Variability of Morphological Traits of the Generative Shoot of *Matthiola Caspica* (Busch) Grossh. in Piedmont Dagestan

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Abstract. The paper presents the results of studying the variability of the morphological traits of the generative shoot *Matthiola caspica* (Busch) Grossh. in Piedmont Dagestan. The material for the study was the life processes of *M. caspica* of three cenopopulations: Buynaksky (Talgi, 270), Suleiman-Stalsky (Kasumkent, 410 m) and Tabasaransky (Maraga, 520 m) areas. The greatest contribution to the differentiation of cenopopulations by individual components of dispersion in the traits “length inflorescence” (39.9%), “length vegetative features” (38.5%), “number flowers” (37.1%) and index trait “density inflorescences” (16.5%). The distinctions revealed as a result of the discriminates analysis make it possible to select diagnostic characters that introduce specific differences in *M. caspica* cenopopulations within the Piedmont floristic region. The total accuracy of the classification matrix for the three studied cenopopulations was 82.2%, where the “Maraga” cenopopulation (90.0%) is highly self-identical.

1 Introduction

At present, the number of genera in the family Cruciferae Juss. (Brassicaceae Burnett) has more than 370 and more than 4 thousand species [1]. At the same time, in the world, the genus *Matthiola* Ait. includes 50 species [2]. V. I. Dorofeev cites 6 species for the European part of Russia, and 4 species of the genus *Matthiola* for the Russian Caucasus [3, 4]. Almost all species of the genus *Matthiola* of the Russian Caucasus are represented in the flora of Dagestan – *Matthiola caspica* (Busch) Grossh., *Matthiola daghestanica* (Conti) Busch and *Matthiola odoratissima* (Pall. ex Bieb), except for *Matthiola tatarica* (Pall.) DC. [5, 6].

According to the literature data, *Matthiola caspica* is a semi-rosette, taproot, grayish-green semi-shrub up to 50 cm high. The plant is white-tomentose. Stems are thick, numerous, rough, branched, glabrous or pubescent in the lower part of the stem. The leaves are localized in the lower part of the stem, oblanceolate-spatulate, serrated. The inflorescence is a brush, the axis of the inflorescence is bare. Pedicels less than 8 mm long.

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Petals are yellowish, long, tapered, with corrugated edges. Pods are thick, glabrous or slightly pubescent, up to 16 cm long, with a wide stigma, usually obliquely erect. Fruit pedicels, rarely pubescent. Seeds flat, with narrow membranous wing. Blooms in April-May. Propagated by seeds. Xerophyte. Calcepetrophyte. It grows in the foothills of Dagestan on clay slopes up to the middle mountain belt. Listed in the Red Book of Dagestan. Limiting factors: population decline, economic development, and destruction of habitats [7-10].

Thus, low indicators of seed productivity of *M. caspica* are associated with disturbances in embryogenesis, unfavorable environmental conditions, insufficient number of pollinators, and lesions by phytophages. It is necessary to follow the following recommendations: search for new localities of the species, monitoring of populations, carrying out measures to limit livestock grazing, collection, creation of a genetic seed bank, introduction to botanical gardens with subsequent reintroduction into natural conditions [11].

Comprehensive researches of cenopopulations of rare and endemic plants are important for ensuring the success of introduction and reintroduction work. They allow you to find out the biotic and abiotic requirements of plants to the environment, the mechanisms of reproduction, reproductive biology, symbiotic relationships, the presence of pests and diseases. Field studies can help in identifying the species that have filled the niche vacated as a result of the extinction of the species of interest to us, in predicting its relationship with specific communities, and, most importantly, in clarifying the reasons for the extinction of the species [12, 13].

The study of the complex of morphological traits of the generative shoot of plants explains, in some cases, the features of the life cycle of plants, the ecological differences in different habitats of the species, and the ability to self-maintain in natural populations [14-16].

M. M. Magomedmirzaev [17] argued that the reproduction of wild plant resources occurs in the process of ecological and geographical differentiation of the species. The activity on opening and using the reserves of hereditary variability of traits in natural plant populations, which is necessary not only for breeding, but also for the introduction of new species from the natural flora and the preservation of the gene pool of rare and endangered species, has not been sufficiently developed.

It is well known that the rarest species have small ranges, are found in a limited number of habitats, within which they have a very low abundance [18].

