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Yield, Antioxidant Activity and Total Polyphenol Content of Okra Fruits Grown in Slovak Republic

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Abstract: Climate change, linked with an increase in temperature, contributes to the possibility growing of non-typical and lesser-known vegetable species in the Slovak Republic, including okra. Seven okra cultivars were tested as part of this study, which focused on the basic yield parameters, antioxidant activity and total polyphenol content in okra fruits. The statistical analysis of obtained results revealed significant differences in all monitored parameters of okra. The selection of "plastic" crop cultivars that can produce a steadier yield in each growing year is required due to the significant climate variations between growing seasons. In this regard, the okra cultivar 'Baby Bubba' can be recommended. The results also showed the high antioxidant activity and polyphenol content of okra pulp and seeds. Okra has a higher nutritional quality than other vegetable species frequently grown in the Slovak Republic. Okra cultivars 'Burgundy', 'Pure Luck F1' and 'Jing Orange' can be suggested from a nutritional perspective. Finally, it is possible to state that okra cultivars showed good yield potential and nutritional quality compared to the studies realized in countries in which okra is known and commonly used by the human population.

Keywords: okra; cultivar; yield; polyphenols; antioxidant activity; Slovak Republic

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1. Introduction

Okra (*Abelmoschus esculentus* (L.) Moench.) is a fruit vegetable species from the *Malvaceae* family [1]. Depending on the growing area, it is known under different names, e.g., okra, gumbo, bamya, lady's fingers, bhindi, and qui kui [2]. The origin of okra is unclear, but it is thought to have come from Africa. There is evidence that it was grown in Egypt before 2000 BC [1]. Another literature source indicates that the area of okra's origin is Ethiopia or Sudan [3]. In 2020, 10.5 million tons of okra fruits were produced on an area of 2.53 million hectares worldwide, according to the FAOSTAT database. Okra is currently grown primarily in India, followed by different countries in Africa (Nigeria, Sudan, Mali, Coast Ivory, Egypt) and Asia (Iraq, Pakistan) [4]. Okra is lesser-known vegetable species in the Slovak Republic (or Central Europe generally), rarely grown in local gardens [5].

Okra is a low-cost vegetable crop that has a variety of nutritional values and potential health benefits [6]. Different parts of okra fruit (mucilage, seed, and pods) contain various important bioactive substances with therapeutic characteristics, including phenolic compounds, vitamins C and E and other substances [7–9]. Okra fruits are rich in phytochemicals which may have therapeutic effects on various chronic diseases (e.g., type 2 diabetes, cardiovascular and digestive disorders) and liver detoxification, antibacterial and chemopreventive properties [6]. Phenolic substances (mostly flavonoids) and polysaccharides are highlighted as major components responsible for the beneficial, health-promoting properties of okra fruits [10,11]. Phenols were referred to as substances with strong antioxidant activity in numerous earlier studies [12–16]. The consumption of foods rich in natural antioxidants is associated with a lower risk of diseases, including cancer and cardiovascular disorders, connected with oxidative stress [17–21].

Climate change, associated with an increase in temperature, contributes to the possibility of growing unusual and lesser-known vegetable species within the area of the Slovak Republic, or Central Europe in general. The idea of warm-climate crops growing in the Central European zone was already discussed for eggplant (*Solanum melongena* L.) [22]. Okra is currently grown primarily in Asia and Africa; thus, it is a crop that is easily adaptable to changing conditions in our region. Another view is that of people increasingly traveling around the world and discovering many new species and tastes, and okra can be used and processed in gastronomy in different ways (cooked, baked, soup ingredient, dried seeds as a coffee substitute, etc.) [23]. Okra mucilage is also appropriate for use in industrial and medicinal processes [24]. These facts were reasons for the realization of a two-year field experiment with okra. The cultivar is likely the most important factor affecting the yield and quality of grown crops. The aim of this study was to evaluate the yield potential and fruit quality of seven okra cultivars (polyphenol content, antioxidant activity) with different colors of fruits/pods (red, green, white). It was hypothesized that differences in yield and qualitative parameters will be found between okra cultivars. Nowadays, it is necessary to identify "plastic" cultivars of okra, or vegetables in general, that can adapt well to changing climatic conditions and maintain stable production between specific growing seasons. This fact is crucial for potential growers of okra in Central Europe.

2. Materials and Methods

2.1. Experiment Locality

The two-year field experiment was established in the Botanical Garden of the Slovak University of Agriculture in Nitra in 2018 and 2019. Geographical data of this locality are 48°18′ N; 18°05′ E; 144 m a. s. l. [25]. The climate of the experimental locality is typically characterized by warm, dry summer and a mildly warm, dry or very dry winter. The basic climatic characteristics from the experimental area for both vegetation years are described in Table 1. Temperature and sum of precipitation were evaluated according to the long-term average of these characteristics (1961–2010). The vegetation period (May–September) in 2018 can be evaluated as colder and markedly wetter compared to this period in 2019.

Table 1. Average temperature (T) and sum of precipitation (mm) within vegetation period in 2018 and 2019.

