Tablica 2. Kemijska svojstva tla ogledne parcele u Blagaju**

Location	Depth in cm	pH in H <sub>2</sub> O	pH in KCl	Org. substance %	Total lime %
Blagaj	0-30	7,73	7,66	4,33	37,67
	30-60	7,72	7,62	3	33

The values of the active reaction (pH in H<sub>2</sub>O) in both analyzed soil depths are equal (7.73 and 7.72), and the soil is basic. The values of the substitution reaction (pH in 1M KCl) showed very similar values to the pH in water, which is unusual. It shows an alkaline reaction of the soil and a minimal drop in the value (7.62) at a depth of 30-60 cm, i.e. a tendency to decrease the alkalinity of the soil. The content of total lime in both analyzed depths (37.67% and 33%) shows that it is a very carbonated soil (Škorić, 1982). The values of the content of organic matter at a depth of up to 30 cm (4.33%) show good humus. According to the value of the content of organic matter (3%) at a depth of (30-60 cm) Škorić (1992), it is also considered good humus.

Climatic conditions

**Table 3 Basic climatic factors in the examined period of 2014-2015 for the area of Blagaj**

**Tablica 3. Osnovni klimatski čimbenici u ispitivanom razdoblju 2014-2015. godine za područje Blagaja**

Year	II	III	IV	V	VI	VII	VIII
Average monthly temperatures (°C)							
2014	10.3	12.4	14.6	17.8	22.6	23.5	24.1
2015	7.4	10.7	13.8	20.0	24.1	29.5	26.6
Maximum monthly temperatures (°C)							
2014	19.4	24.5	24.9	30.4	35.2	34.4	35.6
2015	16.9	22.5	26.4	31.4	34.9	41.9	39.6
Minimum air temperatures (°C)							
2014	2.4	2.2	5.4	8.8	11	14	15
2015	-1	1.8	1.9	8.9	13.6	19.2	16.2
Mean precipitation sums (l/m <sup>2</sup> )							
2014	204.0	76.0	116.0	96.0	118.0	137.0	133.0
2015	149.9	91.9	96.6	37.8	34.1	23.9	86.7

The lowest average monthly temperature in the growing season of 2014 was recorded in March, 12.4 °C, while in the same month of 2015, the lowest average monthly temperature was 10.7 °C. Observing the highest mean monthly temperatures, it can be concluded that the highest mean monthly temperature was recorded in July 2015 when it was 29.5 °C, while the highest mean monthly temperature in 2014 for the growing season was recorded in August when it was 24.1 °C. It is evident from the maximum monthly temperatures that in 2014 the maximum temperature recorded in August was 35.6 °C, while in 2015 the highest maximum temperature was recorded in July when it was 41.9 °C. Observing the month of March as the beginning of the vegetation in both investigated years, it can be concluded that the maximum temperature was higher in 2014 than in 2015 in the same month. The minimum temperature was - 1 °C in February 2015. The entire area of sub-Mediterranean Herzegovina is characterized by large temperature fluctuations, both during the year and during the day (up to 20 °C). The lowest temperature recorded in the growing

season in 2014 was (2.2 °C) in March. In 2015, the minimum air temperature in the same month was (1.8 °C). The highest minimum temperature in 2014 was recorded in August when it was 15 °C, and in 2015 the highest minimum temperature was recorded in July when it was 19.2 °C, with a note that the data for August 2015 was compiled in 23 days. One of the characteristics of the sub-Mediterranean climate is the unfavorable distribution of precipitation during the year, with over 60% of the annual precipitation falling in the cold part of the year. In the researched period of 2014-2015, there were certain deviations from the amount of precipitation, so that the amount of precipitation in 2014 was significantly higher, and in 2015 significantly lower, with a note that the data are for the month of August 2015 it was composed in 23 days. The highest amount of precipitation in the observed period was recorded in 2014 (880.0 l/m<sup>2</sup>), while in 2015 for the observed period it is evident that the average amount of precipitation is lower and was (520.9 l/m<sup>2</sup>). In the vegetation period (March-August), the highest amount of precipitation was recorded in July 2014 (137.0 l/m<sup>2</sup>), while a very modest amount of precipitation was recorded in the same month of 2015 (23.9 l/m<sup>2</sup>). For the growing season of 2015, the highest amount of precipitation was recorded in the month of April (96.6 l/m<sup>2</sup>).

