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Flower morphometry of members of the genus *Dactylorhiza* Necker ex Nevski (Orchidaceae) from the Altai Mountains of Kazakhstan

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Abstract. *Sumbembayev AA, Abugalieva SI, Danilova AN, Matveyeva EV, Szlachetko DL. 2021. Flower morphometry of members of the genus* Dactylorhiza *Necker ex Nevski (Orchidaceae) from the Altai mountains of Kazakhstan. Biodiversitas 22: 3545-3555.* Several species of *Dactylorhiza* (Orchidaceae) from the Altai mountains of Kazakhstan have been investigated regarding their morphological flower variability. Significant metric characters were identified allowing to differentiate between the four species: *D. incarnata*, *D. fuchsii*, *D. maculata* and *D. salina*. The morphometric structure of flowers was analyzed by comparing 17 metric parameters in representatives of 11 populations. We identified the most variable and stable traits as well as distinctive features for each species. A high degree of flower morphometric diversity was revealed from principal component analysis for species and populations. Cluster analysis demonstrated the structure of the population diversity. Structural schemes have been compiled from data of the photographic processing of flower morphometry, the analysis of variance ANOVA, and the degree of variation at the population level. Useful characters are provided for further taxonomic work on members of the genus *Dactylorhiza* in Kazakhstan.

Keywords: flower scheme, metric characters, population diversity, species identification

INTRODUCTION

The genus *Dactylorhiza* Necker *ex* Nevski (Orchidaceae) consists of about 75 species (Averyanov 1990a, Ståhlberg and Hedrén 2008) − most species recorded from northwestern Europe and southern Siberia (Delforge 2001; Efimov 2016). The Flora of Kazakhstan (1958) lists eight species of *Dactylorhiza*; the Euro-Siberian *D. fuchsii* (Druce) Soo ranks as endangered in the Red Data Book of Kazakhstan (2014). The study area encompasses four species from the nominal section of *Dactylorhiza*, i.e. *D. incarnata* (L.) Soo and *D. salina* (Turcz. ex Lindl.) Soo from the subsection *Dactylorhiza*, as well as *D. fuchsii* (Druce) Soo and *D. maculata* (L.) Soo from the subsection *Maculatae* (Parl.) Aver. − all of which being classified as of "Least concern" by the IUCN (2020).

Dactylorhiza is a taxonomically complex genus (Delforge 2001; Hedren 2001a, 2001b; Bateman 2003; Pillon et al. 2006; Shipunov and Efimov 2015; Brandrud et al. 2020). Its representatives are marked by a high phenotypic variability, which often complicates attempts of drawing borderlines between species even within the same or close plant communities (Naczk 2018; Averyanov 1990). These issues have been addressed variously on the basis of morphology (van Straaten 1988; Shipunov et al. 2005a), micromorphology (Hedrén 2009; Gamarra et al. 2015; Akbulut 2016) morphometry (Tyteca 1999; Pedersen 2002; Shipunov 2005b; Bateman 2006; Ashish 2012; Shirokov 2020), anatomy (Aybeke et al. 2010), molecular biology (Bateman et al. 2003; Shipunov et al. 2004; Devos et al. 2006; Pillon et al. 2007; Inda et al. 2010; Balao 2017), and molecular genetics (Givnish 2015; Efimov 2016; Bateman 2018a, 2018b; Kakia 2020).

The Kazakhstan part of the Altai Mountain country (Kazakhstan Altai) is the largest fragment of the Sayan-Altai Mountain system, representing its southwestern outskirts located within Kazakhstan (kazgeo.ucoz.org). The climatic conditions of the Kazakhstan Altai are determined its location in the center of the Eurasian continent with an equal distance from the oceans in each direction (Baytulin 2011). For this region, a recent survey lists all members of the orchid family along with distribution data, including the genus *Dactylorhiza* (Sumbembayev et al. 2020).

There are relatively few studies using morphometry to estimate population variability and those are mainly concentrated on terrestrial orchids from temperate regions (Bateman and Denholm 1988; Bateman and Farrington 1989; Dufrêne et al. 1991). Taxa of the genus *Dactylorhiza* have largely been distinguished on the basis of features of flower lip and spur (Renz 1984; Bateman 2018, Akbulut 2020). Many problematic issues on *Dactylorhiza* remain in regard to their taxonomy and regional occurrence (Vakhrameeva 2014).

The main goal of this research has been to study the morphological variability of the flowers of the members of *Dactylorhiza* from the Altai mountains of Kazakhstan using metric characters, allowing to divide their populations into morphological groups along representative and reliable diagnostic features.

MATERIALS AND METHODS

Field expeditions to the Altai mountains of Kazakhstan were carried out in 2019 and 2020, during which 11 populations of four species were studied: *D. incarnata* (L.) Soo, *D. fuchsii* (Druce) Soo, *D. maculata* (L.) Soo, and *D. salina* (Turcz. ex Lindl.) Soo classified according to Averyanov (1990a) in the nominal section of *Dactylorhiza*. The species were determined according to Averyanov (1988, 1989, 1990b). The locations of the studied populations of *Dactylorhiza* Necker ex Nevski are presented in Figure 1. The plant material collected included inflorescences of live plants; 20 samples from each population (Table 1).

To characterize the ecological requirements of species, descriptions of the stages of ecological factors were used (Landolt 1977). The levels of ecological scales (insolation, humidity, soil acidity, soil nutrient richness) were determined in specific natural habitats (Table 1). For a qualitative characteristic, only fully formed, developed inflorescences in the phase of mass flowering were selected. Inflorescences were stored in alcohol (96%)/glycerin/water (4:2:1). For measurements, one flower was taken from the central part of each inflorescence. The measurements were carried out using a Micros MC300 microscope (Austria). Morphometric characters are used according to Kirilova (2018). To characterize the morphometry of the flower shape, 17 metric parameters were studied (Figure 2).