Month	2018		2019	
	T (°C)	P (mm)	T (°C)	P (mm)
January	−2.3 N	49.7 VW	2.4 VH	50 VW
February	3.2 H	21.8 D	−0.9 C	27 N
March	8.1 VH	15.6 VD	3.4 C	36 N
April	9.4 N	21.4 D	15.4 EH	16 VD
May	9.3 EC	134.8 EW	18.8 VH	29 VD
June	18.7 N	29.0 VD	20.7 H	44 D
July	21.9 H	21.0 VD	21.7 H	13 VD
August	22.3 VH	83.7 VW	22.5 VH	3 ED
September	16.2 N	60.3 W	16.4 N	55 W
October	12.0 H	15.0 VD	11.9 N	14 VD
November	8.4 VH	88.8 VW	3.9 N	24 VD

December	3.3 H	45.1 N	−1.6 C	58 W
Total	-	586.2	-	369
Mean	10.9	-	11.2	-

Notes: EC—extraordinarily cold; C—cold; N—normal; H—hot; VH—very hot; EH—extraordinarily hot; ED—extraordinarily dry; VD—very dry; D—dry; W—wet; VW—very wet; EW—extraordinarily wet.

2.2. Fertilization

The field experiment with okra was established on medium–heavy soil, classified as Fluvisol [26]. The basic agrochemical characteristics of soil in the experimental area were analyzed before experiment establishment (Table 2). Only nitrogen and sulfur were applied, according to soil analyses. Sulfur and part of the nitrogen were applied two weeks before planting (9 May 2018; 6 May 2019) in the form of DASA (26%N; 13%S; Duslo a. s., Šaľa, Slovak Republic) fertilizer (2018: 50 g m^{-2}; 2019: 47 g m^{-2}). The remaining dose of calculated nitrogen was divided into two applications—two and four weeks after planting (7 June 2018 and 21 June 2018; 4 June 2019 and 20 June 2019). It was applied in the form of LAD27 fertilizer (ammonium saltpeter; 27%N; Duslo a. s., Šaľa, Slovak Republic).

Table 2. Soil analyses before experiment establishment in 2018 and 2019.

Year	pH/KCl	Nutrients (mg kg^{-1} of Soil)						Humus Content (%)
		N_{min}	P	K	S	Ca	Mg	
2018	7.04 N	6.4 L	75.0 M	368 H	2.5 VL	6350 H	763.4 VH	3.29 G
2019	6.89 N	13.0 M	77.5 M	495.0 VH	5.0 L	5200 H	964.0 VH	3.75 G

Notes: N_{min}—mineral (inorganic) nitrogen; N—normal; VL—very low; L—low; M—medium; H—high; VH—very high; G—good; humus—ratio of organic matter in soil.

2.3. Plant Material

Seven okra cultivars with different fruit colors were tested in the experiment: ‘Blondy’ (white; Priemer Seeds Direct, Salisbury, UK); ‘Burgundy’ (red; Priemer Seeds Direct, Salisbury, UK); ‘Jing Orange’ (red; Priemer Seeds Direct, Salisbury, UK); ‘Baby Bubba’ (green; JustSeed Ltd., Wrexham, UK); ‘Cajun Delight F1’ (green; Johnsons Seeds, Kentford, UK); ‘Clemson Spineless’ (green; Chiltern Seeds, Wallington, UK); ‘Pure Luck F1’ (green; Chiltern Seeds, Wallington, UK). Seeds of individual okra cultivars were chosen and purchased according to their availability on the market.

Seedlings were prepared before planting and experiment establishment. Seeds were sown into the multipots with pot sizes 50 × 50 × 62 mm on 10 April 2018 and 5 April 2018. Seedlings were regularly irrigated.

2.4. Planting, Harvest and Sample Preparation

Okra seedlings were planted in the experimental area on 23 May 2018 and 20 May 2019 with a plant spacing of 0.60 × 0.40 m. Within each okra cultivar, 27 plants were planted and divided into three repetitions with 9 plants. Sprinklers were used to irrigate plants based on the weather. The soil was hoed several times for the removal of weeds and soil crust. Protection against diseases and pests was not necessary.

The total yield of okra fruits consisted of 13 partial harvests carried out in accordance with the required fruit maturity (3 July 2018–27 August; 28 May 2019–23 August 2019). Manually harvested okra fruits were crispy and approximately 50 mm long. Okra fruits were weighed immediately after harvest. The average weight of fruits and yield per plant were calculated based on the quantity and weight of harvested okra fruits. Okra yield per hectare was sequentially recounted for the used plant spacing and plant density (41,667 plants per hectare).

For each repetition, the average sample of okra was prepared from 10 fruits harvested on 10 August 2018 and 2 August 2019. During sample processing, pods and seeds were separated. Fruits (pulp) were quartered, and their opposing sections were used and cut with a ceramic knife. Seeds and pulp from okra fruits were analyzed separately. The antioxidant activity in the fresh matter of okra pulp and seeds was analyzed. Okra samples for determination of total polyphenol content and antioxidant activity were lyophilized at −55 °C at the Institute of Nutrition and Genomics, Faculty of Agrobiology and Food Resources, Slovak University of Agriculture in Nitra (ilShin TFD 5503, ilShin BioBase Europe BV, Ede, Netherlands).

2.5. Determination of Antioxidant Activity

The total antioxidant activity (AOA) of okra pulp and seeds was analyzed at the Department of Chemistry, Faculty of Education, Janos Selye University in Komárno, Slovak Republic. The AOA was estimated by the method of Brand-Williams et al. [27] using DPPH (2.2-diphenyl-1-pikrylhydrazyl) scavenging activity calculated as inhibition of DPPH radicals in mg Trolox equivalents (TEAC) kg^{-1} dry weight (d.w.). A Jenway 6301 spectrophotometer (Bibby Scientific, Stone, UK) was used to measure the absorbance at 517 nm.