## Methods

Thirty fruits for each selected cultivars nectarine were analyzed and the analyses were replicated two times (total of 30 fruits from each cultivar per year). From the marked nectarine trees, fruit sampling was done by hand picking. Desirable morphological characteristics such as fruit weight (g), fruit length (mm), fruit width (mm), fruit thickness (mm), weight epidermis (g), fruit stone height (mm), fruit stone width (mm), fruit stone weight (g) and fruit stone thickness (mm). Analysis of morphological characteristics was done using the IBPGR descriptor for peach and nectarine, International Board for Plant Genetic Resources, (IBPGR, 1984). The weight of the fruit was determined by measuring on an analytical scale with an accuracy of 1/10 gr. The height, width and thickness of the fruit and stone were measured with a sliding scale, a caliper, with a precision of 0.1 mm. All obtained indicators, which have a descriptive or numerical character, were made simultaneously with the same methodology for each researched cultivar. Chemical analyses of fruits show total soluble dry matter (°Brix), pH, total content of total acids (g/l). The chemical evaluation included qualitative and quantitative determination of individual sugars (fructose, glucose, sucrose and sorbitol) in the nectarine

fruits on the HPLC, used for chemical analysis. The content of total soluble dry matter (SSC) was measured with a refractometer and is expressed as a percentage of soluble substances in 100 g of juice and expressed as a percentage (%). Determination of sugar (glucose, fructose and sucrose) was performed by HPLC and expressed in g/100g. Total titration acidity (TA) was determined by titration with NaOH 0.1 N to pH 8.1 (AOAC 1984) and was expressed as the percentage of malic acid as dominant in 100 g of fresh nectarine fruit.

#### Statistical analyses data

Statistical analysis. Data for each parameter measured were subjected to an analysis of variance (ANOVA). Differences between treatments were assessed using the (Microsoft excel) as well as testing the environment differences by Tukay-W-test. F test, and the least significant difference (LSD) was calculated at 0.05 probability level ( $P \leq 0.05$ ). The analysis of the results of the evaluation of the morphological characteristics of the tested nectarine cultivars in the mentioned areas was carried out using principal component analysis (PCA - Principal Component Analysis) (Hotelling, 1936) based on the correlation matrix in the computer program R v. 3.2.3 (R core team, 2016). Principal component analysis (PCA) was performed using mean values of 18 morphological and chemical characteristics after fruit analysis. The combinations of experimental factor modalities based on the first two components are shown graphically in the form of spatial distribution of the analyzed nectarine cultivars. Principal components explain the variability of the data in a concise way as well as the interrelationships of the variables.

## RESULTS AND DISCUSSION

### Morphological fruit characteristics

Analysis results of morphological fruit characteristics are given in the table 4.

**Table 4 Average values of morphological fruit characteristics of tested cultivars of nectarine for period 2014-2015**

**Tablica 4. Prosječne vrijednosti morfoloških karakteristika plodova ispitivanih sorti nektarine za razdoblje 2014.-2015.**

Cultivars	Fruit weight (g)	Fruit length (mm)	Fruit width (mm)	Thickness fruit (mm)	Fruit stone weight (g)	Fruit stone length (mm)	Fruit stone width (mm)	Fruit stone thickness (mm)
Sun Grand	118.53 <sup>a</sup>	48.94 <sup>ad</sup>	47.49 <sup>ac</sup>	44.55 <sup>ac</sup>	8.72 <sup>a</sup>	29.53 <sup>a</sup>	23.04 <sup>a</sup>	13.32 <sup>a</sup>
Caldesi 2000	149.24 <sup>d</sup>	59.09 <sup>bc</sup>	61.18 <sup>bd</sup>	55.39 <sup>bc</sup>	10.29 <sup>ab</sup>	33.03 <sup>c</sup>	24.82 <sup>ab</sup>	15.26 <sup>c</sup>
Venus	148.37 <sup>bc</sup>	60.48 <sup>c</sup>	54.80 <sup>c</sup>	51.34 <sup>b</sup>	13.95 <sup>c</sup>	42.95 <sup>d</sup>	27.68 <sup>bc</sup>	20.09 <sup>d</sup>

There were significant ( $P < 0.05$ ) differences among the different letters in the same columns.