To date, only the study and evaluation of the morphological features of *Matthiola caspica* plants from the Talgi Gorge [19] and the Khadum Range (environs the village of Miatli) [11] are given in the literature.

In this work, we carried out a comparative assessment of the variability of the morphological traits of the generative shoot of *M. caspica* plants from three.

2 Materials and Methods

The material for the study was samples of *M. caspica* plants coeval state (g_1), collected in 2022, in natural populations along the high-altitude ecocline within Piedmont Dagestan: from 270 to 520 m above sea level. A brief ecological and geographical description of the field material collection points is given in Table 1.

Table 1. Brief ecological and geographical characteristics of material collection points.

No	Place / Habit area	Exposition / Cutslope ratio / Altitude above sea level	Geographical bearings

1.	Buynaksky district, environs of village Talgi / Gorge, slopes on the road	South-east / 25-35° / 270	N 42° 52' 35" E 47° 26' 44"
2.	Suleiman-Stalsky district, environs of village Kasumkent / valley of the river Kurakh	South-west / 35-40° / 410	N 41° 39' 55" E 48° 7' 31"
3.	Tabasaransky district, Environs of village Maraga / sandy and rocky slopes along the road	South-west / 30° / 520	N 41° 57' 55" E 48° 6' 31"

As a result of reconnaissance trips, a new locality of *M. caspica* was discovered – the Suleiman-Stalsky district (environs of village Kasumkent, the Kurakh river valley). The other two points are listed in the Red Book of Dagestan [10]. A schematic map of field material collection points is shown in Figure 1.

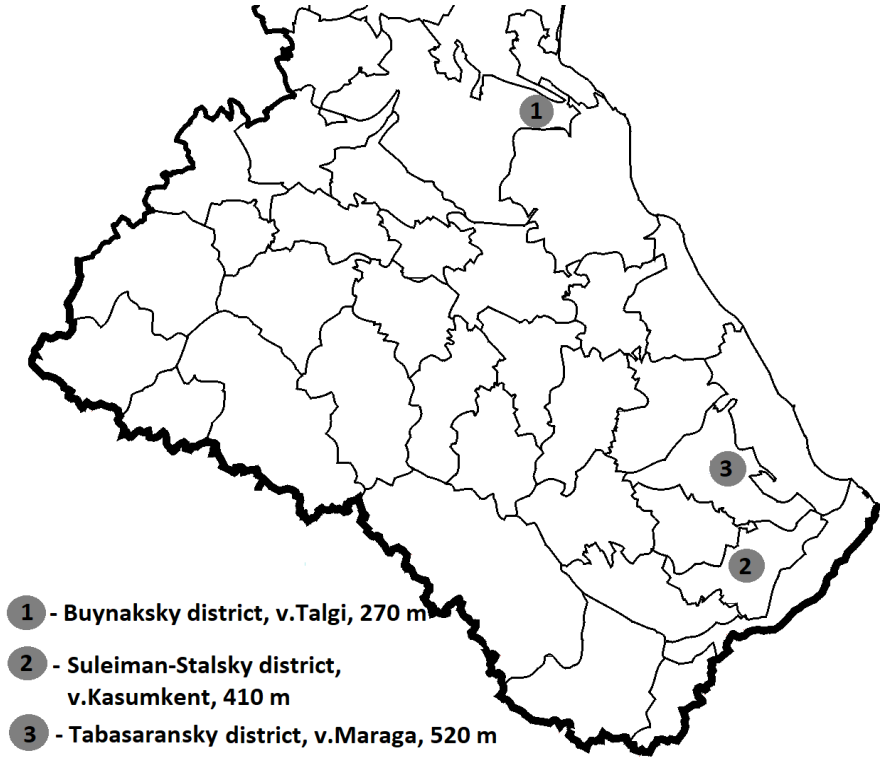

Fig. 1. Schematic map.

In order to study the variability, we selected 10 morphological characters (linear, numerical, weight) and 2 index characters (Table 2). Measurements were made with a ruler with an accuracy of 1 mm. Weighing was carried out on a BMK 303 electronic balance with an accuracy of 1 mg.

Table 2. Morphological and index traits of the generative shoot of *Matthiola caspica*.

