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Research Article

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Morphological characteristics of selected flower parts of *Cucurbita pepo* L. Styriaca Group

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The study aimed to determine the variability of some morphological characters on flowers of selected plants within the population of ESO variety of Styrian oil pumpkin (*Cucurbita pepo* L. Styriaca Group). For experimental evaluation, we used two years (2020–2021) measurements of 1792 selected pistillate and staminate flowers from individual plants grown in the field conditions in the Kolíňany settlement (the Slovak Republic). We determined for staminate flowers the range for the length of petals (25.00–134.00 mm), width of petals (14.00–92.00 mm), width of sepals (3.00–31.00 mm), height of sepals (3.00–34.00 mm), length of anther (4.00–24.00 mm), weight of flowers (0.97–11.81 g), weight of petals (0.27–7.14 g), weight of sepals (0.07–2.70 g) and weight of stamens (0.05–6.21 g). High degrees of variability were confirmed for all characters. We determined for pistillate flowers the range for the length of petals (41.00–121.00 mm), width of petals (10.00–100.00 mm), length of the pistil (5.70–15.72 mm), weight of flower (2.91–33.59 g), weight of petals (0.90–9.92 g), weight of sepals (0.61–2.93 g), and weight of pistil (0.07–1.72 g). Variability for traits confirmed moderate to high degree of variability. Our obtained results can serve as a basis for the taxonomy of the species (morphometric approach), for its selection, but also culinary purposes, where edible flowers are still used to a greater extent in gastronomy in the preparation of meals. For this purpose, genotypes with the production of larger flowers could be particularly interesting.

Keywords: Styrian oil pumpkin, staminate flower, pistillate flower, morphometric analysis, variability

Introduction

Pumpkin (*Cucurbita* spp.), which belongs to the family Cucurbitaceae Juss., is a worldwide important agricultural crop produced and consumed all over the world. Numerous agricultural products are major sources of functional components consisting of nutrients and bioactive phytochemicals which may provide substantial health benefits and contribute to the good status of human health. Pumpkin fruits are an extremely healthful agricultural crop with a balanced mixture of beneficial nutrients for human health and nutrition (Dhiman et al., 2009; Dar et al., 2017; El Khatib and Muhieddine, 2019). Recently, an increasing interest has been given not only to the pumpkin flesh and its by-products mainly seeds and peels (Aruah et al., 2010; Lebeda et al., 2017; Tripti et

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al., 2019; Horčinová et al., 2022; Öztürk et al., 2022), but also to its flowers and some vegetative parts (e.g. buds, tender stem tips, leaves, tendrils), which are also used as vegetables (Nee, 1990; Merrick, 1991; Lira, Andres and Nee, 1995; Ghosh and Rana, 2021). Flower buds and flowers of *C. pepo* are also edible and several products gaining its importance as a functional food (Gutierrez, 2016; Ghosh and Rana, 2021).

Flores De Calabaza in Mexico, Classic stuffed peppers in West America, Pakoda or Vajji in India are dishes prepared from pumpkin flowers. In general, the flowers are used as raw in salads, cooked with other vegetables, and steamed in soups. Canned blossoms are also available in the local Mexican markets but always fresh blossoms are preferred for consumption (Ghosh and Rana, 2021). The delicate texture and slightly sweet flavour of *C. pepo* flowers have made them one of the favourite ingredients. These flowers are a rich source of healthy constituents such as phenols and flavonoids (hesperidin, quercetin-3-O-glucoside, catechin, epicatechin, rutin, and syringic acid as dominant compounds), carotenoids (Morittu et al., 2019; Ghosh and Rana, 2021), and are used in traditional medicine (Lu et al., 2016; Dar et al., 2017; Morittu et al., 2019).

The hypoglycaemic effects of *C. pepo* flower extract obtained *in vitro* are confirmed *in vivo*. The extract also affected *in vivo* lipid metabolism but did not reveal benefits on ROS production. Finally, obtained results highlighted *C. pepo* flowers as a food aimed at satisfying both taste and health (Morittu et al., 2019).

Few people grow *Cucurbita* flowers for decorative purposes as a flower lasts only one morning. Only one species (*C. maxima*) is known to have very aromatic flowers (Lira et al., 1995).