#### Fruit weight

Fruit weight is a major quantitative inherited factor determining yield, fruit quality and consumer acceptability. The fruit weights significantly changed among cultivars and ranged from (118.53 g) to (149.24 g) (Table 4). The smallest fruit weight was measured in the cultivar Sun Grand, which in 2014 was (115.46 g), while in 2015 the average fruit weight for the same variety was (121.61 g). Which can be related to the climatic conditions as well as the note that it is an early ripening cultivar. The highest average fruit weight in the two-year period was measured in the Caldesi 2000 cultivar. The Venus cultivar in both years had variations in fruit weight, which can be related to the change in climatic conditions in the final phase of fruit ripening, so the average fruit weight in 2015. year was smaller and amounted to (134.99 g), while in 2014 the average weight of the fruit was (161.76 g). Mean fruit weight and its variation recorded in our study corresponded quite well to data observed in literature. (Zec, 2009). Although the mean fruit weight was generally a little smaller and different for cultivar Venus in researches of Rakonjac and Živanović (2008) also Özkan and Özdil (2012). For cultivar Caldesi 2000 the mean fruit weight was lowest than in research (Milošević et al. 2012)



### The length of the fruit

Fruit length ranged from (48.94 mm) in cultivar Sun Grand to (60.48 mm) in cultivar Venus. An increase in fruit length was observed in all cultivars in 2015, among which the cultivar Caldesi 2000 is the most prominent with an average fruit length in 2015 of (62.75 mm). Özkan and Özdil (2012) conducted research in Turkey and cultivar Venus in the period 2009-2011 had the average length of the fruit (60.08 mm) which is similar in this research.

### The width of the fruit

Based on the research results, it can be concluded that the cultivar Caldesi 2000 had the highest fruit width, with an average of (61.18 mm), while the cultivar Sun Grand had the lowest average fruit width, with (47.49 mm). The smallest average fruit width was the cultivar Sun Grand (47.1 mm) in 2014, and the largest was the cultivar Caldesi 2000 (59.26 mm) in 2014. Average fruit width of Venus cultivar in year 2014-2015 was (54.80 mm). Özkan and Özdil (2012) state that the average width of the fruit of the cultivar Venus in the period 2009-2011 was (63.52 mm), which is visibly less compared to the results obtained in this research.

### Fruit thickness (mm)

Table 1 illustrates that according to this parameter as well, Caldesi 2000 cultivar stands out. This cultivar had significantly higher value compared to other two cultivar in both experimental years. It is evident that the cultivar Sun Grand had the smallest average fruit thickness during both observed years, with an average of (44.55 mm) in the period 2014-2015. The cultivar Caldesi 2000 had the largest fruit thickness (55.39 mm). The cultivar Caldesi 2000 had an average fruit thickness in 2014 (50.49 mm), and in 2015 it was significantly more (60.29 mm). Cultivar Venus had the smallest oscillation in fruit thickness, which averaged for 2014-2015 (51.34 mm).

### The weight of the fruit stone

When it comes to this quality, we have registered a variation considering the year of experiment. Therefore, in period 2014-2015 we can register statistically significant bigger weight of the fruit stone in cultivar Venus with (13.95 g), but the lowest average of weight stone had cultivar Sun Grand (8.72 g). Cultivar Sun Grand had a higher average pod weight in 2015 when it was (9.15 g) compared to 2014. In 2015, the Caldesi 2000 cultivar had an average stone weight (11.05 g), while in 2014 (9.54 g). Cultivar Venus had the highest average stone weight in 2014 when it was (14.60 g).

### Fruit stone length

We can notice that cultivar Venus has had a significantly bigger stone length with (42.95 mm) as average for period 2014-2015, but the lowest average had cultivar Sun Grand (29.53 mm). In 2014, the cultivar Caldesi 2000 had an average stone height of (32.06 mm), while in 2015, the average stone height was (34.00 mm).

### Fruit stone width

The highest average stone width was found for Venus with (27.68 mm), respectively, but the lowest ones were for Sun Grand (23.04 mm).

### Fruit stone thickness

The average stone thickness for period 2014-2015 of the Venus cultivar (20.09 mm) was significantly greater than that of the other two. The lowest value observed in cultivar 'Sun Grand' (13.32 mm).

### Chemical characteristic

The glucose, fructose and sucrose contents variety were also investigated. Sucrose, glucose, fructose, and total acid were measured using HPLC. Data were recorded as g/100 g fresh weight. Total acids were computed as the sums of the individual acids.

