Short communication

HEAT STRESS EFFECT ON CUCURBITA SPECIES NUTRITIONAL QUALITY PARAMETERS

Alternative Crops and Cultivation Practices

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SUMMARY

This study aimed to assess the overall effect of heat stress on total carotenoids and sugars content in butternut squash (*Cucurbita moschata*) and pumpkin (*Cucurbita maxima*) fruit flesh. The study comprised thirty accessions of each plant species, grown under field conditions following standard agronomic practices, including irrigation. The experiment was performed over the course of seven consecutive seasons (2016-2022), enabling the comparisons between temperate and heat stress growing conditions. Number of days with maximum daily air temperature ≥ 30°C was compared to 30-year (1991-2020) mean (34 days) and used as criterion for distinguishing between temperate and heat stress seasons. Heat stress affected carotenoids content, whereas sugars content remained comparable between the two temperature regimes. Although observed in both species, the decrease in carotenoids content was less pronounced in pumpkins (32.0 vs. 26.5 mg/kg fresh weight) than in butternut squashes (38.3 vs. 13.3 mg/kg fresh weight, mean values for temperate and heat stress seasons, respectively). Given the substantial variation in carotenoids content observed within both *C. moschata* and *C. maxima* species, further research should focus on the responses of individual accessions to heat stress, as well as on the correlations among fruit flesh quality parameters and agronomic yield.

Keywords: carotenoids content, *Cucurbita*, heat stress, multi-year trial, sugars content

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INTRODUCTION

Although originating from and therefore thriving in warmer and temperate climates, plants from genus *Cucurbita* may evince substantial losses in fruit yield and nutritional quality that are due to heat stresses occurring throughout the growing season. The plants are particularly sensitive at the beginning and amidst reproductive phase, when the pollination, setting and accelerated growth of young fruits take place. Even short-term exposure to maximum daily temperatures of ≥ 30 °C was potentially associated with numerous adverse effects. In Southeastern Europe, such temperatures have become increasingly frequent, especially during the June–August period. Therefore, it is important to adapt cultivation practices and breeding strategies to the heat stress conditions (Sanjur et al., 2002; Paris, 2016).

The aim of this study was to investigate if the heat stress occurring throughout the reproductive phase of field-grown *Cucurbita moschata* and *Cucurbita maxima* accessions affects the key determinants of their fruits nutritional quality and flavor, i.e. total carotenoids and sugars content.

MATERIAL AND METHODS

The samples for the investigation were taken from the ripe fruits of *Cucurbita moschata* and *Cucurbita maxima* accessions belonging to diverse breeding collection of the Institute of Field and Vegetable Crops, Novi Sad, Serbia. Accessions were selected to reflect the full range of variation in the collection regarding fruit morphology (Picture 1), agronomic traits and nutritional quality. Sixty accessions in total,