Most members of the Cucurbitaceae are monoecious, which means each plant has flowers with only stamens along with other flowers which are only pistillate at the same plant. These are commonly called male (staminate) and female (pistillate) flowers (Whitaker and Robinson, 1986; Lira et al., 1995; Rzedowski and Rzedowski, 2001).

Cucurbita flowers are large, gamopetalous with tubular-campanulated corollas, and showy, with a cream-coloured or light yellow or bright-yellow orange corolla. Flowers grow from the axil of a leaf. Staminate flowers have column-like stamens, with free or more or less connivent filaments, and the yellowish anthers are joined together forming a cylindrical or narrowly pyramidal structure. Pollen is orange coloured. Pistillate flowers have an inferior ovary with numerous horizontally positioned ovules, the styles are fused in almost their entire length or are only shortly free in the apex. The pistil consists of three carpels fused in one ovary with 3 short styles partially fused at their base, each of which ends with a bilobed stigma. Stigmas are large, fleshy or sunken, or lobulated, and slight modifications can be seen in the structure of the perianth regarding the staminate ones, mainly corresponding to differences in the size of one or some of its parts (Agbagwa and Ndukwu, 2004; Caracuel et al., 2012; OECD, 2016).

Both the staminate and pistillate flowers are pollinated by various wild bees (Hurd et al., 1971; Lobo and Bravo Méndez, 2021), and produce large amounts of abundant nectar (Teppner, 2000). Nectaries are found in a chamber at the base of the stamens in staminate flowers and a lower ring at the base of the pistil in pistillate flowers (Nepi and Paccini, 1993; Nepi et al., 2001; Vidal et al., 2006).

The experiment aimed to determine the production and variability of some morphological characters on flowers taken from selected individual plants within the ESO variety of oil pumpkin (*Cucurbita pepo* Styriaca Group).

Material and methodology

Biological material

In the experiments, 1792 flowers from randomly selected plants from the cultivated population of *Cucurbita pepo* Styriaca Group on an area of 150 ha situated near the Kolíňany settlement (SW part of the Slovak Republic) were evaluated. Flowers were taken in July and August 2020, and 2021 and analyzed in the laboratory at the Institute of Plant and Environmental Sciences in Nitra (the Slovak Republic). The nomenclature of plant names is according to Danihelka et al. (2012).

Morphometric analysis

A total of 7 quantitative characters were evaluated in the pistillate flowers and 9 quantitative characters in the staminate flowers:

1. Pistillate flowers (female) – 53 flowers were evaluated in the 2020 year:
   - length of petals (g), width of petals (mm), length of pistil (mm), weight of whole flower – fertile and sterile flower parts (g), weight of petals (g), weight of sepal (g), weight of pistil (g).

2. Staminate flowers (male) – 591 flowers were evaluated in 2020 and 1148 flowers in 2021:
   - length of petals (g), width of petals (mm), length of sepal (mm), width of sepal (mm), length of anther (mm), weight of whole flower – fertile and sterile flower parts (g), weight of petals (g), weight of sepal (g), weight of stamens (g).

The flowers and their parts were measured in the fresh weight by digital scale (Kern ADB-A01S05, Germany; KERN DS – type D-72336, Kern and Sohn GmbH, Germany), accurate to 0.01 g. Flowers were measured by ruler and digital calliper (METRICA 111 – 012, Czech Republic) accurately to 0.02 mm.

Image analysis

Shape and colour of staminate and pistillate flowers and details of individual parts.

Images were obtained using the stereomicroscope ZEISS SteREO Discovery.V20 (MicroImaging GmbH 37081 Göttingen, Germany), Fuji FinePix S 7000, and Panasonic DMC FZ50 digital cameras.

Statistical analysis

It was evaluated the variability of each character using descriptive statistics. For the characteristics, it was used the basic descriptors of variability: average, minimum measured value, maximum measured value, and the coefficient of variation (%). The degree of variability was determined by the coefficient of variation values. The given parameter is independent of the unit of the evaluated character. Theoretically, they can acquire different values (Stehlíková, 1998). We used analysis of variance (ANOVA) in the program STATISTICA 1.10 to determine the dependence between individual characters.

Results and discussion

Variability of flower characters

In pumpkins, we distinguish between staminate and pistillate flowers on the same plant. The flowers of *Cucurbita* are monoecious, large, yellow, solitary; corolla sympetalous; stamens 3; filaments free but anthers confluent into a head, one 1-locular, the others 2-locular, loculi elongated, sigmoid-flexuous; female flowers with 3 rudimentary stamens at the bottom of the calyx (Hutchinson, 1969; Teppner, 2004; Baranec et al., 2009).