Traits	**Symbol**
Linear, mm	
Length shoot	LS
Length inflorescences	LI

Length vegetative features	LVP
Numbers, pcs.	
Number leaves rosettes	NLR
Number leaves shoots	NLS
Number flowers	NF
Postages, mg	
Mass leaves rosettes	MLR
Mass caulis and leaves	MSL
Mass inflorescences	MI
Mass shoot	MS
Index	
Reproductive effort (MI/MS)	RE
Density inflorescences (NF/SI)	DI

For mathematical processing of the obtained results, methods of descriptive statistics, dispersion and discriminates analyzes were used. The processing of the received data was carried out using the program *Statistica v. 13.*

3 Results and Discussion

Comparative characteristics of the average values of the generative shoot of the studied M. caspica plants from different cenopopulations are presented in Table 3. The lowest average values were noted in the plants of the "Kasumkent" cenopopulation in terms of the length of the shoot (292.2 mm), the length of the vegetative features (143.4 mm), the number of leaves (6.0 pcs.), the mass of caulis and leaves (506.3 mg), the mass of the inflorescence (263.4 mg) and the total mass of the shoot (1130.8 mg).

The maximum average values were observed in most cases in plants of the cenopopulation "Talgi" for the length of the shoot (353.5 mm), the length of the inflorescence (193.9 mm), the number of rosette leaves (6.6 pcs.), the number of flowers (15.1 pcs.) and reproductive effort (25.1), mass of inflorescences (307.9 mg), as well as in plants of the "Maraga" cenopopulation in terms of the length of the vegetative features (203.4 mm), the number of shoot leaves (8.7 pcs.), mass caulis and leaves (688.9 mg), the total mass of the shoot (1264 mg) and the density of the inflorescences (1.1).

Table 3. Average values and coefficients of variation of morphological features of *Matthiola caspica* for three cenopopulations.

Traits (n=30)	**Talgi – 270 m**		**Kasumkent – 410 m**		**Maraga – 520 m**	
	X±Sx	**CV, %**	**X±Sx**	**CV, %**	**X±Sx**	**CV, %**
Linear, mm						
LS	353.5±6.47	10.0	292.2±10.47	19.6	315.7±7.65	13.3
LI	193.9±6.00	16.9	148.8±9.09	33.5	112.3±7.41	36.1
LVP	159.7±5.35	18.3	143.4±4.96	18.9	203.4±7.26	19.5
Numbers, pcs.						
NLR	6.6±0.13	10.9	6.0±0.19	16.9	6.5±0.27	23.1
NLS	7.6±0.17	12.3	8.1±0.22	14.6	8.7±0.46	28.7
NF	15.1±0.26	9.5	14.4±0.47	18.0	11.5±0.37	17.6
Postages, mg						
MLR	326.7±13.96	23.4	359.8±20.14	30.7	296.7±22.30	41.2
MSL	582.3±23.80	22.3	506.3±34.54	37.4	688.9±44.83	35.6
MI	307.9±17.21	30.6	263.4±14.33	29.8	282.2±22.99	44.6
MS	1217.9±44.16	19.9	1130.8±59.60	28.9	1264.5±68.61	29.7
Index						
RE	25.1±0.86	18.9	23.5±0.77	18.1	22.6±1.39	33.8
DI	0.8±0.02	18.0	1.1±0.07	34.9	1.1±0.08	38.2

The assessment of variability in terms of the coefficient of variation (CV) at the intra- and interpopulation level showed that the average values of linear (only shoot length) and numerical traits of "Talgi" cenopopulation plants are characterized by relative determinism, that is, a low level of variability according to the S. A. Mamaev scale [20]. In general, there is increased and high variation in traits. A very high variation was observed in weight characteristics (mass of rosette leaves and mass of inflorescences) in plants of the "Maraga" cenopopulation.

The analysis of the variability of the studied traits was carried out using two models of analysis of variance – a one-factor model and a model taking into account linear regression in terms of the degree of influence of the altitude factor. Table 4 shows the final results reflecting the contribution of the intergroup components of the variance to the overall variability of traits [21].

Table 4. ANOVA of variance on the vertical gradient of *Matthiola caspica* traits, taking into account the linear regression model (in %).