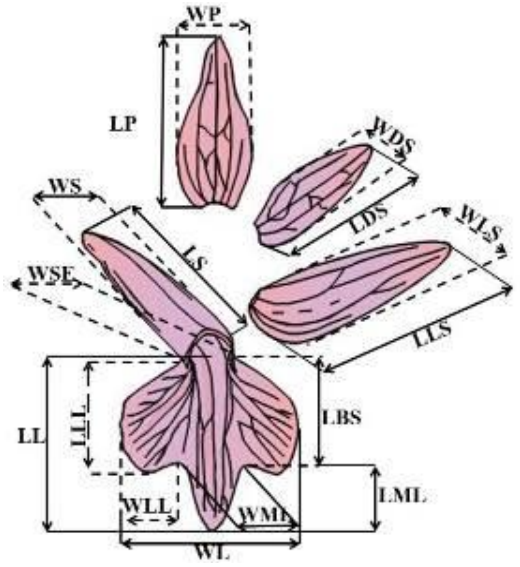

Figure 2. Flower morphometric features. Legend: LL: Length of labellum, mm; WL: Width of labellum, mm; WSE: Width of spur entrance, mm; LDS: Length of dorsal sepal, mm; WDS: Width of dorsal sepal, mm; LLS: Length of lateral sepals, mm; WLS: Width of lateral sepals, mm; LS: Length of spur, mm; WS: Width of spur (in the middle), mm; LLL: Length of lateral lobe of labellum, mm; WLL: Width of lateral lobe of labellum, mm; LBS: Length from the base of spur entrance to base of sinus, mm; LO: Length of ovary, mm; [LML=LL-LBS]: Length of labellum middle lobe, mm; WML: Width of labellum middle lobe, mm; LP: Length of petals, mm; WP: Width of petals, mm

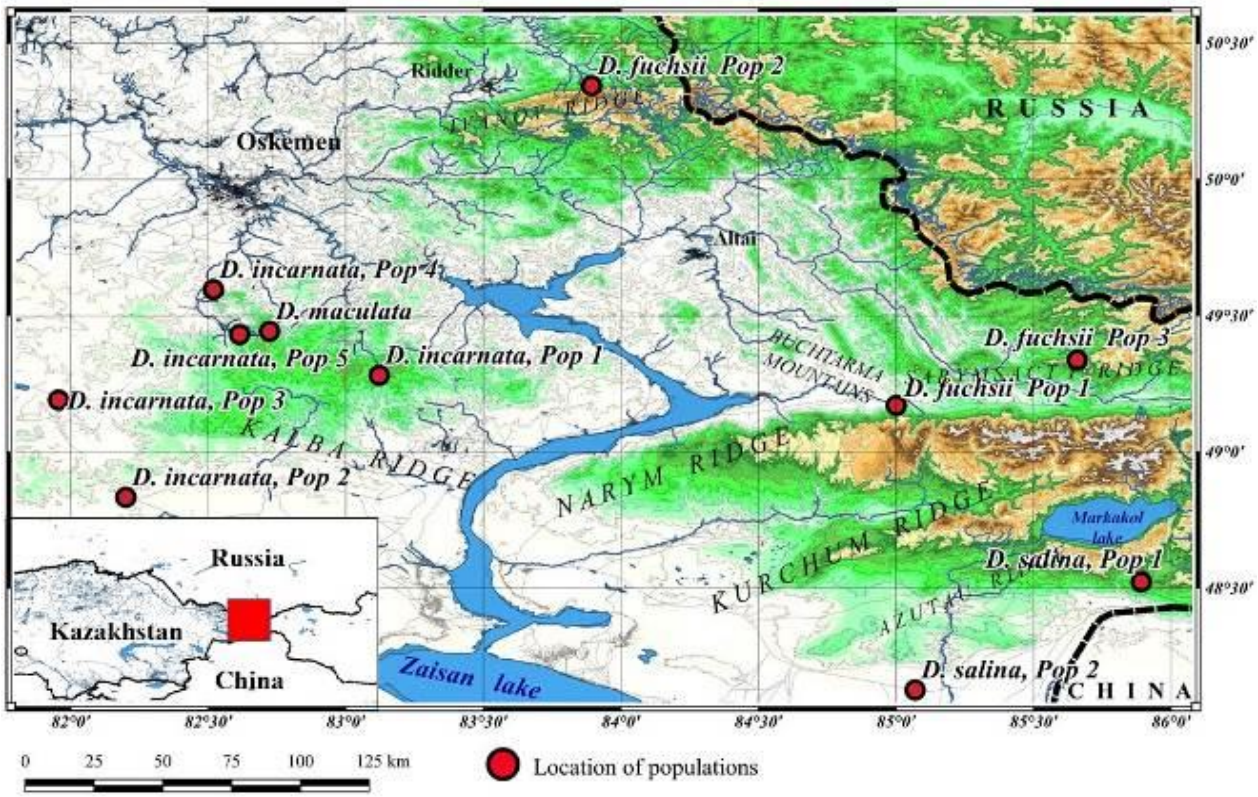

Figure 1. Locations of the examined populations of species of *Dactylorhiza* Necker *ex* Nevski in the Altai region of Kazakhstan

Table 1. Ecological and phytocenotic characteristics of the locations of the studied populations of *Dactylorhiza*

Species, population	Location	Geographical coordinates	L	F	R	N	Habitat
Dactylorhiza fuchsii (Druce) Soo, Pop 1	Bukhtarma mountains, vicinity of Maimyr Village, Batash tract, valley of Naryn river	49.17055 E 85.00027 N 739 m a.s.l.	3-4	3-4	3	3	Birch forest, underneath tree canopy
D. fuchsii (Druce) Soo, Pop 2	Ivanov ridge, southwestern foothills, tract "Gray meadow", Bolshaya Poperechka river valley	50.34388 E 83.89277 N 1212 m a.s.l.	4	4	4	3	Fir-birch edge, moist glade, mossy
D. fuchsii (Druce) Soo, Pop 3	Sarymsakty Ridge, north-western foothills, near Topkain Village	49.33694 E 85.65777 N 912 m a.s.l.	3-4	3	3	3	Creek valley, mixed forest
D. salina (Turcz. ex Lindl.) Soo, Pop 1	Azutau ridge, Mramorny pass, northeastern foothills, Karagashty tract	48.52277 E 85.89055 N 1289 m a.s.l.	4-5	4	4	2-3	Forb meadow
D. salina (Turcz. ex Lindl.) Soo, Pop 2	Azutau ridge, foothills of the southeastern slope, southwest of Markakol Village	48.12611 E 85.06888 N 465 m a.s.l.	5	3-5u	4	2	Flooded saline meadow
D. maculata (L.) Soo	Kalba highlands, eastern part, southwestern periphery of Koktau mountains, near Algabas Village	49.44277 E 82.72277 N 891 m a.s.l.	4	4-5	3	2	Swampy meadow
D. incarnata (L.) Soo, Pop 1	Kalba highlands, eastern part, mountain pass Umysh	49.280556 E 83.121111 N 1230 m a.s.l.	4-5	3-4	3	2	Creek valley, herbaceous meadow
D. incarnata (L.) Soo, Pop 2	Kalba highlands, southwestern foothills of the southeastern outskirts, northern spurs of the Karazhal mountains, Kokpektinka river valley	48.833333 E 82.200278 N 600 m a.s.l.	4	3	3	2	Swampy lowland, edge of willow and birch forest, under the canopy of sparse bushes
D. incarnata (L.) Soo, Pop 3	Kalba highlands, eastern part, southwestern spurs, foot of the Saryzhal ridge, Shar river valley, near Kalbatau Village	49.190278 E 81.955833 N 525 m a.s.l.	5	3	3	2-3	Wet meadows, damp depressions and willow forest edges
D. incarnata (L.) Soo, Pop 4	Kalba highlands, Koktau mountains, Shat tract, near Toganas Village	49.59583 E 82.51861 N 634 m a.s.l.	4	4-5	3	3	Mountain valley along stream, mossy cover
D. incarnata (L.) Soo, Pop 5	Kalba highlands, southwestern part of the Koktau mountains, Sibin depression, Lake Tortkara area	49.43083 E 82.61388 N 791 m asl.	5	4-5u	3	2	Creek valley, flood meadow