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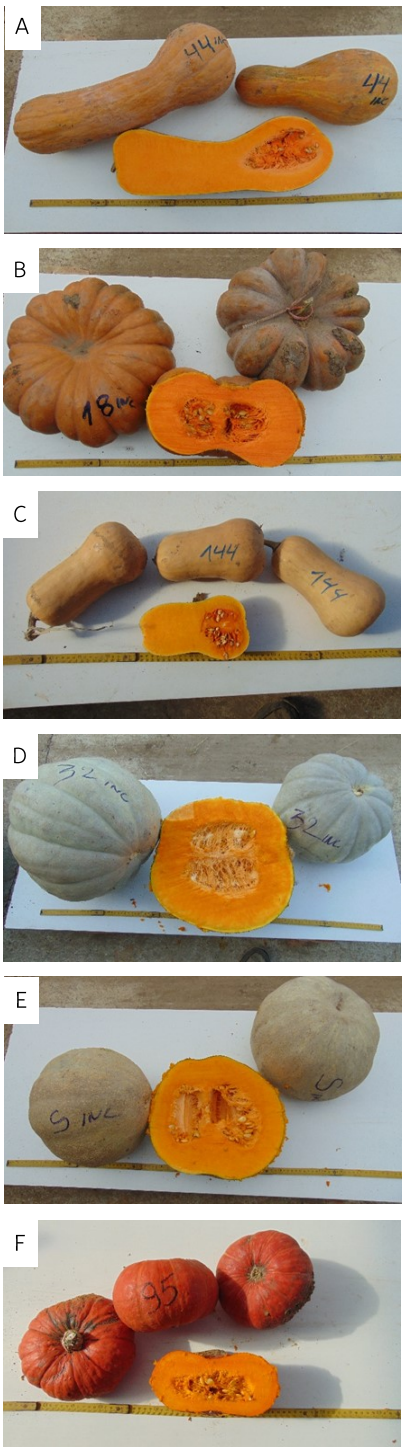
thirty of each plant species, were grown at the Institute's experimental field located near Bački Petrovac (N 45°20', E 19°40', 82 m altitude). The experimental plots consisted of 20.0 m long rows with ten plants. The intra- and inter-row spacing was 2.0 and 5.0 m, respectively. The replicated plots were arranged in randomized blocks. Serbia).



Picture 1. *Cucurbita moschata* (A, B, C) and *Cucurbita maxima* (D, E, F) fruit morphology

Standard regional agronomic practices were applied and included autumn deep ploughing, fertilizing with 16:16:16 NPK at the rate of 200 kg/ha, pre-sowing land preparation, hand-sowing in the first decade of May, weed management, plant protection as required, and sprinkler irrigation. The fruits were harvested in the late September–early October.

Sampling included 4-5 fruits per experimental plot, the replicated fruit flesh samples were combined and analyzed as a single composite sample representing each accession. Total carotenoids (mg/kg fresh weight) and sugars (mg/g fresh weight) contents were analyzed according to the procedures described in Brdar-Jokanović et al. (2019).

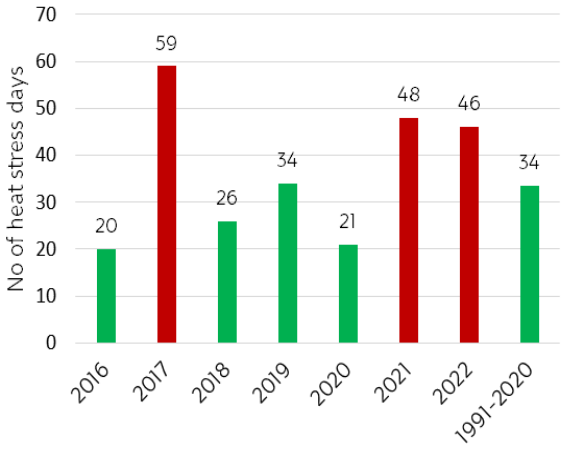


Figure 1. Total number of days with maximum daily temperature ≥ 30 °C (June-August), 2016-2022 and 30-year mean (1991-2020). Temperate and heat-stress seasons are marked green and red, respectively

The experiment was carried out in seven consecutive seasons, 2016-2022. The data on the maximum daily temperatures noted in June, July and August were taken from the official website of the Republic Hydro-Meteorological Service of Serbia (2025). The number of days with maximum daily air temperature ≥30 °C (heat stress days) was compared with the 30-year mean (1991-2020; Figure 1) to classify seasons. Seasons with ≤ 34 such days were considered temperate (2016, 2018, 2019, and 2020); the remainder were classified as heat stress seasons (2017, 2021, and 2022). Data were analyzed by ANOVA. Basic statistic parameters (mean value, range, and coefficient of variation) were calculated.