2.6. Determination of Total Polyphenol Content

The analysis of total polyphenol content (TPC) in okra pulp and seeds was conducted at Institute of Horticulture, Faculty of Horticulture and Landscape Engineering, Slovak University of Agriculture in Nitra, Slovak Republic. The TPC was estimated according to Lachman et al. [28]. The sample absorbance was measured at a wavelength of 765 nm in comparison to a blank by using a Shimadzu UV/VIS-1240 spectrophotometer (Shimadzu Corporation, Duisburg, Germany). The TPC of okra samples was expressed in milligrams of gallic acid equivalent (GAE) per kilogram of dry weight (mg GAE kg^{-1} d.w.)

2.7. Statistical Analysis

Data were statistically processed by analysis of variance (ANOVA) at a significance level of $p \leq 0.05$. If significant differences were detected between the treatments, the averages were compared and the mean separation was performed using Scheffe's test. All factors for yield parameters are shown by 3D scatter plots. Correlation analysis was used to test relationships between quantitative variables. The processing was carried out in the Statistica 14.0 software package (StatSoft Inc., Tulsa, OK, USA).

3. Results and Discussion

3.1. Average Weight of Fruits

The statistical analysis of obtained results showed significant differences in the average weight of fruits (AW) among tested okra cultivars and experimental years (Figure 1). Values of AW ranged from 23.7 (Blondy, 2019) to 36.1 g (Jing Orange, 2018).

In contrast to our findings, a study from Mexico [28] reported significantly lower values of okra fruit weight (7.3–15.3 g). A lower AW was similarly reached in studies conducted in Pakistan [29] using 5 okra cultivars (8.2–10.1 g), India [30] using 7 cultivars (11.3–17.2 g), Egypt [31] using 5 cultivars (5.7–11 g) and Bangladesh [32] using 14 cultivars (14.0–17.8 g). In a study [33] in Nigeria using two cultivars, a higher AW of okra fruits was shown compared to previous studies (20.4–22.6 g). In a study [34] in Guinea, higher values of AW (26.0–31.9 g) were found. Significant differences among studies, and compared to results of our study, can be caused by many factors, e.g., growing location with different agro-ecological conditions (rainfall, temperature, etc.) [35], plant spacing used [36,37], planting date [31,38], vegetation period duration and harvesting date [39]. The size of harvested okra fruits is one of the most significant factors influencing AW (or yield). For example, Olivera et al. [40] categorized okra fruits into eight size categories ranging from "less than 40 mm" to "120–140 mm".

Data show that almost all cultivars reached higher average fruit weight in the 2018 season compared with 2019. Consequently, the growing season can be considered a crucial factor for okra fruit weight. In Baby Bubba, Cajun Delight and Pure Luck, there was no significant difference in average fruit weight between years, indicating a certain stability in the changing growing conditions.

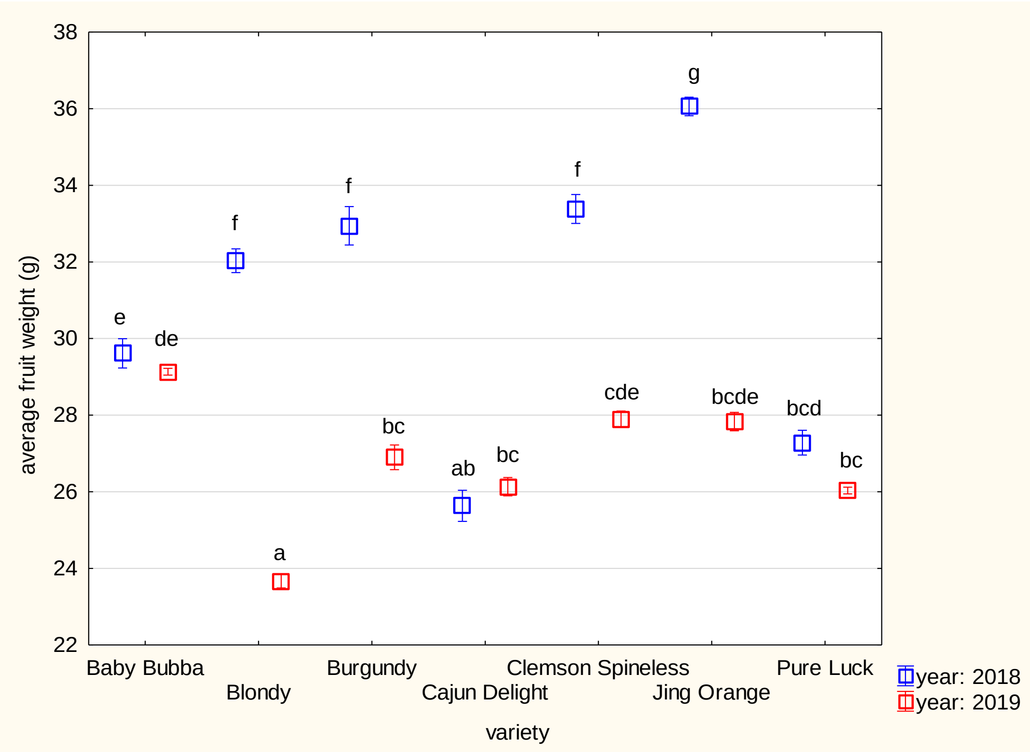

Figure 1. Average weight of okra fruits by Scheffe test (error bars represent SD; different letters among cultivars and years show statistically significant differences at the level $p < 0.05$).

3.2. Yield per Plant and Hectare

The statistical analysis of obtained results showed significant differences in the yield per plant (Y/P) and yield per hectare (Y/H) among tested okra cultivars and experimental years (Figures 2 and 3). The Y/P ranged from 278.1 (Jing Orange, 2019) to 566.1 g (Blondy, 2018). The Y/H ranged from 11.59 (Jing Orange, 2019) to 23.59 t ha^{-1} (Blondy, 2018).