Traits	**h^2**	**r^2**	**r_{xy}**
Linear, mm			
LS	23.9***	8.9**	-0.30**
LI	39.9***	39.7***	-0.63***
LVP	38.5***	19.1***	0.44***
Numbers, pcs.			
NLR	5.3	0.1	-0.04
NLS	7.2*	7.2*	0.27*
NF	37.1***	32.8***	-0.57***
Postages, mg			
MLR	5.9	1.3	-0.12
MSL	13.3**	4.5*	0.21*
MI	3.2	1.1	-0.10
MS	3.0	0.4	0.06
Index			
RE	3.2	3.1	-0.18
DI	16.5***	15.1***	0.39***

Note: h^2 – the strength of the influence of the factor; r^2 – coefficient of determination; r_{xy} – the correlation coefficient between the height level and the trait under study.

The results of a one-way regression analysis showed that a small difference between h^2 and r^2 indicates a strong effect of height on the variability of the traits: "length inflorescence", "number flowers" and "density inflorescence". An average negative correlation was noted between height (coenopopulations) and linear ("length shoot", "length inflorescence", "length of the vegetative features"), numerical ("number leaves shoot", "number flowers"), postages ("mass caulis and leaves") and index ("density inflorescence") traits.

An assessment of the variability of the morphological traits of the generative shoot of *M. caspica* from three contrasting cenopopulations: "Talgi" (270 m), "Kasumkent" (410 m) and "Maraga" (520 m), showed a significant role of intraspecific differentiation. Based on the results of one-way analysis of variance, significant differences between populations were revealed in most of the studied traits of the generative shoot of *M. caspica*. The greatest contribution to the differentiation of cenopopulations according to the relative components of dispersion is made by the traits "length inflorescence" (39.9%), "length vegetative features" (38.5%), "number flowers" (37.1%) and the index trait "density inflorescence" (16.5%) (Figure 2).

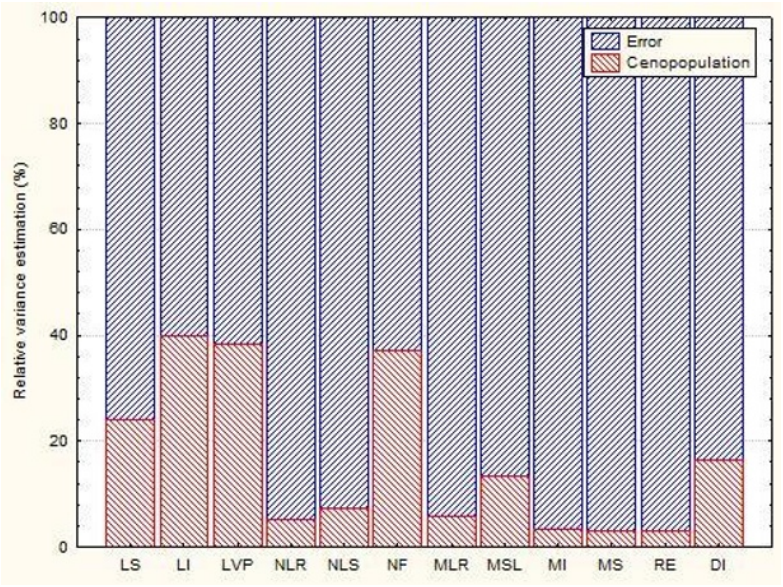

Fig. 2. The results of ANOVA of variance of the studied traits of *Matthiola caspica* by the grouping variable "cenopopulation".

Discriminates analysis with a step-by-step exclusion of morphological traits of the generative shoot of *M. caspica* ("Talgi", "Kasumkent" and "Maraga") showed that the most discriminating features are some linear and numerical indicators – "number flowers", "length inflorescence", "number leaves rosettes", "length vegetative features", as well as postages – "mass caulis and leaves" and "mass leaves rosettes". Mahalanobis distance squares showed the isolation of the "Maraga" cenopopulation from others (Figure 3).