Genetic and environmental conditions play a role in influencing the sex expression of flowers, and their development into male or female states. *Cucurbita* can exhibit wide variation in the proportion of male to female flowers on a plant (OECD, 2016). Many authors reported that the production of female flowers is frequently less than that of male flowers (Zomlefer, 1994; Janick and Paull, 2007; Kiramana and Isutsa, 2017). Temperature and day length influence how long a plant remains in the male phase, as well as the ratio of male to female flowers. High temperatures, high light intensity, and long-days favour the production of male flowers and a longer male phase. Low temperatures, low light intensity, and short days favour the development of female flowers. The number of developing fruits already present in a plant also affects the flower ratio (Robinson and Decker-Walters, 1997; McCormack, 2010).

In *C. pepo*, Nepi and Pacini (1993) found a 16.5 : 1 relation between the number of male and female flowers. The first flowers are staminate (male), after which three or four pistillate (female) flowers appear. Although pistillate flowers differentiate later in plant development, females develop faster than males, resulting in near synchronization at the anthesis of the flowers of both generative organs (Janick and Paull, 2007).

Sex expression in cucurbits is also influenced by hormones produced within the plant. Maynard (2007) studied the effect of gibberellins and ethylene on the development of staminate and pistillate flowers, respectively. Natural and synthetic auxins promote pistillate flower development.

Staminate flowers

The staminate flowers variability was evaluated with a total of the following nine quantitative characters: the length of petals, the width of petals, the width of sepals, the height of sepals, the length of an anther, the weight of the whole flower, the weight of petals, the weight of sepals and the weight of stamens. Statistical indicators of the variability of quantitative traits are presented in Table 1.

Length and width of petals

Male flowers are on pedunculate raceme with 6–10 flower heads or sometimes solitary with very long peduncles, more numerous and earlier than the female flower (Agbagwa, and Ndukwu, 2004; Vidal et al., 2010).

The results of the statistical analysis show that the tested genotypes in 2020 reached the length of the petals in the range from 40 mm to 132 mm.

Table 1 Main statistical indicators of the variability of staminate flowers in the experimental population of *Cucurbita pepo* L. Styriaca Group

Characters	Year	n	min	max	x̄	V %
Length of petals (mm)	2020	591	40.00	132.00	80.08	21.26
	2021	1148	25.00	134.00	90.98	16.08
Width of petals (mm)	2020	591	14.00	90.00	27.18	18.96
	2021	1148	25.00	92.00	54.09	19.14
Width of sepals (mm)	2020	591	3.00	31.00	17.01	20.38
	2021	1148	5.00	25.00	14.14	25.56
Height of sepals (mm)	2020	591	6.00	34.00	10.23	29.38
	2021	1148	3.00	23.00	9.99	23.35
Length of the anther (mm)	2020	591	4.00	24.00	12.07	22.39
	2021	1148	5.00	24.00	13.88	20.92
Weight of whole flower (g)	2020	422	1.20	11.81	3.63	32.98
	2021	1151	0.97	9.99	3.25	35.47
Weight of petals (g)	2020	1151	0.40	7.14	2.29	37.98
	2021	422	0.27	6.32	2.29	37.64
Weight of sepals (g)	2020	422	0.15	2.70	0.69	43.52
	2021	1149	0.07	2.40	0.24	55.82
Weight of stamens (g)	2020	422	0.10	6.21	1.00	44.69
	2021	1149	0.05	1.00	0.20	36.01

n – the number of measurements; min, max – minimal and maximal measured values; x̄ – arithmetic mean; V – coefficient of variation (%)

The value of the coefficient of variation indicates a high degree of variability (21.26%). In 2021, genotypes reached values ranging from 25 to 134 mm, and a moderate degree of variability was determined (16.08%). In terms of width, in 2020 a range of 14 to 90 mm was determined. In 2021, the value of the trait was determined in the range from 25 to 92 mm. The average value of the coefficient of variation was found for both years (18.96–19.14%).