Significant variability of okra Y/P and Y/H, primarily dependent on the okra cultivar, was also found in various studies with this crop realized in the USA and several countries in Asia and Africa. Various studies with okra showed lower Y/P. In a study [29] in Pakistan, Y/P varied from 99.2 to 156.8 g, dependent on the okra cultivar. The Y/P (seven cultivars) ranged from 144.6 to 238.8 g in a study in India [30]. In a study [38] in Bangladesh, significant variability of okra Y/P and Y/H was also found, depending on the cultivar and planting date of okra (122.9–244.4 g; 4.60–9.11 t ha^{-1}).Significant differences in okra Y/P and Y/H were presented in another study [41] in Bangladesh in which the values were in the ranges of 111.7–309.3 g (Y/P) and 9.53–13.67 t ha^{-1} (Y/H), depending on the planting date and plant spacing. In a variant with the spacing of 0.60 × 0.40 m (as in our study), a significantly lower okra yield was found (195.1 g; 7.51 t ha^{-1}).

In an Ethiopian study [35], 33 okra cultivars were tested, and Y/H ranged from 9.44 to 32.88 t ha^{-1}. In a study in Pakistan with six okra cultivars [42], Y/H varied in the range of 13.11 to 17.50 t ha^{-1}. In a study in India with five cultivars [43], values of Y/H ranged from 9.45 to 13.67 t ha^{-1}. In a study in the Philippines with three okra cultivars [44], Y/H varied from 20.31 to 21.34 t ha^{-1}. The okra Y/H in a Nigerian study [45] with three cultivars was in the range 13–14 t ha^{-1}. Results of okra Y/H in previous studies are consistent or comparable with okra Y/H found in our study, despite the use of slightly different growing technology and different okra cultivars.

On the contrary, lower Y/H was found in two studies with okra [33,37] realized in Nigeria (2.71–9.90 t ha^{-1}; 3.45–7.36 t ha^{-1}) compared to our study. According to the FAOSTAT database [4], a significantly lower okra Y/H compared to all previous studies was reached in the world in the period 2011–2020 (3.40–5.35 t ha^{-1}). Within individual presented studies, many different cultivars of okra were used. The cultivars 'Baby Bubba' and 'Clemson Spineless' were tested in a study [46] in the USA in which significantly lower values of Y/H were found compared to our experiment (BB 6.14 t ha^{-1}; CS 12.21 t ha^{-1}).

Results of all experimental studies show a strong impact of cultivar and growing area on the yield of okra fruits. The assortment of grown okra cultivars in the world is wide, and the selection of a suitable cultivar is a very significant factor in okra production.

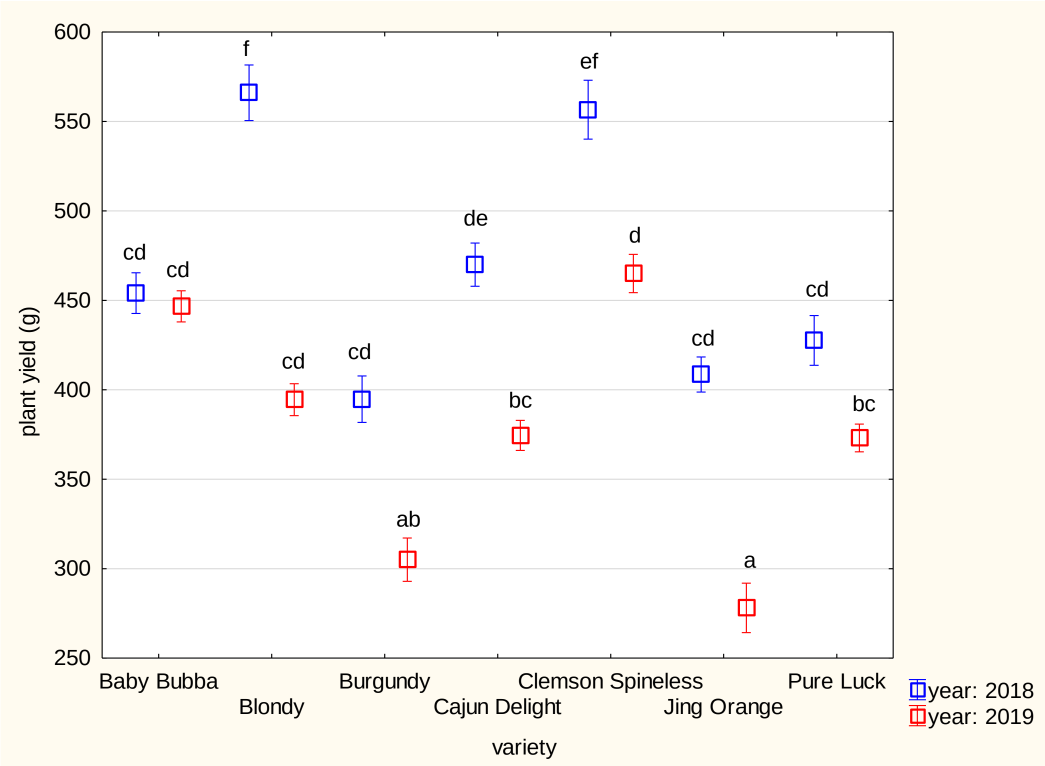

Figure 2. Yield of okra fruits per plant by Scheffe test (error bars represent SD; different letters among cultivars and years show statistically significant differences at the level $p < 0.05$).