Note: Ecological scales (Landolt 1977): L: illuminance scale: 1. completely shady plant, often growing in conditions less than 3% of full light; 2. mostly shady plant (more often at 10% of full illumination); 3. penumbra plant (at a relative illumination of more than 10%); 4. semi-light (often in full light, but sometimes with some shading); 5. completely light plant, unable to tolerate shading. F: humidity scale: 1. on very dry soils, indicator of dry habitats; 2. on dry soils, avoids very dry and very wet soils; 3. on medium dry to moist soils; 4. on wet to damp soils; 5. on soils saturated with water, avoids moderately moist habitats; 5w. on very damp soils after rain; 5u. in flooded areas; 5s. plants with leaves floating in the water; 5i. plants live in water, but most of their leaves are above water. R: soil acidity scale: 1. on very acidic soils (pH less than 4.5); 2. on acidic soils (pH 3.5-5.6); 3. on slightly acidic soils (pH 4,5-7,5), never on very acidic, but sometimes on neutral and slightly alkaline soils; 4. on alkaline soils (pH 5.5-8.0); 5. only on alkaline soils (pH above 6.5); x. on very acidic and alkaline soils, often avoids medium conditions, as it does not withstand competition with other species. N. soil nutrient richness scale (especially nitrogen): 1. on very rich soils; 2. on poor soils; 3. on soils from medium-dry to medium-rich; 4. on rich soil; 5: on soil rich (especially in nitrogen), never found on poor

Comparison of the average values of the population traits is shown in the Supplement. For each population, the labellum shape index was calculated (Heslop-Harrison 1951), according to the formula:

$$IL = \frac{2 * LL}{LBS + LLL}.$$

Data for principal component analysis (PCA), correlation analyses and the construction of a dendrogram of similarity (cluster analysis) were processed in the R-studio program (Version 1.3.1093). ANOVA analysis was carried out using the STATISTICA 10.0 program. Flower structure schemes were built in Autodesk AutoCAD 2016.

RESULTS AND DISCUSSION

Species boundaries and rank of individual specimens can more accurately be determined by comparing the characters displayed by representatives of entire populations and by identifying groups of similar and closely related populations (Kirillova 2018). Statistical analysis of our results on flower structure of the four studied species of *Dactylorhiza* revealed significant and stable differences between them.

Populations of *D. fuchsii* (Figure 3.A) were identified from three habitats (Figure 1). Environmental conditions there ranged from deciduous forest to edges of mixed forest (700-1200 m a.s.l.). The insolation in these populations

ranged from partial shade to scattered light at forest edges. There is a direct effect of amount of light on the length of labellum middle lobe and length of lateral sepals (Figure 4.A). The plots were characterized by moisture ranging from medium dry to moist soils. Soils are slightly acidic, less often alkaline with an average richness of nutrients (Table 1). An inverse correlation of soil richness was noted on the length of the labellum middle lobe.

Labellum shape index is 1.4-1.8 (Supplement). Distinctive typological features (Figure 5A) are the length of ovary 9.470-10.825 mm and length of the labellum middle lobe 2.515-4.927 mm. A direct correlation could be observed between the length of labellum and length of labellum middle lobe, and between the length of labellum and length of the lateral sepals (Figure 4.A).

Dactylorhiza salina (Figure 3.B) in the Kazakhstan Altai is typically found growing on the Azutau ridge and its foothills (Figure 1). Two, spatially distant populations of the species were identified. The ecological optimum of the species varies between flooded saline and damp forb meadows at an altitude of 465-1289 m a.s.l. (Table 1). Soil moisture significantly affects the length of spur and the dorsal sepal width (Figure 4.B). Populations of the species occupy semi-light or fully insolated areas with moist soils, often in flooded areas. Insolation significantly affects the length of spur and the width of the dorsal sepal. Soils are alkaline, at pH 5.5-8.0, but poor in nutrients. Soil acidity and soil richness are inversely correlated with the dorsal sepal width (Figure 4.B).

The labellum shape index for two of the populations of *D. salina* was 1.1-1.2 (Supplement). The distinctive characteristic features (Figure 5B) are length of spur 9.805-13.817 mm, and length of the lateral lobe of the labellum 6.905-7.050 mm. A high correlation is observed between the length of the lateral lobe of the labellum and the length from the base of the spur entrance to the base of the sinus (Figure 4.B).

Individuals of *D. maculata* (Figure 3.C) in the Kazakhstan Altai are concentrated in a single isolated population in the southwestern periphery of the Koktau mountains of the Kalba ridge (Figure 1). The plants occupy a swampy meadow at an altitude of 891 m a.s.l. The area is characterized by little shading and damp or water-soaked soil. The soil substrate is slightly acidic and poor in nutrients (Table 1).