Peniašteková (2008) mentioned diameter of *C. pepo* flowers in the interval 70–110(-180) mm and Chrtková (Chrtková, 1990) reported in her study diameter of *C. pepo* flowers in the range (50-)70–110(-200) mm without differentiation between male and female flowers. Teppner (2004) recorded *Cucurbita* flowers more or less bigger, in cultivated species up to 100–130 mm long and up to 200(-220) mm in diameter.

Umiel et al. (2007) studied some characteristics of pumpkin male and female flowers, such as the number produced per plant of each, male and female, corolla length, and corolla texture for suitability for the production and marketing of the squash flowers as culinary item, which is known for centuries (Paris and Janick, 2005).

The accessions of *C. pepo* subsp. texana produced smaller corollas than those of *C. pepo* subsp. pepo and overall, the corolla length of male flowers was larger than that of female flowers (Umiel et al., 2007).

Width and height of sepals

In the first year, the range of width of sepals was determined from 3 to 31 mm. In the second experimental year, the value of the value of the trait was determined in the interval from 5 to 25 mm with medium and high degrees of variability for both years (20.38–25.56%).

For the height of the sepals, we recorded a range from 6 mm to 34 mm, and in the next year of evaluation, the value of the trait was determined in the range from 3 to 23 mm. A high degree of variability was determined in both evaluated years (23.35–29.38%) (Table 2).

Length of anther

In the first experimental year we determined values in the interval from 4 to 24 mm for the length of anther with a high coefficient of variation (22.39%) and the next year we determined an interval from 5 to 24 mm with a high degree of variability (20.92%), which points to some differences between genotypes.

Weight of the whole flower

We recorded a relatively high variability for the weight of whole flowers (32.98–35.47%) in both years with the following intervals 1.20–11.81 and 0.97–9.99 g.

Weight of petals and sepals

When we compared the first and second experimental years and intervals of values 0.40–7.14 and 0.27–6.32 g for the weight of petals, results point to a very high coefficient of variation (37.64–37.98%) and thus very significant differences between genotypes. The same differences we recorded for the weight of sepals with a significantly high degree of variability (43.52–55.82%) and values for a character in the range 0.15–2.70 g and 0.07–2.40 g in both experimental years.

Weight of stamens

In the last evaluated character, we recorded the weight of stamens in the intervals 0.10–6.21 and 0.05–1.00 g, respectively for the first and second experimental year. The medium and high degree of variability between genotypes confirmed the values of the coefficient of variation (36.01–44.69%).

Pistillate flowers

The pistillate flowers variability was evaluated with a total of the following seven quantitative characters: the length of petals, the width of petals, the length of the pistil, the weight of the whole flower, the weight of petals, the weight of sepals and the weight of pistil. Statistical indicators of the variability of quantitative traits are presented in Table 2.

The basic indicators of the variability of quantitative traits of pistillate flowers are presented in Table 2.

Length and width of petals

In the experimental year 2020, the length of petals was determined in the range from 41 mm to 121 mm (Table 2), and the width of petals from 10 to 100 mm. Coefficients of variation indicated a moderate and high degree of variability in both characters (19.30–26.16%).

Weight of whole flower, petals, and sepals

The weight of the whole flower was determined in the range from 2.91 to 33.59 g. The experimental evaluation determined the weights of petals and the weight of sepals in the intervals from 0.90 to 9.92 g and from 0.61 to 2.93 g, respectively. The values of the coefficients of variation indicated a high degree of variability between genotypes (29.84–44.64%) for all evaluated traits.

Length and weight of pistil

Another characteristic of female flowers was the length of the pistil with values from 5.70 to 15.72 mm. The coefficient of variation indicated a moderate degree of variability between genotypes (17.45%). The weight of the pistil was determined in the range of 0.07 to 1.72 g. The coefficient of variation pointed to a high degree of variability between genotypes (42.32%) for all evaluated genotypes.

The weight ratio of individual parts of the flowers was also evaluated during the years 2020 and 2021 (Figure 1). From the obtained experimental data, the ratio of the basic parts of the flowers was determined, represented by 65–71% petals, 21–29% sepals, and 6 to 8% is the economically less used part of the flowers – stamens (contained pollen grains).