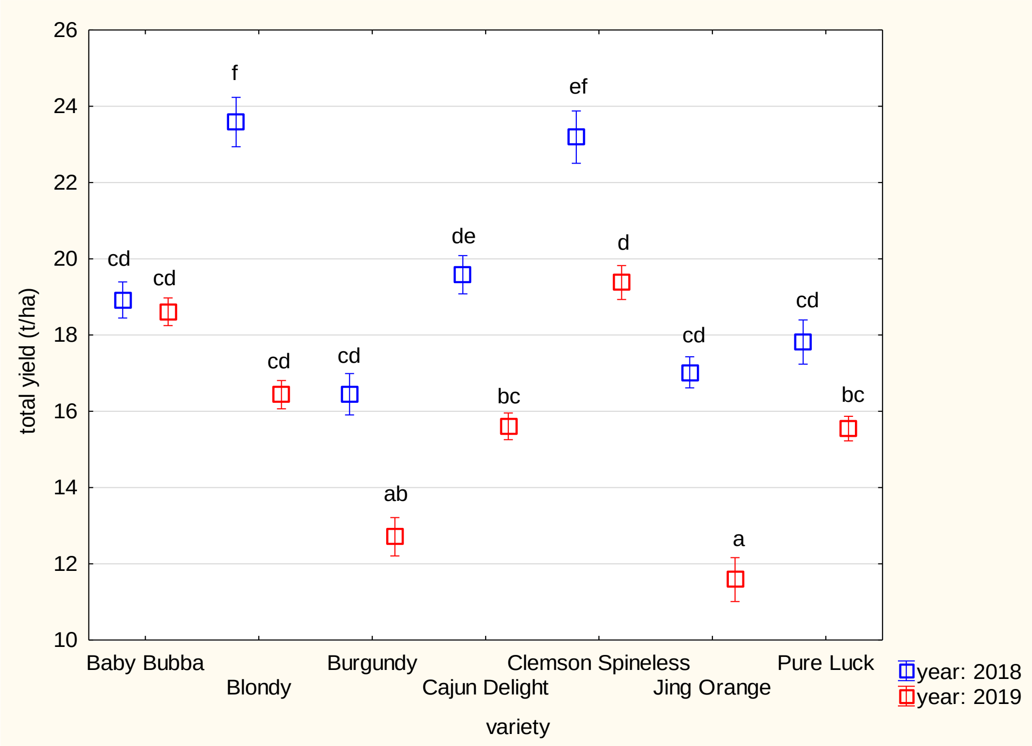

Figure 3. Yield of okra fruits per hectare by Scheffe test (error bars represent SD; different letters among cultivars and years show statistically significant differences at the level $p < 0.05$).

In an Egyptian study [31], huge differences in okra Y/P, depending on the sowing date, were found (94.9–586.2 g). The author also found a significant effect of growing year on the value of Y/P, which was 300.6 g (on average) in 2011 and 287.4 g in 2012; these values are consistent with the range of Y/P found in our study. A significant effect of growing year on the okra Y/H was also presented by Ijoyah and Dzer [47] in a Nigerian study. Authors similarly found higher okra Y/H in a growing year with a higher rainfall sum (2010; 6.0 t ha^{-1}) in comparison with a growing year with a lower rainfall sum (2011; 5.7 t ha^{-1}). This fact was also confirmed in our study and other studies with okra [48,49].

A statistically significant effect of the experimental year on the Y/H was found for most of the okra cultivars (Table 3). The average yield was higher in the growing year 2018, characterized by a higher rainfall sum, compared to the year 2019. Thus, the growing season can be classified as an important factor influencing this parameter.

In cultivars 'Baby Bubba' and 'Pure Luck', differences in okra Y/H between experimental years were evaluated as statistically non-significant (NS). Both cultivars exhibited considerable yield: 18.7 t ha^{-1} ('Baby Bubba') and 16.7 t ha^{-1} ('Pure Luck'). Thus, these okra cultivars can be characterized as plastic cultivars in relation to changing climate conditions. This fact is very important for potential growers from the aspect of crop yield stabilization in individual growing years.

Table 3. Effect of the cultivar and growing year on the mean yield and qualitative parameters of okra fruits.

Source of Variance	AW	Y/P	Y/H	AOA Pulp	AOA Seed	TPC Pulp	TPC Seed
Cultivar	***	***	***	***	**	***	***
Year	***	***	***	***	**	***	***
Cultivar x Year	***	***	***	NS	NS	***	**

Notes: AW—average fruit weight; Y/P—yield per plant; Y/H—yield per hectare; AOA—antioxidant activity; TPC—total polyphenol content. Differences depending on cultivar, year and interaction cultivar x yield by Scheffe test; non-significant (NS) or significant at $p \leq 0.05$ (*), 0.01 (**), or 0.001 (***).

Table 3 summarizes individual levels of statistical differences for all evaluated factors. From the summary of the analysis of variance, it is obvious that the effect of both production season (year) and cultivar on yield and nutritional parameters was strong. On the contrary, the interaction effect in AOA for pulp and seed was non-significant.

3.3. Antioxidant Activity

Okra fruits have a variety of culinary applications. In addition, okra seeds can be roasted and mashed to create a coffee alternative without caffeine content [22,50]. Various studies showed significant variability of AOA (or nutritional quality generally) in dependency on the vegetable or fruit part consumed, e.g., peel, pulp or seeds [51–53]. For this reason, the AOA of okra was separately determined for fruit pulp and seeds. The statistical analysis of results revealed significant differences in the AOA of pulp among examined okra cultivars and experimental years (Table 4). The AOA in okra pulp ranged from 485.71 (Clemson Spineless, 2018) to 536.00 mg TEAC kg^{-1} d.w. (Burgundy, 2019). On the other hand, differences in the AOA of seeds among examined okra cultivars and experimental years were determined as statistically non-significant. The AOA in okra seeds ranged from 594.51 (Baby Bubba, 2018) to 600.36 mg TEAC kg^{-1} d.w. (Burgundy, 2019)

Table 4. Antioxidant activity of okra cultivars (mg TEAC kg^{-1} d.w.).