The labellum shape index in *D. maculata* is 1.3 (Supplement). Distinctive features in the morphometric structure (Figure 5C) are width of labellum at base 2.7-4.1 mm, length of spur 6.9-9.5 mm, and length of ovary 12.6-17.0 mm. High correlations are observed between length of labellum and length of lateral lobe of the labellum, as well as width of lateral lobe of the labellum and width of labellum. An inverse correlation has been noted between the length of the spur and the width of the lateral sepals (Figure 4.C).

Populations of *D. incarnata* (Figure 3.D) were identified in five locations (Figure 1), ranging from mountain stream valleys to flooded meadows at an altitude of 525-1230 m a.s.l. The areas occupied by these plants are fully insolated, rarely with little shading. The plots are characterized by a large variation in the degree of soil moisture: from moist soils to flooded areas (Table 1). Soil moisture appears to directly affect length of the dorsal sepal and width of spur (Figure 4.D). The soil substrate is slightly acidic or neutral and poor in nutrients. An inverse correlation is observed for the width of the dorsal sepal with decreasing soil acidity (Figure 4.D).

A **B** **C** **D**

Figure 3. Inflorescences of: A. *Dactylorhiza fuchsii*; B. *D. salina*; C. *D. maculata*; D. *D. incarnata*.

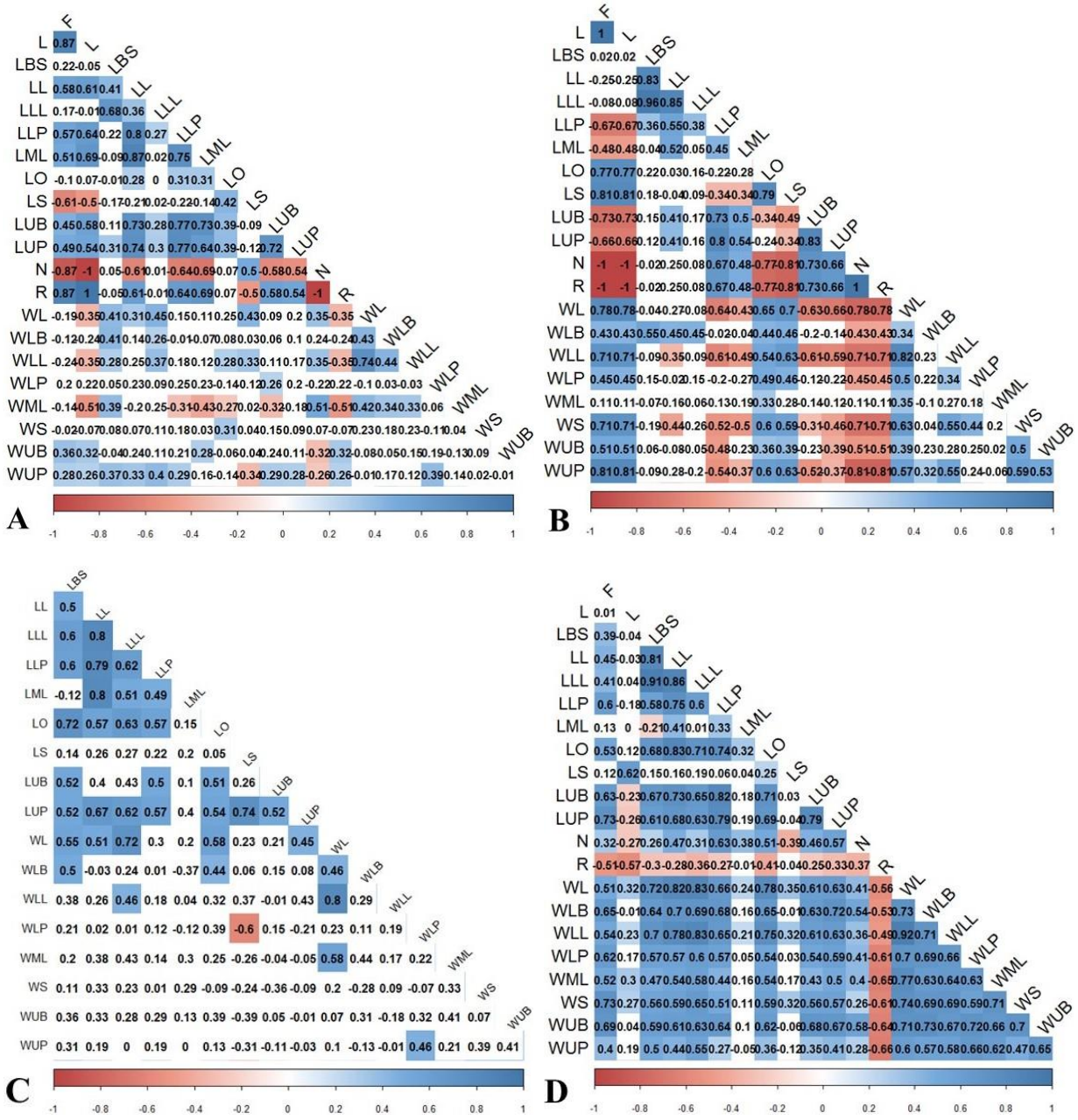

Figure 4. Correlation between morphometric characters of flowers and environmental factors: A. *D. fuchsii*; B. *D. salina*; C. *D. maculata*; D. *D. incarnata*

The labellum shape index for the five populations of *D. incarnata* was recorded as 1.2-1.4 (Supplement). Distinctive specific features of the structure of flowers (Figure 5D) are: width of labellum at base 2.320-4.163 mm and length of labellum middle lobe 1.340-2.278 mm. Correlations were noted between the length of the lateral lobe of the labellum and length from the base of the labellum entrance to the base of the sinus, width of lateral lobe of the labellum and width of labellum (Figure 4.D).

Analysis of variance (ANOVA) (Table 2) revealed a significant effect of environmental factors on all morphological characters of *D. incarnata* populations.

The environmental effect on *D. fuchsii* populations is manifested in all morphological traits, except for the width of the lateral sepals and width of spur. The environment affects all morphometric characters of *D. salina*, except for length of labellum, length of lateral lobe of the labellum, length from the base of labellum entrance to base of sinus, and width of labellum middle lobe. The effect of the environment on the phenotype of *D. maculata* cannot be determined, due to the singularity of the population and habitat.

The PCA plot for species differences (Figure 6) suggests an arrangement of populations with an influence of geography and environmental conditions on the morphology of the studied species. In addition, some isolation from other populations of the studied species was

revealed for the second population of *D. fuchsii*, the fourth population of *D. incarnata*, and the population of *D. salina*.