RESULTS AND DISCUSSION

The accessions of *Cucurbita moschata* and *Cucurbita maxima* species differed significantly ($p < 0.01$, not shown) in terms of the fruit flesh total carotenoids and sugars content. The variability was evident both between and within the species. Since a large number of phenotypically highly divergent accessions were included in this seven-year experiment, the differences were expected and comparable to the results of Jacobo-Valenzuela et al. (2011), Salehi et al. (2019), and Ninčević Grassino et al. (2023). Mean values and variation of the analyzed parameters are shown in Table 1. Accessions of the *C. maxima* had a higher mean total carotenoid content than those of *C. moschata*, whereas the opposite pattern was observed for total sugars content. The greatest variation was recorded for carotenoids content in *C. moschata*. In contrast, variation in sugars content was comparable between the two species. As the study focused on assessing the overall effects of heat stress on fruit nutritional quality parameters in the two species, rather than the variability among individual accessions, the results were subsequently interpreted at the species level.

Table 1. Total carotenoids and sugars content in *Cucurbita moschata* and *Cucurbita maxima* accessions, seven-year (2016-2022) means

Plant species	Parameter	Total carotenoids content (mg/kg fresh weight)	Total sugars content (mg/g fresh weight)
Cucurbita moschata	Mean value	27.6	26.6
	Range	10.5 – 44.9	19.1 – 34.5
	CV (%)	52.7	20.2
Cucurbita maxima	Mean value	29.8	23.3
	Range	20.3 – 39.6	19.3 – 32.8
	CV (%)	24.5	20.1

CV–coefficient of variation

The total carotenoids content observed across individual seasons is presented in Figure 2. Total carotenoids levels were significantly higher during the temperate seasons compared to the heat stress seasons. This pattern was most evident when comparing the carotenoids content in seasons characterized by the lowest and highest numbers of warm days (2016 and 2017, respectively). The reduction in carotenoids content under heat stress was particularly pronounced in *C. moschata*, indicating a lower tolerance to elevated air temperatures, at least with respect to the nutritional quality of the fruit flesh. The comparatively lower *C. moschata* tolerance to heat stress, as mediated by antioxidant and chaperone systems involved in plant cellular protection against abiotic stress, was reported by Murtazina et al. (2024) and Yurina & Murtazina (2025). In that regard, *C. maxima* might be recommended for cultivation in heat stress prone environments.

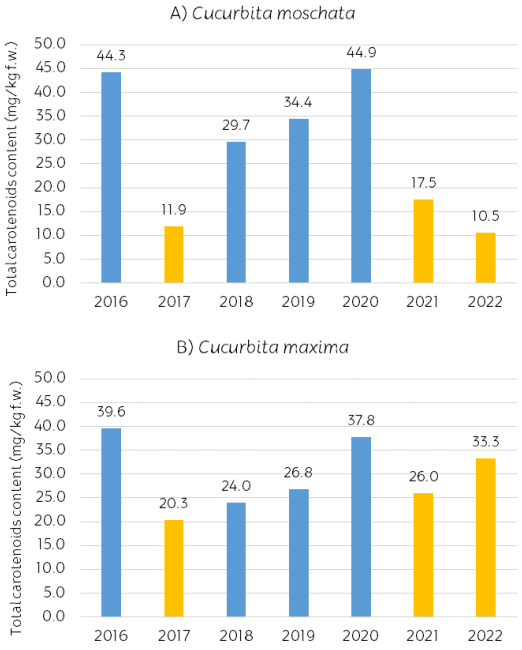


Figure 2. Total carotenoids content (mg/kg fresh weight) in *Cucurbita moschata* (A) and *Cucurbita maxima* (B) accessions, for individual seasons (temperate and heat stress seasons are represented with blue and yellow bars, respectively)