Cultivar	Pulp		Seeds	
	2018	2019	2018	2019
Baby Bubba	494.64 ± 7.17 ^{abc}	502.54 ± 3.47 ^{abcd}	594.51 ± 2.12 ^{abc}	597.54 ± 1.85 ^{a}
Blondy	501.29 ± 3.47 ^{abcd}	505.66 ± 2.86 ^{bcd}	595.12 ± 2.15 ^{a}	595.84 ± 1.90 ^{a}
Burgundy	524.99 ± 4.09 ^{ef}	536.00 ± 1.90 ^{f}	598.55 ± 2.20 ^{a}	600.36 ± 1.97 ^{a}
Cajun Delight	502.54 ± 4.09 ^{abcd}	511.48 ± 2.19 ^{cde}	597.14 ± 1.81 ^{a}	597.94 ± 1.92 ^{a}
Clemson Spineless	485.71 ± 7.56 ^{a}	491.53 ± 3.81 ^{ab}	595.32 ± 1.21 ^{a}	596.13 ± 1.85 ^{a}
Jing Orange	517.71 ± 3.76 ^{de}	527.07 ± 4.06 ^{ef}	596.93 ± 1.85 ^{a}	598.75 ± 2.12 ^{a}
Pure Luck	519.0 ± 4.38 ^{def}	528.31 ± 3.14 ^{ef}	598.75 ± 1.75 ^{a}	599.56 ± 1.82 ^{a}

Different letters among cultivars and years show statistically significant differences at the level $p < 0.05$ according to Scheffe test.

The antioxidant activity of okra, analyzed using the DPPH method, was expressed in experimental studies by various units (e.g., % of DPPH inhibition, mg mL^{-1} of extract, μmol TE g^{-1} d.w). Due to this fact, it is difficult to make a precise comparison between our results and those of other studies. However, a number of studies highlighted the significant cultivar-dependent variability in the AOA of okra fruits. There was 1.5- or 2-fold variability in AOA of okra fruits among cultivars in several experimental studies [10,11,54–58].

Results from our study revealed significant differences in AOA between pulp and seeds in all tested okra cultivars. This is consistent with the study of Khomsug et al. [59], who discovered multiple-fold higher values of AOA in the seeds compared to the pulp of okra fruits by using two different methods of AOA determination (DPPH and ABTS).

According to the study of Karunasiri et al. [60], okra can be classified among vegetable species with high AOA. Okra had the highest AOA, followed by bitter gourd, eggplant, tomato, pepper, carrot, beans and beetroot.

3.4. Total Polyphenol Content

The contribution of okra consumption to human health is through the intake of health-promoting substances with antioxidant properties. Results of several studies suggested that phenolic compounds might be the main contributors to the antioxidant potential of okra fruits and antioxidant substances abundant in okra fruits [11,61–64]; thus, TPC was analyzed in the okra assortment.

The statistical analysis of obtained results showed significant differences in total polyphenol content (TPC) in fruit pulp and seeds among tested okra cultivars and experimental years (Table 5). Values of TPC in okra pulp ranged from 2434.12 (Clemson Spineless, 2018) to 3988.72 mg TEAC kg^{-1} d.w. (Jing Orange, 2019). Values of TPC in okra seeds ranged from 16612.60 (Clemson Spineless, 2018) to 33539.09 mg TEAC kg^{-1} d.w. (Pure Luck F1, 2019).

Table 5. Total polyphenol content in okra cultivars (mg GAE kg^{-1} d.w.).

Cultivar	Pulp		Seeds	
	2018	2019	2018	2019
Baby Bubba	2626.33 ± 17.17 ^{b}	3149.63 ± 36.09 ^{e}	17,301.82 ± 66.77 ^{b}	18,218.79 ± 65.22 ^{c}
Blondy	2455.13 ± 16.86 ^{a}	2929.96 ± 34.63 ^{c}	17,763.52 ± 118.36 ^{bc}	18,846.22 ± 56.41 ^{d}
Burgundy	3127.12 ± 15.87 ^{de}	3603.19 ± 57.59 ^{f}	27,538.64 ± 107.99 ^{g}	28,446.71 ± 142.68 ^{h}
Cajun Delight	2910.14 ± 11.18 ^{c}	3563.59 ± 38.81 ^{f}	21,493.01 ± 58.45 ^{e}	22,552.80 ± 53.26 ^{f}
Clemson Spineless	2434.12 ± 15.21 ^{a}	3020.71 ± 24.98 ^{cd}	16,612.60 ± 113.73 ^{a}	17,730.79 ± 95.51 ^{b}
Jing Orange	3521.38 ± 26.17 ^{f}	3988.72 ± 32.74 ^{h}	21,658.27 ± 108.77 ^{e}	22,486,35 ± 118.07 ^{f}
Pure Luck	3167.22 ± 5.90 ^{e}	3775.65 ± 37.40 ^{g}	32,140.08 ± 129.60 ^{i}	33,539.09 ± 199.08 ^{j}

Different letters among cultivars and years show statistically significant differences at the level $p < 0.05$ according to Scheffe test.