PCA (Figure 7) demonstrates differences in representatives of various populations or species, and the similarity within or closely related populations. An insignificant isolation of several samples from other individuals was recorded for the second population of *D. fuchsii* and the first population of *D. salina*.

The cluster analysis was built on the basis of the average indicators of the characteristics (Supplement). The dendrogram (Figure 8) shows a graphical representation of the results of the morphometric measurements. The dendrogram divides all populations into 4 main clusters.

Table 2. Results of ANOVA

Species	Factor	df	Ss	MS	F
D. fuchsii	Environment	2	3.194	1.597	17.52***
	Genotype	19	2.538	0.134	0.724
D. incarnata	Environment	4	10.522	2.631	17.19***
	Genotype	19	3.102	0.163	1.119
D. salina	Environment	1	4.649	4.649	56.57***
	Genotype	19	2.279	0.12	0.8960

Note: Ss: sum of squares, df: degree of freedom, MS: mean square, F: Fisher's coefficient, P: value; * P<0.01; ** P<0.05; *** P<0.001

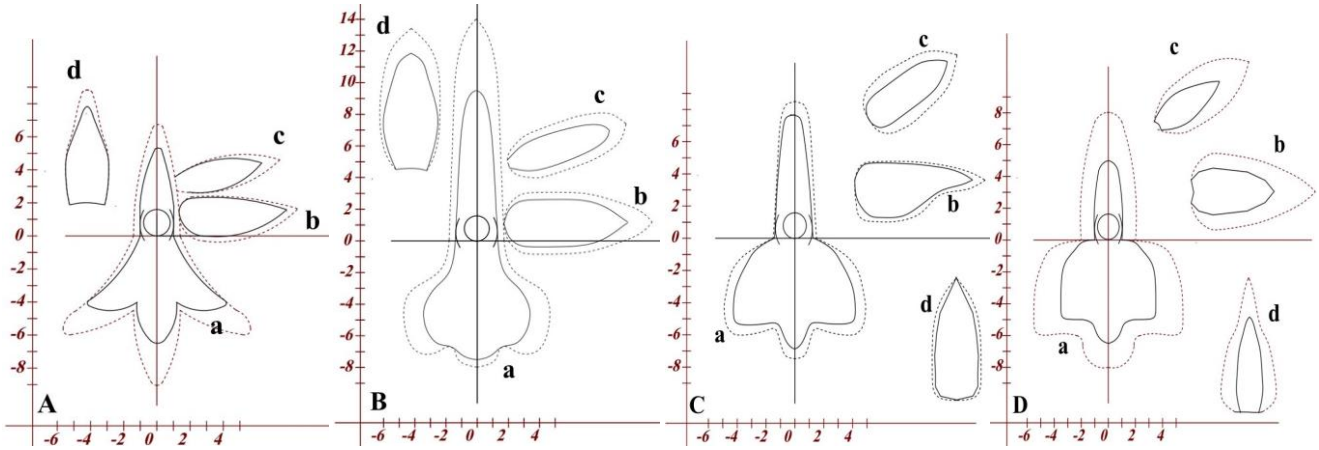

Figure 5. Schemes of the flower structure based on the average metrics of characteristics (mm): A. *Dactylorhiza fuchsii* (Druce) Soo; B. *D. salina* (Turcz. ex Lindl.) Soo; C. *D. maculata* (L.) Soo; D. *D. incarnata* (L.) Soo; a. labellum-spur, b. lower petal of the outer circle of the perianth, c. upper petal of the outer circle of the perianth, d. upper petal of the internal circle of the perianth; maximum sizes are marked by a dotted line.

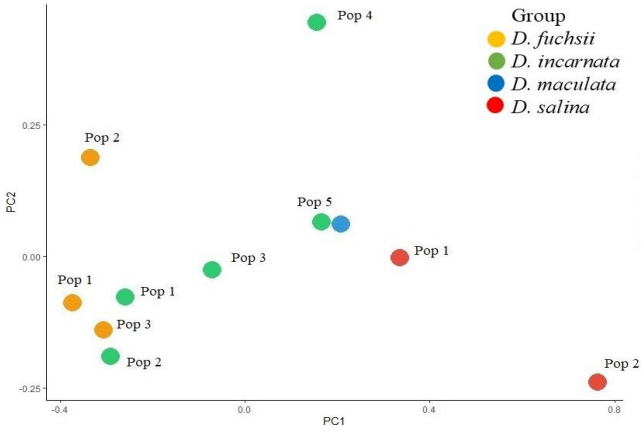

Figure 6. Principal component analysis (PCA) for species differences of *Dactylorhiza* based on metric characteristics of flower structure

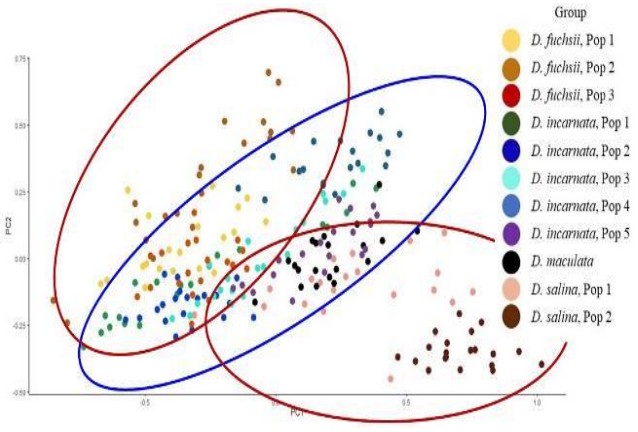

Figure 7. PCA for population differences in *Dactylorhiza* based on metric characteristics of flower structure

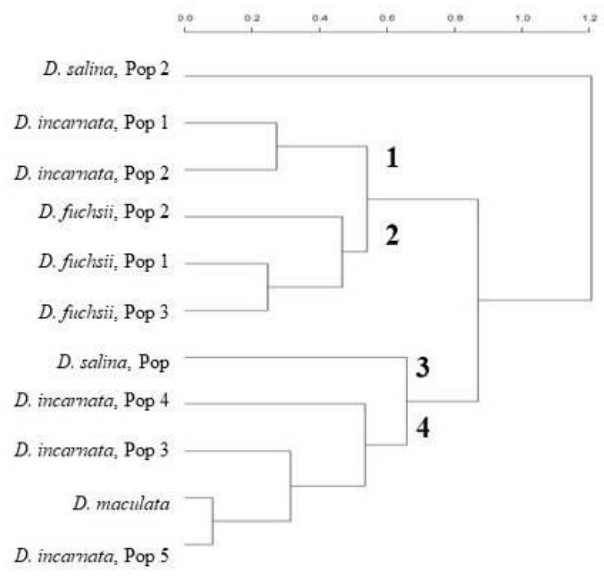

Figure 8. Hierarchical clustering of populations of species of *Dactylorhiza* based on the average values of metric features of flower structure