**Table 5 Average values of the chemical characteristics of the fruit of the tested nectarine cultivars**

**Tablica 5. Prosječne vrijednosti kemijskih svojstava ploda ispitivanih sorti nektarine**

Cultivars	Total soluble dry matter (° Brix)	Total acid (g/l)	pH	Fructose (g/100g)	Glucose (g/100g)	Sucrose (g/100g)
Sun Grand	11.35 <sup>ad</sup>	6.58 <sup>ab</sup>	4.01 <sup>ab</sup>	0.77 <sup>b</sup>	0.93 <sup>a</sup>	7.24 <sup>ad</sup>
Caldesi 2000	11.25 <sup>d</sup>	5.89 <sup>a</sup>	3.78 <sup>a</sup>	0.85 <sup>ab</sup>	0.76 <sup>a</sup>	5.17 <sup>ab</sup>
Venus	11.45 <sup>ab</sup>	8.47 <sup>d</sup>	3.71 <sup>a</sup>	2.14 <sup>cd</sup>	2.60 <sup>f</sup>	5.97 <sup>ab</sup>

There were significant ( $P < 0.05$ ) differences among the different letters in the same columns.

#### Total soluble dry matter

All cultivars had greater levels than 11 °Brix. The highest value (11.45 °Brix) was recorded in cultivar Venus, while the lowest value (11.25 °Brix) was recorded in cultivar Caldesi 2000.

Analyzing the year 2014, the cultivar Caldesi 2000 had the lowest content of dry matter, when it was (9.4%), and the cultivar Sun Grand had the highest content (10.8%). In 2015, all cultivars had a higher dry matter content, so the highest dry matter content was recorded in the Caldesi 2000 cultivar when it was (13.1%), and the lowest in the Sun Grand cultivar when it was (11.9%). The results can be related to the climatic factors that prevailed during the ripening periods of the nectarine cultivars, and it can be concluded that they were significantly more favorable in 2015, which refers to higher average temperatures and lower rainfall. The study Özkan and Özdil (2012) stated that the average content dry matter of the cultivar Venus in the period 2009-2011 amounted (8.70 %).

#### Contains of fructose, glucose and sucrose

For the period 2014-2015 cultivar Venus had the highest glucose (2.60 g/100g), and fructose (2.14 g/100 g) contents. The lowest glucose content (0.76 g/100 g) was determined in Caldesi 2000 and the lowest fructose content (0.77 g/100 g) was detected in Sun Grand. Sun Grand had the highest (7.24 g/100 g) and cultivar Caldesi 2000 lowest (5.17 g/100 g) sucrose contents, respectively. Observing the years and cultivars, it can be concluded that in

2014, cultivar Sun Grand had the lowest fructose content (0.721 g/100g), and cultivar Venus had the highest (1.553 g/100g). In 2015, the lowest fructose content had the cultivar Caldesi 2000, and it was (0.612 g/100g), and the largest cultivar was Venus (2.721 g/100g). Analyzing the years, it can be concluded that in 2014 the Caldesi 2000 cultivar had the lowest glucose content, when it amounted to (0.654 g/100g), and the Venus cultivar had the highest content (1.356 g/100g).

In 2015, the cultivar Sun Grand had a glucose content (0.978 g/100g), which is higher than the cultivar Caldesi 2000 in the same year, and evidently lower than the cultivar Venus of the same year. Analyzing the examined years, it can be concluded that in 2014 the Caldesi 2000 cultivar had the lowest glucose content (3.348 g/100g), and the Sun Grand cultivar had the highest sucrose content (6.732 g/100g). In 2015, cultivar Caldesi 2000 had the lowest sucrose content (6.988 g/100g), and cultivar Sun Grand had the highest content (7.742 g/100g), which is less than cultivar Venus in the same year. Based on the results of the chemical parameters related to the sugar content in the fruits of the tested nectarine varieties, it can be concluded that the conditions were significantly more favorable in 2015, when the average temperatures were significantly higher and the amount of precipitation significantly lower during the ripening periods of the mentioned nectarine cultivars. Colarič et al. (2004) state that the glucose content of the investigated Venus cultivar was (10.65 g/kg), which is in accordance with the results obtained in this research. The content of sucrose for the investigated cultivar Venus was (66.92 g/kg), which is in accordance with the results obtained in this research. In the research Rakonjac and Živanović (2008) state that the cultivar Venus in 2000-2002. year had a sucrose content (7.10%, 6.37%, 5.04% and an average of 6.17%), which is in accordance with the results obtained in this research for the same cultivar.