In various studies, TPC was not specifically analyzed for pulp and seeds as in our experiment; thus, it is difficult to precisely compare them with our experiment. In a study in Ghana [65] with 25 okra cultivars, approximately 10-fold differences in TPC were found (6820–63220 mg GAE kg^{-1} d.w.). This study highlighted the significant influence of cultivar on the TPC of okra fruits, and the findings were further supported by other studies on okra in which TPC values ranged from 2882 to 12730 mg GAE kg^{-1} d.w. [66–70].

Regarding the TPC in okra seeds, various studies revealed significant differences in TPC values, which ranged from 278.3 to 13000 mg GAE kg^{-1} d.w. [10,59,71–72]. These results are significantly lower in comparison with the TPC of okra seeds found in our experiment.

In our study, TPC levels in okra seeds were 6–10-fold higher than those in fruit pulp. This finding is consistent with other studies in which significant differences between okra pulp and seeds were presented. Khomsug et al. [59] found 13-fold higher TPC in okra seeds (1424.8 mg GAE kg^{-1} d.w.) compared to the okra pulp (1424.8 mg GAE kg^{-1} d.w.). More than 29-fold higher TPC in okra seeds (13,000 mg GAE kg^{-1} d.w.) was found in comparison with fruit pulp in the study of Phornvillay et al. [73]. More than 10-fold differences between okra seeds and pulp were found in a different study [74].

Okra is lesser-known vegetable species in the Slovak Republic. However, according to various studies, okra is a vegetable species with TPC that is comparable to or higher than that in vegetable species traditionally grown in our area, e.g., onion, garlic, tomato, sweet pepper and cabbage. This was discussed in a study [75] in Burkina Faso. The author analyzed TPC in 15 different vegetable species, and okra was found to have the second highest value of TPC (2526 mg GAE kg^{-1} d.w.), followed by lemon (2035 mg GAE kg^{-1}), spinach (1825 mg GAE kg^{-1}), onion bulbs (1559 mg GAE kg^{-1}) and leaves (1033), zucchini (1002 mg GAE kg^{-1}), garlic (741 mg GAE kg^{-1}), cabbage (493 mg GAE kg^{-1}), etc.

3.5. Correlation of AOA and TPC

The statistical analysis of obtained results revealed the high significance of the correlation between AOA and TPC in okra pulp (R = 0.78611475; R2 = 0.61797640; p = 0.000000). This indicates that the AOA value of okra pulp is caused to a considerable extent by polyphenol abundance (Figure 4). In okra seeds, statistical model is also characterized by high significance and correlation between AOA and TPC (R = 0.58826275; R2 = 0.34605306; p = 0.000042). However, the determination coefficient is weak (Figure 5), and it is possible to state that the AOA of okra seeds can be influenced by an abundance of other factors. Romdhane et al. [61] indicate that okra seeds are also a good source of zinc, vitamin C and carotenoids, important bioactive substances for human nutrition. The significant variability of all mentioned substances within the okra assortment has been proved in previous experimental studies [76,77]. All these substances and their variable contents could have a significant impact on the total antioxidant activity of okra seeds.

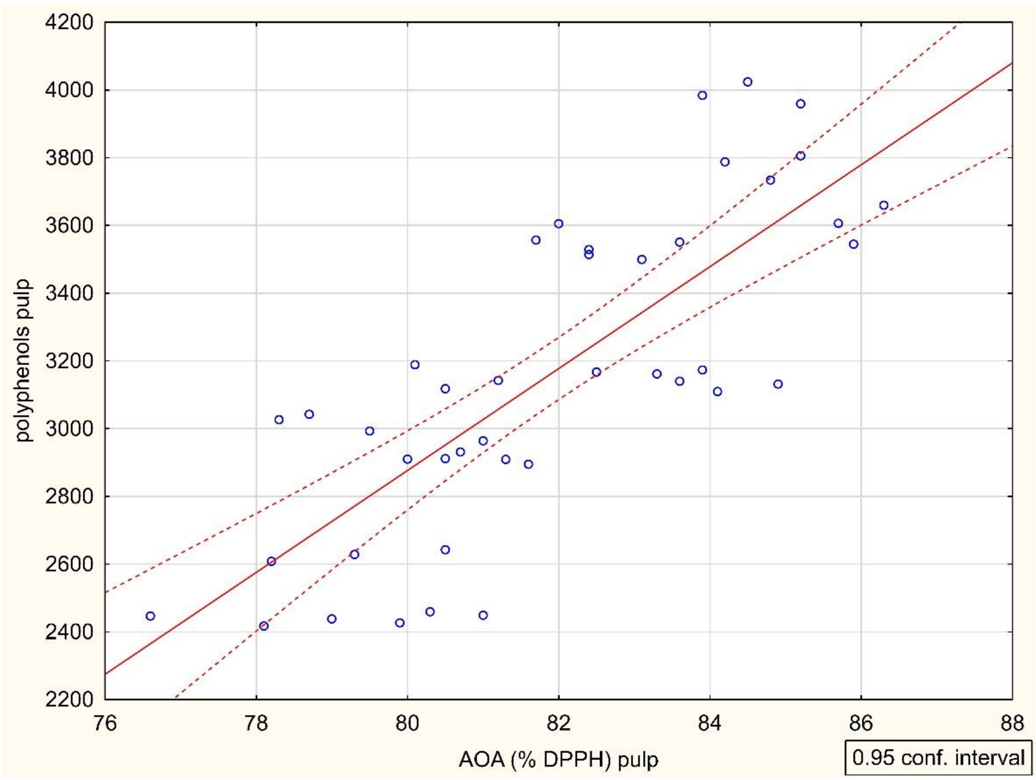

Figure 4. The correlation of AOA and TPC in okra pulp.