Discussion

In an earlier study, Kirillova (2018) studied 16 populations of four species (*D. fuchsii*, *D. maculata*, *D. incarnata*, and *D. traunsteineri*) based on 13 diagnostic features of flowers. We here studied 11 populations of four *Dactylorhiza* species from the Kazakhstan Altai, analyzing the morphometric characteristics of flowers using 17 metric features of flowers (Figure 2). Additional attention was paid to the following characters: width of labellum at base, width of the dorsal sepal, width of the lateral sepals, width of labellum middle lobe, length and width of the petals. This study's results overlap with Shipunov (2004) and Ståhlberg (2008) work, where the morphometry of similar species was studied and the labellum shape index was used as the main parameter. This study qualitatively complements the earlier studies on *Dactylorhiza* in Kazakhstan (Flora of Kazakhstan 1958; Averyanov 1988, 1989, 1990b), where only length of labellum, length of spur and width of spur were used for taxonomy of metric flower features.

The established correlation between environmental conditions and morphological characteristics (Figure 4) showed a strong environmental effect on the morphometric characteristics of flowers. The main environmental factors were insolation and soil moisture. ANOVA analysis for "Genotype-Environment" dependence confirmed the significant influence of the specific natural habitats on the studied species.

PCA data on species differences (Figure 6) confirm the influence of geography and environmental conditions on the morphology of the studied species. Thus, according to the PCA, the second population of *D. fuchsii* is noticeably distant from other populations of the species in terms of morphological characteristics. According to the schematic map (Figure 1), this population is geographically distant and differs in altitudal zonal affiliation. The fourth population of *D. incarnata*, is separated from other populations of the species by PC2. This was inpart due to the northernmost location (Figure 1) and shaded growing conditions (Table 1), which apparently leads to larger flowers among the populations of the species. The second population of *D. salina* is separated from all other populations by PC1. Perhaps, in addition to being a unique species, this may be due to the southeastern remoteness of its occurrence (Figure 1) and the lowest altitudinal zoning (465 m asl.).

The PCA of population differences (Figure 7) showed high intraspecific diversity. The studied populations were conditionally divided into three groups (enclosed in ellipses in Figure 7). The first group consists of the populations of *D. fuchsii*; the second group of populations of *D. incarnata*; and the third group of the population of *D. salina*. Thus, the populations of *D. fuchsii*, *D. maculata*, and *D. incarnata* differ markedly in PC1, and the populations of *D. salina* in PC2 also confirm the PCA in terms of species diversity.

Cluster analysis (Figure 8) grouped the studied populations into 4 main clusters. The first and second populations of *D. fuchsii* are closely related and stable. A separate cluster 1 is formed in the dendrogram, which confirms the PCA data. Populations of *D. fuchsii* differ from others both in morphology and in their ecology and form a separate cluster 2. The third, fourth, and fifth populations of *D. incarnata* and the only population of *D. maculata* form cluster 4. Geographically, these populations are located close to each other (Figure 1), occupying the central part of the Kalba ridge under the same ecological conditions. Two populations of *D. salina* form cluster 3 and the outgroup, since the morphological differences of the species differ significantly from other species of the genus *Dactylorhiza*. Populations of *D. salina* grow in isolation in the southeast of the Kazakhstan Altai, which also confirms the species' isolation into a separate cluster.

Finding different species in the same clusters and finding populations of the same species in different clusters does not mean that flower morphometry is less useful to distinguish between *Dactylorhiza* species. In seems obvious that the ecological habitat conditions have a significant impact on morphometric characters. Thus, the specific ecological conditions of the Kazakhstan Altai (high continental climate, short hydration period, xerophytic of flora) have a significant impact on the plants' features.

The particular living conditions of the ecotypes of the species of *Dactylorhiza* in the Kazakhstan Altai impose a significant effect on their morphometric structure, which may vary considerably from those prevailing in Siberia (Efimov 2020) or Central Asia (Akzhygitova et al. 2003).

In addition, it is important to take into account the diversity of optimal ecological conditions in a limited area in the studied region: from flooded meadows and river valleys to the edges of dark coniferous and mixed forests. Specimens growing in shade are usually larger than meadow ecotypes, which are usually associated with a richer substrate (Table 1). There is also a clear effect of altitudinal zoning of the habitats: mountain ecotypes are

larger, but shorter than plants growing in the plains at lower altitudes.

In summary, samples of four species of the genus *Dactylorhiza* were collected in the Kazakhstan Altai. Particular metric features were identified that allow to distinguish the four closely related species. The morphometric structure of flowers was studied using 17 metric parameters in generative individuals of 11 populations. A significant effect of the environment on the morphometric characters of flowers was proven. The most variable and stable traits, as well as distinctive features for each species, were established. The PCA for species and population diversity showed a high degree of morphological diversity of ecotypes. Cluster analysis graphically displayed the structure of the population diversity of the studied species. Structural schemes were drawn up. The reported features can serve as a basis to further elaborate on the taxonomy of the genus *Dactylorhiza* in the Kazakhstan Altai region and for future work on these plants occurring in Kazakhstan as a whole.