#### Contents total acid

There were statistically significant differences among species in terms of total acid contents for period 2014-2015. Cultivar Venus had the highest acid content (8.47 g/l), while Caldesi 2000 had the lowest (5.89 g/l), total acid content. While some of the values determined in this study were close to the values reported in other studies, some values were found to be higher, and some were found to be lower. In 2014, the cultivar Caldesi 2000 had the lowest content of total acids (5.35 g/l), and the cultivar Sun Grand had the highest content of total acids (7.8 g/l). In 2015, cultivar Sunn Grand had the lowest

content of total acids (5.36 g/l), and cultivar Venus had the highest (9.25 g/l). These results can be related to the climatic conditions that were specific for each of the research years, as well as to the cultivar characteristics. Colarič et al. (2004) state that the content of total acids for the studied Venus cultivar was (11.50 g/kg), which is in contrast with the results obtained in this research. Bassi and Selli (1990) state that the content of total acids in nectarine cultivars from 10 to 16 g/kg may result in unsatisfactory taste and aroma. In the research Rakonjac and Živanović (2008) state that the cultivar Venus had a content of total acids (0.98%, 1.04%, 1.07% and an average of 1.05%), while in the paper Özkan and Özdil (2012), state that the average content of total acids for the cultivar Venus amounted to (1.37 g/l).

## pH

The highest average value of pH was recorded in the cultivar Sun Grand and was (4.01%), while the lowest average value was recorded in the cultivar Venus (3.71). Observing the years individually, it can be evident that in 2014 the highest pH was measured in the cultivar Sun Grand and was (4.14), and the lowest pH was measured in the cultivar Venus (3.62). Caldesi 2000 cultivar in 2014 had a pH of (3.68), while in 2015 the pH value of this cultivar was slightly higher and was (3.78). In the study of Özkan and Özdil (2012), for the period 2009-2011 cultivar Venus had pH (3.54), so that was a lower result than the result in our research. The results of the research can be linked to the climatic conditions during the ripening period of the tested nectarine cultivars, and it can be concluded that higher monthly temperatures and lower rainfall significantly affected the pH content in the fruits of the Venus and Caldesi 2000 cultivars.

## PCA analysis

Analyzing the results of the five main components of the PCA analysis shown in tables 6 and 7, one can see the contribution of each of the 18 analyzed properties in the total variability present in the analyzed set of tested nectarine cultivars. Each of the 18 observed traits is found with a high value of eigenvectors in one of the first two principal components.

**Table 6 Eigenvalues, proportion of variance and cumulative variance associated with the first two principal components (PCA), estimated from the correlation matrix of morphological characteristics of 18 variables for 3 nectarine cultivars**

**Tablica 6. Svojtvene vrijednosti, udio varijance i kumulativna varijanca povezane s prve dvije glavne komponente (PCA), procijenjene iz korelacijske matrice morfoloških karakteristika 18 varijabli za 3 sorte nektarine**

Variables	PCA1	PCA2
Eigenvalue	11.437	6.563
Proportion of variance (%)	63.537	36.463
Cumulative variance (%)	63.537	100.000

By analyzing the obtained results, it can be concluded that through the dominant eigenvectors in the first principal component (PCA), which accounted for 63.537% of the total variance of the research. The most significant properties of the first component refer to the morphometric properties of the fruit of the tested nectarine cultivars. The highest values of the eigenvectors had the characteristics of the stone. Lower values of eigenvectors showed the chemical characteristics of the fruit.

As part of the second main component, which amounts to 36.463% of the total variability of the experiment, most of the properties with a high value for the eigenvector are related to the morphological characteristics of the fruit. Of the above, the traits with the highest value of eigenvectors are fruit weight and height (15.2361 and 15.1601).