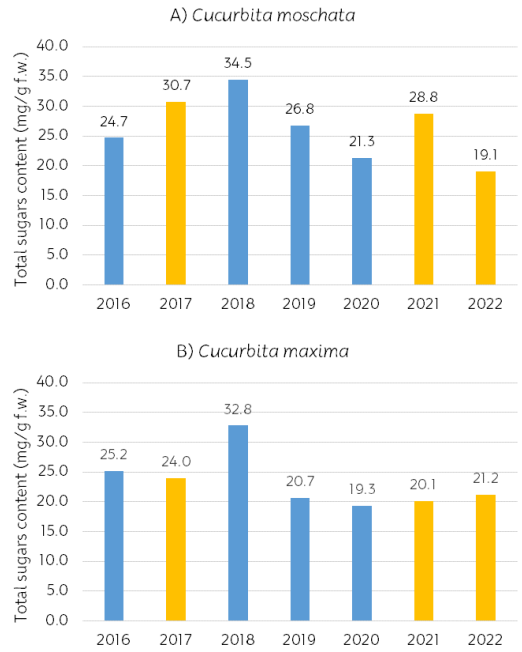


Figure 3. Total sugars content (mg/g fresh weight) in *Cucurbita moschata* (A) and *Cucurbita maxima* (B) accessions, for individual seasons (temperate and heat stress seasons are represented with blue and yellow bars, respectively)

Generally, *C. moshata* exhibited higher values of total sugars content with respect to *C. maxima*, which was in accordance to the results of Tateishi et al. (2004), Pevicharova & Velkov (2017) and Abbas et al. (2020). Despite a marginally higher mean total sugars content in temperate seasons relative to heat-stress seasons, no consistent pattern emerged for either plant species (Figure 3). The result indicates that multiple environmental factors and their interactions may contribute to sugars accumulation in the fruits of *C. moscata* and *C. maxima* species.

CONCLUSIONS

The results of this multi-year study indicate that heat stress has a detrimental effect on total carotenoids content in the fruit flesh of plant species *Cucurbita moschata* and *Cucurbita maxima*, with *C. maxima* demonstrating greater overall tolerance. Conversely, total sugars content could not be clearly linked to seasonal fluctuations in temperature regimes.

Given the importance of nutritional quality in food and feed, these findings should be considered when initiating production, as well as when planning future strategies for the development of new cultivars.

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SAŽETAK

EFEKAT TOPLOTNOG STRESA NA PARAMETRE NUTRITIVNOG KVALITETA KOD *CUCURBITA* VRSTA

MILKA BRDAR-JOKANOVIĆ, BILJANA KIPROVSKI

Cilj rada je bila procena efekta toplotnog stresa na ukupan sadržaj karotenoida i šećera u mesu plodova muskatne tikve (*Cucurbita moschata*) i bundeve (*Cucurbita maxima*). U ogled je uključeno po trideset akcesija ovih biljnih vrsta, gajenih u poljskim uslovima uz primenu standardnih agrotehničkih mera, uključujući navodnjavanje. Eksperiment je sproveden tokom sedam uzastopnih sezona (2016-2022), što je omogućilo poređenje između umerenih sezona i onih u kojima je uočen toplotni stres. Broj dana sa maksimalnom dnevnom temperaturom vazduha ≥ 30°C upoređen je sa 30-godišnjim (1991-2020) prosekom (34 dana) i korišćen je kao kriterijum za razlikovanje između umerenih i sezona sa toplotnim stresom. Toplotni stres je uticao na sadržaj karotenoida, dok se sadržaj šećera nije značajno razlikovao u uslovima dva temperaturna režima. Iako je primećeno kod obe vrste, smanjenje sadržaja karotenoida bilo je manje izraženo kod bundeva (32,0 naspram 26,5 mg/kg sveže mase) nego kod muskatnih tikava (38,3 naspram 13,3 mg/kg sveže mase, srednje vrednosti za umerene sezone i one sa toplotnim stresom, po redosledu). S obzirom na značajne varijacije u sadržaju karotenoida primećene kod vrsta *C. moschata* i *C. maxima*, dalja istraživanja bi trebalo da se fokusiraju na pojedinačne akcesije u uslovima toplotnog stresa, kao i na korelacije između parametara kvaliteta mesa ploda i agronomskog prinosa.
KLJUČNE REČI: *Cucurbita*, sadržaj karotenoida, sadržaj šećera, toplotni stres, višegodišnji ogled

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