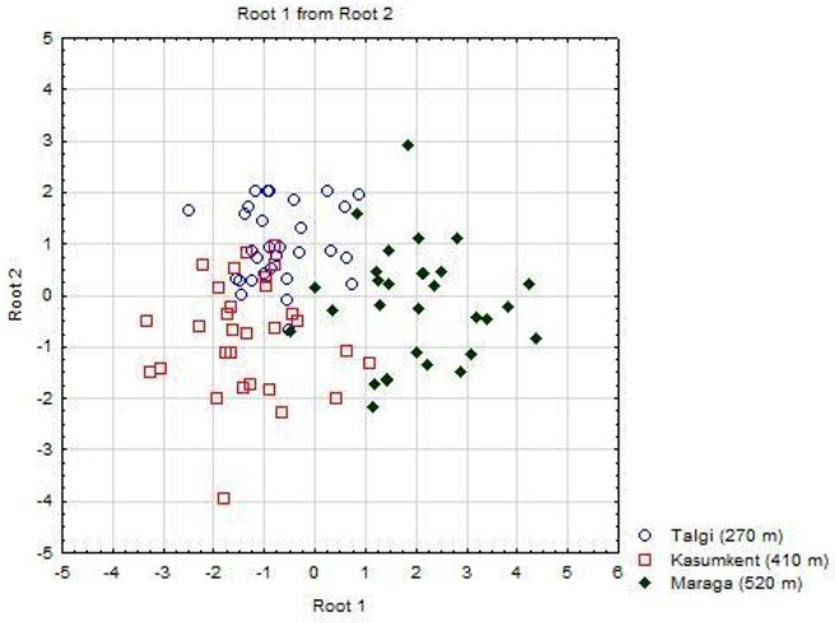

Fig. 3. Results of the discriminates analysis on the morphological features of the generative shoot of *Matthiola caspica.*

Thus, between populations, there is a clear separation in space of the two roots of canonical analysis and partial self-identification. The location along root 1 states the relationship with moisture and the predominance of generative structures in plants of the cenopopulations "Talgi" and "Kasumkent" in comparison with "Maraga", where traits of the vegetative sphere predominate. As for root 2, the division is insignificant and is possibly associated with the specific and microclimatic features of the model sites.

4 Conclusion

A preliminary analysis of the variability of *Matthiola caspica* plants from three contrasting cenopopulations of Piedmont Dagestan on the basis of generative shoot showed a certain role of intraspecific differentiation, which is of scientific interest for further experimental study of issues related to the natural and clonal renewal of a rare species of regional flora, which has undergone intense anthropogenic impact.

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References

1. R. Govaerts, E. Lughadha, N. Black, Sci. Data, **8**, 215 (2021).
2. W. T. Aiton, Catalogue of the Plants Cultivated in the Royal Botanic Garden at Kew, **4**, 119 (1812).
3. V. I. Dorofeev, Turczaninowia, **3**, 5 (2002).
4. V. I. Dorofeev, Turczaninowia, **3**, 6 (2003).
5. R. A. Murtazaliev, *Abstract of the flora of Dagestan*, **1,** 234 (2009).
6. R. A. Murtazaliev, Botanical Herald of the North Caucasus, **2** (2016).
7. E. G. Chernyakovskaya, *Flora of the USSR*, **8** (1939).
8. A. A. Grossgeim, *Flora of the Caucasus* (Nymphaeaceae-Platanaceae), **4**, 248 (1950).
9. A. L. Galushko, *Flora of the North Caucasus. Determinant*, **2** (1980).
10. M. A. Magomedova, *Red Book of the Republic of Dagestan*, 278 (2020).
11. R. M. Osmanov, F. A. Vagabova, F. I. Islamova, Dagestan State Pedagogical University, **3**, 14 (2020).
12. O. H. Frankel, M. E. Soulé, *Conservation and Evolution* (1981).
13. Yu. N. Gorbunov, D. S. Dzybov, Z. E. Kuzmin, I. A. Smirnov, *Guidelines for the reintroduction of rare and endangered plant species* (2008).
14. W. Kotowski, R. Diggelen Van, Light as an environmental filter in fen vegetation, **15** (2004).
15. K. Kostrakiewicz-Gieralt, Acta Agrobotanica, 67, 25 (2014).
16. R. M. Osmanov, Z. A. Guseynova, D. M. Anatov, BIO Web of Conferences, **43**, 01006 (2021).

17. M. M. Magomedmirzaev, Results of science and technology, **3**, 134 (1978).
18. S. A. Trepet, V. V. Akatov, *Rare species and their conservation*, 178 (2019).
19. M. A. Magomedova, Proceedings of the Institute of Geology of the Dagestan Scientific Center of the RAS, **65**, 130 (2015).
20. S. A. Mamaev, *Patterns of morphogenesis and species differentiation in woody plants*, 29 (1975).
21. A. Afifi, S. Eisen, *Statistical analysis*, 488 (1982).