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Table S1. Results of measurements of metric features

Abbrev.	Feature name (values in mm)		*D. fuchsii* Pop. 1	*D. fuchsii* Pop. 2	*D. fuchsii* Pop. 3	*D. salina* Pop. 1	*D. salina* Pop. 2	*D. maculata*	*D. incarnata* Pop. 1	*D. incarnata* Pop. 2	*D. incarnata* Pop. 3	*D. incarnata* Pop. 4	*D. incarnata* Pop. 5
LL	labellum, length	(M±m)	7.130±0.414	8.955±0.890	6.725±0.305	8.080±0.676	7.540±0.209	7.260±0.312	6.510±0.604	6.540±0.183	7.055±0.425	8.042±0.297	7.335±0.212
		min-max	6.0-9.0	5.0-11.6	5.6-8.6	5.6-11.4	6.8-8.2	6.2-9.0	4.7-8.8	5.3-7.3	5.5-8.5	6.8-8.9	6.5-7.9
		C%	12.42	21.28	9.70	17.91	5.92	9.21	19.85	6.00	12.88	7.70	6.20
		P%	2.78	4.76	2.17	4.00	1.32	2.06	4.44	1.34	2.88	1.77	1.39
WL	labellum, width	(M±m)	9.915±0.583	8.565±0.682	9.180±0.411	6.805±0.539	9.085±0.300	8.955±0.403	7.376±0.767	6.210±0.344	8.770±0.908	9.473±0.302	9.385±0.545
		min-max	7.5-12.0	5.9-10.9	7.4-10.4	4.6-8.9	7.8-10.2	7.1-10.7	4.7-9.9	4.9-76	5.8-11.5	8.4-10.6	7.3-11.2
		C%	12.60	17.03	9.56	16.95	7.07	9.63	22.25	11.87	22.14	6.66	12.42
		P%	2.82	3.81	2.14	3.79	1.58	2.15	4.98	2.65	4.95	1.53	2.78
WSE	spur, entrance, width	(M±m)	2.720±0.137	2.440±0.228	2.545±0.125	2.325±0.229	2.705±0.138	3.620±0.148	2.985±0.320	2.320±0.266	2.975±0.281	4.163±0.147	3.440±0.220
		min-max	2.2-3.1	1.6-3.5	2.1-3.0	1.7-3.4	2.1-3.2	2.7-4.1	1.7-4.4	1.3-3.5	2.3-4.9	3.5-4.8	2.4-4.5
		C%	10.77	19.96	10.55	21.07	10.89	8.76	22.91	24.57	20.30	7.35	13.68
		P%	2.41	4.46	2.36	4.71	2.44	1.96	5.12	5.49	4.54	1.69	3.06
LDS	sepal, dorsal, length	(M±m)	5.355±0.349	6.727±0.768	5.19±0.291	8.165±0.366	6.815±0.363	6.805±0.311	5.855±0.345	5.655±0.190	5.625±0.283	7.805±0.179	6.620±0.297
		min-max	4.2-7.0	2.05-8.75	3.9-6.2	7.4-10.0	5.2-8.3	5.7-7.8	4.8-7.1	4.8-6.2	4.5-6.6	7.0-8.5	4.9-7.5
		C%	14.02	24.41	12.01	9.58	11.41	9.78	12.61	7.20	10.77	4.80	9.60
		P%	3.13	5.46	2.68	2.14	2.55	2.19	2.82	1.61	2.41	1.10	2.15
WDS	Width of the dorsal sepal, width	(M±m)	2.125±0.258	2.305±0.137	2.005±0.178	1.977±0.147	2.905±0.177	2.630±0.186	2.765±0.201	1.760±0.178	2.415±0.223	2.726±0.084	2.485±0.143
		min-max	1.1-3.2	1.6-2.7	1.5-2.8	1.5-2.8	2.1-3.5	1.8-3.3	1.7-3.5	0.9-2.4	1.8-4.0	2.4-3.1	2.0-3.2
		C%	25.99	12.74	19.04	15.96	13.05	15.16	15.58	21.61	19.71	6.45	12.34
		P%	5.81	2.85	4.26	3.57	2.92	3.39	3.48	4.83	4.41	1.48	2.76
LLS	sepals, lateral,length	(M±m)	6.435±0.453	8.475±0.680	6.305±0.573	9.695±0.529	8.115±0.272	8.290±0.337	6.510±0.568	6.975±0.272	7.380±0.359	9.657±0.376	8.075±0.380
		min-max	4.2-8.0	5.25-11.0	1.7-7.3	8.1-11.7	6.8-9.0	7.2-10.0	4.2-8.3	5.8-8.0	5.8-9.1	8.5-12.1	6.2-9.3
		C%	15.06	17.17	19.44	11.69	7.18	8.69	18.66	8.36	10.41	8.11	10.07
		P%	3.37	3.84	4.35	2.61	1.60	1.94	4.17	1.87	2.33	1.86	2.25
WLS	sepals, lateral, width	(M±m)	2.260±0.185	2.437±0.220	2.235±0.159	3.105±0.238	3.550±0.185	3.775±0.125	3.135±0.255	2.325±0.248	3.065±0.241	3.800±0.159	3.535±0.230
		min-max	1.6-3.0	1.7-3.5	1.5-2.9	2.3-4.5	3.0-4.5	3.2-4.2	2.2-4.0	1.3-3.1	2.3-4.4	3.2-4.3	1.9-4.0
		C%	17.55	19.36	15.17	16.40	11.13	7.08	17.39	22.84	16.85	8.73	13.93
		P%	3.92	4.33	3.39	3.67	2.49	1.58	3.89	5.11	3.77	2.00	3.11
LS	spur, length	(M±m)	5.855±0.433	5.250±0.353	6.685±0.308	9.805±0.899	13.817±0.408	8.380±0.413	5.567±0.348	6.365±0.264	6.832±0.201	5.321±0.329	8.135±0.230
		min-max	4.2-8.0	3.7-6.7	5.6-7.8	6.6-15.0	12.7-15.9	6.9-9.5	4.2-6.7	5.6-7.6	6.05-7.6	3.4-6.4	6.6-9.1
		C%	15.83	14.38	9.85	19.62	6.32	10.56	13.39	8.87	6.30	12.89	7.88
		P%	3.54	3.22	2.20	4.39	1.14	2.36	2.99	1.98	1.41	2.96	1.76
WS	spur (mid), width	(M±m)	1.735±0.536	1.550±0.138	1.580±0.109	1.795±0.165	2.610±0.215	2.895±0.116	2.249±0.191	1.505±0.177	2.115±0.218	2.831±0.194	3.040±0.248
		min-max	1.0-6.5	1.0-2.0	1.3-2.3	1.2-2.2	1.9-3.5	2.5-3.4	1.60-2.99	0.8-2.4	1.3-2.9	2.2-3.9	2.1-4.2
		C%	66.15	19.04	14.89	19.67	17.62	8.57	18.17	25.18	22.03	14.32	17.45
		P%	14.79	4.26	3.33	4.40	3.94	1.92	4.06	5.63	4.93	3.29	3.90