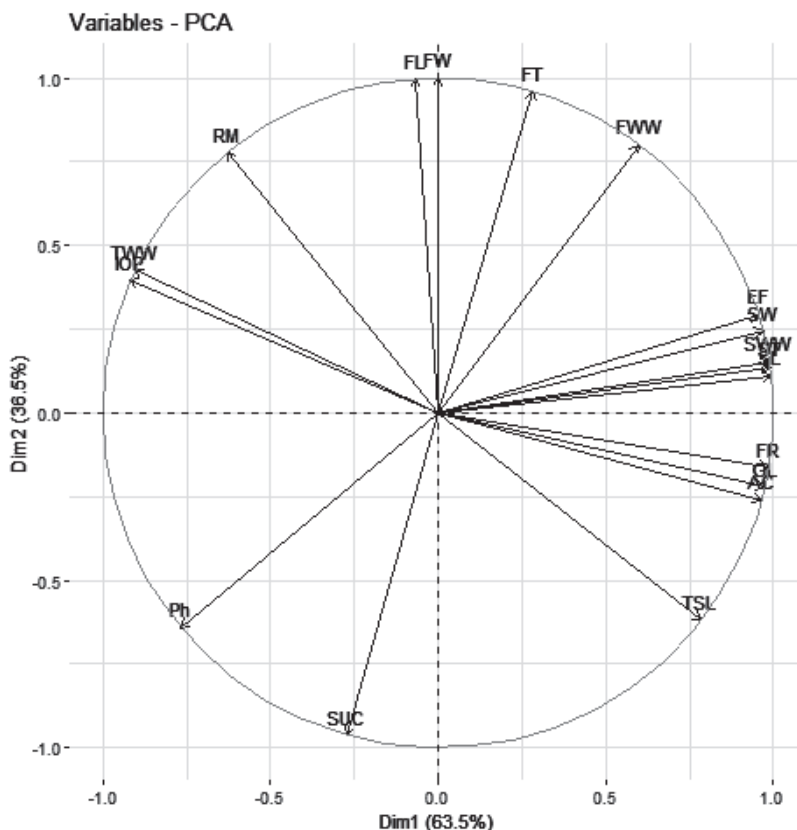
**Table 7 Analysis of 18 quantitative properties of nectarine cultivars in the total variability of the experiment (significant sources of variability in bold)**

**Tablica 7. Analiza 18 kvantitativnih sorti nektarine u ukupnoj varijabilnosti pokusa (značajni izvori varijabilnosti podebljani)**

Characteristics	PCA1	PCA2
Fruit weight FW	8.113457	<b>15.2361</b>
Fruit length FL	4.361623	<b>15.1601</b>
Fruit width FWW	3.137854	<b>9.7684</b>
Fruit thickness FT	7.043926	<b>14.0087</b>
Fruit thickness weight TWW	<b>7.156826</b>	2.7653
Fruit stone weight SWW	6.588845	<b>7.69874</b>
Fruit stone length SL	<b>8.636217</b>	0.1875
Fruit stone width SW	<b>8.214501</b>	0.9223
Fruit stone thickness – ST	<b>8.577545</b>	0.2897
Total soluble dry matter -TSL	5.397023	<b>5.8317</b>
pH	5.146607	<b>6.2681</b>
Total acid AC	<b>8.152536</b>	1.0303
Fructose – FR	<b>8.514732</b>	0.3991
Glucose – GL	<b>8.316429</b>	0.7447
Sucrose – SC	6.383341	<b>14.1238</b>
Fruit shape index - IOP	<b>7.368920</b>	2.3957
Randman fruit meat - RM	3.464884	<b>9.1985</b>
Flowering - EF	<b>7.990799</b>	1.3121

Table 7 presents the variables with the highest eigenvector values in the first two main components:

PCA1 – stone length, stone width, stone thickness, total acidity, fructose content, glucose content, fruit shape index, flowering and thickness fruit weight  
 PCA2 – fruit weight, fruit width, fruit length, skin thickness, stone weight, dry matter content, pH, sucrose content, and randman fruit meat.