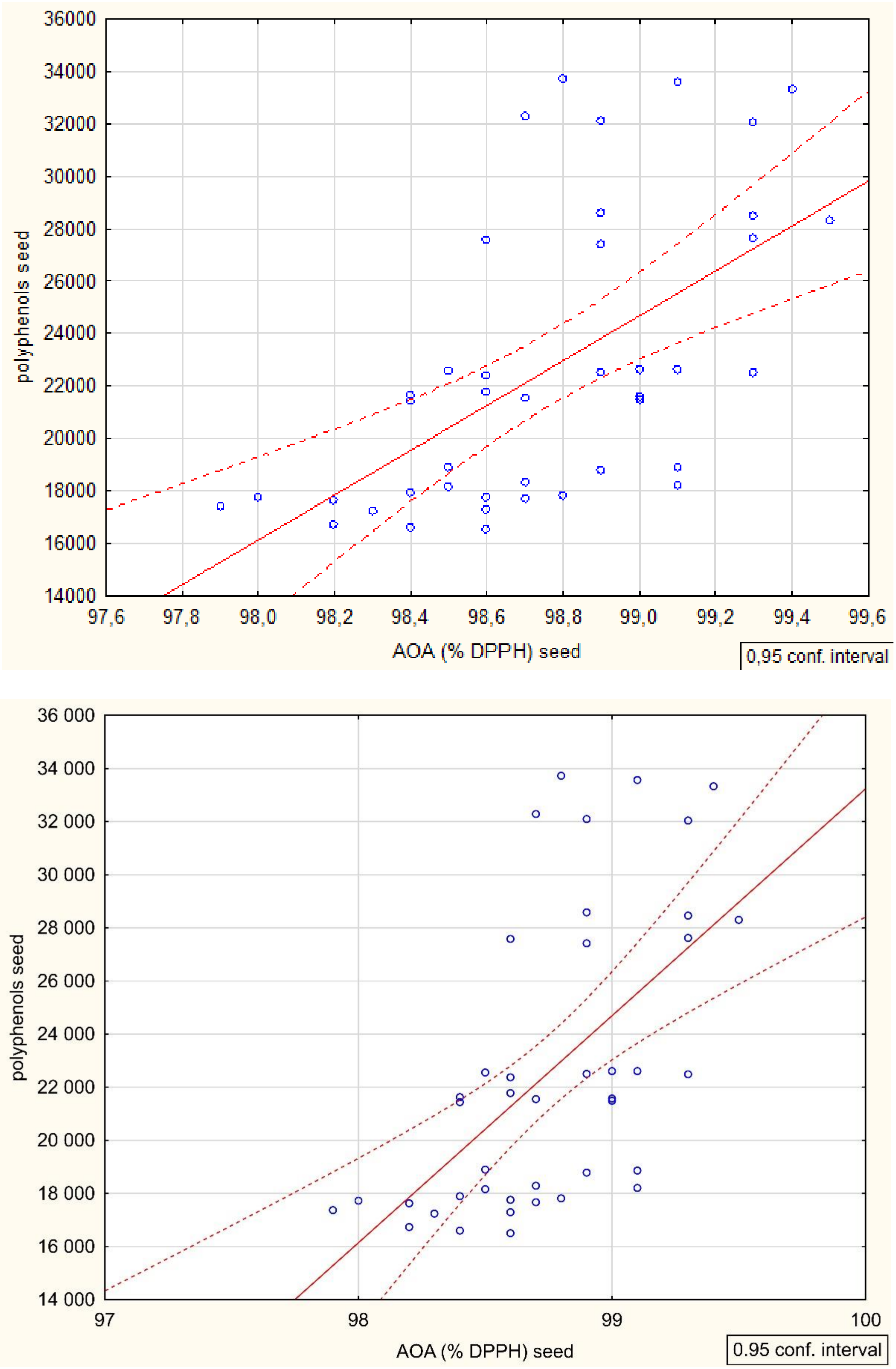

Figure 5. The correlation of AOA and TPC in okra seeds.

4. Conclusions

Changes in climate and dietary preferences (or modern gastronomy) are among the main reasons for testing new vegetable species in the conditions of the Slovak Republic, where they have not been traditionally grown. Okra is currently grown primarily in Asia or Africa. The results of this study emphasize the large variation in yield and qualitative parameters in seven okra cultivars. Findings will be useful for potential growers for better orientation in okra assortment. Additionally, the results of AOA and TPC will be useful for consumers or small growers in local gardens.

Statistically significant differences in okra yield parameters were found among tested cultivars and growing years, except for cultivars 'Baby Bubba' and 'Pure Luck'. For this reason, these two cultivars can be characterized as plastic cultivars in relation to changing climate conditions because statistically NS differences were found in all yield parameters (average fruit weight, yield per plant, yield per hectare) among experimental years.

Statistically non-significant differences were found in the total AOA of okra pulp and seeds among tested okra cultivars. Some of the most important nutritional substances in okra are polyphenols. Statistically significant differences in TPC in okra pulp and seeds were found among tested okra cultivars. Significant differences in AOA and TPC were found between okra pulp and okra seeds in all tested cultivars. This fact can be interesting for consumers because okra seeds can be used as a coffee substitute with high antioxidant potential. According to obtained results, okra cultivars 'Burgundy', 'Pure Luck F1' and 'Jing Orange' can be characterized as nutritionally most interesting.

Generally, when comparing the results of this study to those from studies in countries where okra is a traditional crop, it can be stated that okra grown in the Slovak Republic showed promising yield potential and comparable antioxidant potential and polyphenol content.

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