LLL	labellum, lateral lobe, length	(M±m)	6.010±0.331	5.567±0.618	5.175±0.258	7.050±0.585	6.905±0.256	5.655±0.250	5.380±0.640	4.780±0.250	5.335±0.459	6.163±0.238	5.750±0.312
		min-max	5.0-7.5	1.9-7.0	4.3-6.3	4.5-9.3	6.0-8.1	4.3-6.8	3.5-7.8	3.8-6.0	3.8-6.7	5.1-6.9	4.6-7.0
		C%	11.8	23.75	10.66	17.76	7.94	9.47	25.49	11.19	18.43	8.04	11.60
		P%	2.64	5.31	2.38	3.97	1.78	2.12	5.70	2.50	4.12	1.85	2.59
WLL	labellum, lateral lobe, width	(M±m)	3.715±0.303	3.145±0.324	3.535±0.243	2.557±0.299	3.680±0.223	3.228±0.207	2.565±0.405	2.082±0.157	2.975±0.401	3.547±0.203	3.495±0.327
		min-max	2.5-4.9	2.0-4.4	2.7-4.8	1.7-4.1	3.0-5.0	2.6-4.0	1.3-4.2	1.6-3.0	1.7-4.3	2.6-4.3	2.2-5.1
		C%	17.45	22.01	14.69	25.03	12.95	13.69	33.79	16.18	28.83	11.94	20.03
		P%	3.90	4.92	3.29	5.60	2.89	3.06	7.55	3.62	6.45	2.74	4.48
LBS	labellum, from base of entrance to base of sinus, length	(M±m)	4.615±0.312	4.027±0.376	3.595±0.261	6.830±0.570	6.865±0.255	5.370±0.188	5.170±0.634	4.605±0.321	4.860±0.333	5.763±0.302	5.320±0.225
		min-max	3.0-6.0	3.0-5.5	1.8-4.7	4.3-9.0	6.0-8.1	4.6-6.1	3.5-7.4	3.5-6.0	3.8-5.9	4.1-6.5	4.4-6.3
		C%	14.45	19.96	15.54	17.86	7.94	7.50	26.25	14.90	14.66	10.92	9.04
		P%	3.23	4.46	3.34	3.99	1.78	1.68	5.87	3.33	3.28	2.50	2.02
LO	ovary, length	(M±m)	9.470±0.797	10.402±0.885	10.825±0.664	12.835±0.870	16.585±0.598	14.095±0.528	10.780±1.143	10.660±0.545	12.905±0.711	14.884±0.872	13.825±0.649
		min-max	6.5-12.5	7.0-13.4	8.2-13.2	9.5-16.0	14.2-19.0	12.6-17.0	8.3-16.5	8.5-13.0	10.0-16.5	11.3-17.8	11.7-17.0
		C%	18.01	18.20	13.13	14.50	7.72	8.02	22.70	10.95	11.79	12.22	10.05
		P%	4.03	4.07	2.94	3.24	1.73	1.79	5.07	2.45	2.64	2.80	2.25
[LML=LL-LBS]	labellum, middle lobe, length	(M±m)	2.515±0.283	4.927±0.723	3.130±0.319	1.250±0.300	0.675±0.197	1.890±0.272	1.340±0.176	1.935±0.339	2.195±0.213	2.278±0.204	2.015±0.187
		min-max	1.5-3.5	2.0-8.5	2.3-5.1	0.4-2.5	0.1-1.9	0.9-3.5	0.7-2.3	0.5-3.0	1.6-3.0	1.7-3.3	1.3-2.7
		C%	24.04	31.38	21.82	51.42	62.46	30.85	28.07	37.50	20.77	18.71	19.87
		P%	5.38	7.02	4.88	11.5	13.97	6.90	6.28	8.39	4.64	4.29	4.44
WML	labellum, middle lobe, width	(M±m)	2.980±0.207	2.065±0.064	2.235±0.126	2.205±0.305	2.340±0.267	2.825±0.223	2.664±0.169	1.905±0.248	2.875±0.198	3.205±0.193	3.075±0.272
		min-max	2.0-3.7	1.75-2.30	1.6-2.5	1.2-3.5	1.5-3.5	1.8-3.5	2.0-3.2	0.9-3.0	2.0-3.5	2.7-4.1	2.2-4.1
		C%	14.87	6.72	12.08	2956	24.43	16.87	13.57	27.91	14.71	12.59	18.90
		P%	3.33	1.50	2.70	6.61	5.46	3.77	3.04	6.24	3.29	2.89	4.23
LP	petals, length	(M±m)	5.860±0.217	7.182±0.530	6.115±0.291	8.900±0.379	7.265±0.354	7.290±0.203	6.360±0.659	6.250±0.296	6.085±0.394	8.405±0.263	7.260±0.292
		min-max	5.0-6.7	4.25-8.90	5.2-7.5	7.7-10.5	5.9-8.5	6.2-7.9	2.6-8.7	4.7-7.2	4.6-8.0	7.4-9.5	6.0-8.2
		C%	7.92	15.81	10.20	9.12	10.44	5.95	22.16	10.14	13.85	6.52	8.60
		P%	1.77	3.54	2.28	2.04	2.33	1.33	4.95	2.27	3.09	1.50	1.92
WP	petals, width	(M±m)	2.510±0.159	2.687±0.207	2.355±0.128	2.805±0.268	3.390±0.206	3.220±0.169	2.877±0.186	2.067±0.188	2.800±0.250	3.857±0.138	3.190±0.163
		min-max	1.6-3.0	1.6-3.4	1.9-2.7	1.6-3.9	2.7-4.2	2.6-4.2	2.1-3.6	1.3-2.8	1.9-3.8	3.2-4.3	2.3-3.6
		C%	13.55	16.51	11.65	20.45	13.01	11.25	13.86	19.41	19.11	7.45	10.95
		P%	3.03	369	2.60	4.57	2.91	2.15	3.09	4.34	4.27	1.71	2.45
$IL = \frac{2 * LL}{LBS + LLL}$	Labellum shape index		1.4	1.8	1.5	1.2	1.1	1.3	1.2	1.4	1.4	1.3	1.3

Note: M - average value of the metric feature, m - allowable limits, min-max - minimum and maximum feature values, C% - coefficient of variation of a feature, P% - relative error of the sample mean (accuracy of the experiment)