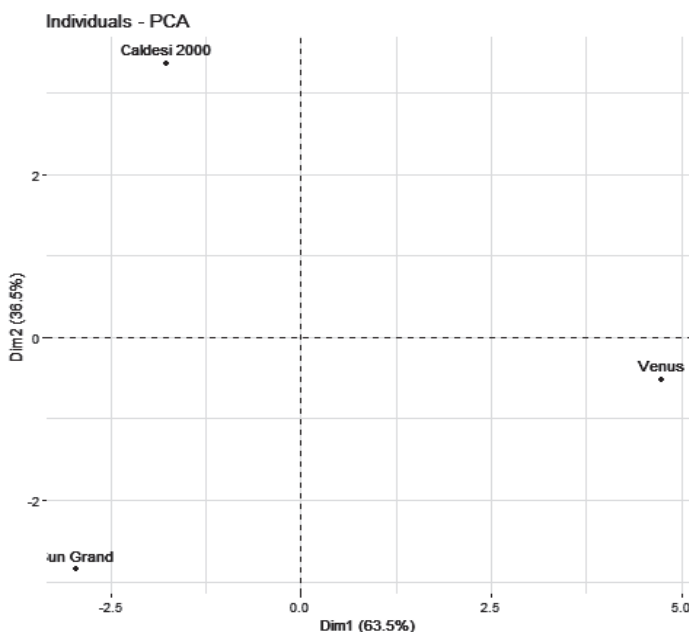
**Graph 1** Grouping and interrelationships of 18 morphological and chemical variables analyzed on three nectarine cultivars, compared to the first two main components (PC1 and PC2)

**Grafikon 1.** Grupiranje i međusobni odnosi 18 morfoloških i kemijskih varijabli analiziranih na tri sorte nektarine, u usporedbi s prve dvije glavne komponente (PC1 i PC2)

From graph 1, it can be seen that there is a strong positive correlation between the morphological and chemical characteristics of the tested nectarine cultivars. The obtained result has a completely logical explanation in that the weight of the fruit and the weight of the stone, as well as all the other listed morphological characteristics, increase proportionally with the development of



the fruit. A strong positive correlation was also observed with the monitored morphological characteristics of the fruit and stone, the index of fruit shape, randman meat. The presence of a negative correlation recorded between chemical characteristics (ph, sucrose content, dry matter content), in a strong negative correlation (fructose content, glucose content and total acidity).



**Graph 2 Individual PCA analysis for three nectarine cultivars**

**Grafikon 2. Pojedinačna PCA analiza za tri sorte nektarine**

Graphs 1 and 2 show the distribution of 3 nectarine cultivars obtained by using the first two main components, which were calculated via the correlation matrix for 18 morphological and chemical traits. It can be concluded that no separation of cultivars was observed in the graph.

Analyzing the first two components that contain 100.00% of the total variability of the experiment, it is evident from the graph that there was no partial degree of overlap between the analyzed nectarine cultivars, which may indicate the fact that they are cultivars with different ripening times, as well as morphologically different nectarine cultivars.

## CONCLUSION

Based on examination of morphological and chemical characteristics of fruits of introduced cultivars of nectarine (Sun Grand, Caldesi 2000 and Venus) in the production plantation of nectarines in Herzegovina, in 2014 and 2015, we can conclude the following:

Regarding the fruit dimensions (weight, width and thickness) Caldesi 2000 had significantly higher values compared to other two cultivars, but average of the length the highest average had cultivar Venus for period 2014-2015. Analysis of fruit stone weight, length, width and thickness, had shown that cultivar Venus significantly higher value. Analysis of chemical characteristic of the fruit has shown that Venus had significantly higher values of total soluble dry matter, total acids glucose, fructose, while pH and sucrose cultivar Sun Grand had higher values. Cultivar Caldesi 2000 is the cultivar that in both research years showed the best quality both in terms of pomological characteristics and in terms of resistance to the ecological conditions of sub-Mediterranean Herzegovina. Cultivar Venus showed satisfactory quality both in terms of resistance to late spring frosts and in terms of fruit quality and size. It should be noted here that extremely high temperatures in the final stage of ripening of the fruits of this cultivar can cause the fruits to burst, as happened in 2015, but for these reasons it is necessary to carry out more intensive continuous irrigation in this period. Cultivar Sun Grand in both research years did not show satisfactory results in terms of resistance to spring frosts, as well as satisfactory fruit size and quality. From this work it can be concluded that the cultivar Sun Grand is not suitable for cultivation in the conditions of sub-Mediterranean Herzegovina.

Based on the PCA analysis, it can be concluded that there were strong positive correlations between certain morphological characteristics of the tested nectarine cultivars, while a strong negative correlation was recorded between certain chemical characteristics of the fruit. It can also be stated that there was no overlapping of nectarine cultivars, which is the expected result, because these are different nectarine cultivars with different ripening times. Each researched cultivars have one or more positive qualities and they have shown high level of adaptability on climate changes in Herzegovina.

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