Other floral characteristics were measured by Ezin et al. (2022). They observed positive correlations between the length of female flower peduncles and the

Table 2 Main statistical indicators of the variability of evaluated pistillate flower traits in the experimental population of *Cucurbita pepo* L. Styriaca Group

Characters	n	min	max	x̄	V %
Length of petals (mm)	53	41.00	121.00	69.05	19.30
Width of petals (mm)	53	10.00	100.00	61.74	26.16
Length of pistil (mm)	53	5.70	15.72	11.70	17.45
Weight of whole flower (g)	53	2.91	33.59	12.54	44.64
Weight of petals (g)	53	0.90	9.92	4.42	30.63
Weight of sepals (g)	53	0.61	2.93	1.43	29.84
Weight of pistil (g)	53	0.07	1.72	0.74	42.32

n – the number of measurements; min, max – minimal and maximal measured values; x̄ – arithmetic mean; V – coefficient of variation (%)

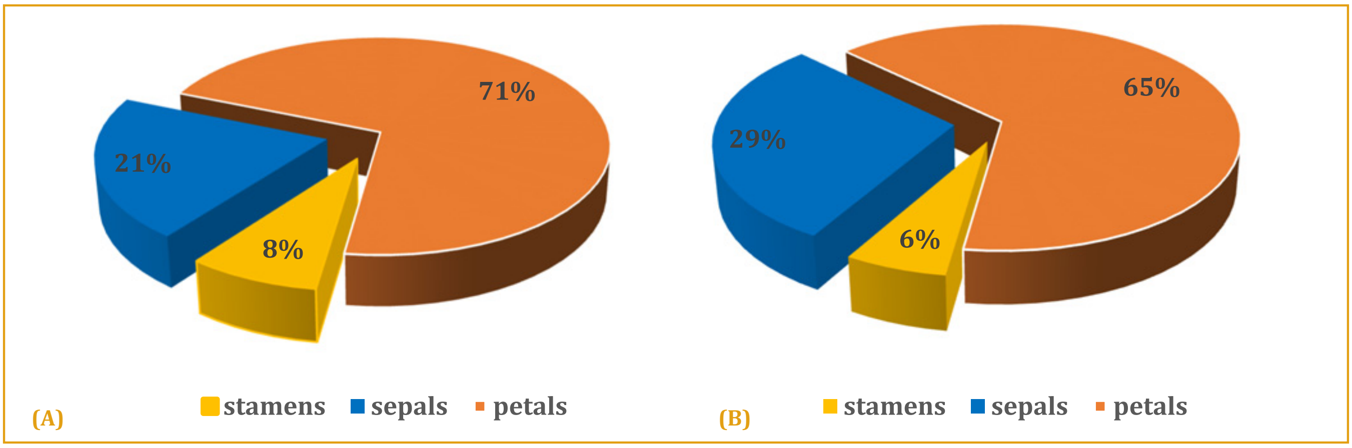

Figure 1 Average weight ratio of the individual basic anatomical parts of the flowers of *Cucurbita pepo* L. Styriaca Group from the total average weight of the fresh flowers (A) 2020 and B (2021) (%)
*– changes are statistically significant compared to the 96% ethanol

male flower peduncles (r = 0.60) as well as between the number of female flowers and the number of male flowers (r = 0.74) cultivated pumpkin landraces.

Lima et al. (2022) recorded positivive association between the petal length and the corolla diameter, and between access to the nectar and the anther size, with a difference between pumpkin cultivars (*C. moschata* Duch.) and cultivation conditions.

Umiel et al. (2007) confirm that *C. pepo* subsp. pepo produced large and firm flowers, which are more suitable for culinary usage than those of the *C. pepo* subsp. texana which are softer, noticeably less firm.

Figure 2 Variability in the shape and colour of staminate and pistillate flowers of *Cucurbita pepo* L. Styriaca Group
A–B – pistillate flowers; C–D – staminate flowers; E – detail of pistil; F–G – detail of stamens; H – detail of staminate flower bud

Conclusions

For the first time are described in detail the weight and size of sepals, petals, stamens, and pistils of *C. pepo* Styriaca Group species. Literary data on this topic is limited. The knowledge obtained can serve as a basis for the taxonomy of the species, for its selection, but also culinary purposes, where edible flowers are still used to a greater extent in gastronomy in the preparation of meals. For this purpose, genotypes with the production of larger flowers could be particularly interesting.

Conflict of interest

The authors have no conflicts of interest to declare.

Ethical statements

This article does not contain any studies that would require an ethical statement.

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