Vitality Structure of Colchicum bulbocodium subsp. versicolor (Colchicaceae, Liliopsida) Populations in the Lower Volga Region

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Abstract—The vitality structure of 23 natural coenopopulations of Colchicum bulbocodium subsp. versicolor from the Lower Volga region has been analyzed in 2014–2019. During this period, the viability of coenopopulations of the studied region varied within a wide range (from 0.45 to 1.51). Comparing to coenopopulations of this subspecies growing in the southwestern part of the Lower Volga region, northeastern coenopopulations are characterized by a lower viability, higher instability, and a wider variability of the latter index. The morphological traits studied correlated poorly among themselves. A high correlation was revealed between only two traits, while a medium correlation was confirmed for six pairs of traits. The largest number of relationships with a significant correlation level was observed for traits such as the plant height and diameter, the length and the width of a bottom leaf, and the claw length. Based on the IQ parameter and the Q criterion, the absolute majority of coenopopulations observed in the period studied were considered as prosperous. A depressive state was reported only for some coenopopulations and only in certain years of monitoring (mainly in 2018). In spring of 2018, the average temperatures during the period of active vegetation and flowering of the studied subspecies were extremely low comparing to other years, which that could have resulted in extreme growing conditions in the region studied and, therefore, a decrease in the vitality of coenopopulations.

Keywords: Colchicum bulbocodium subsp. versicolor, morphometry, vitality, Lower Volga region

INTRODUCTION

Evaluation of the vital state of plant populations is one of the key tasks of population botany. The study of this parameter is extremely important in terms of understanding the adaptivity of plants and their structural components to the conditions of their habitats. The results of such studies of rare and endangered species have an indisputable diagnostic value, since they fully reflect the degree of resistance and the ability of plants to grow under various stress conditions, as well as provide understanding of the ability of populations for self-maintenance and self-recovering under natural conditions.

The vitality of individuals and populations is considered as a heterogeneity of individuals of the same ontogenetic state (populations of the same species) associated with their viability (Proskuryakova, 1968; Zlobin, 1989). Plant vitality often correlates with their size and represents the most important adaptive mechanism working at the population level (Zaugolnova et al., 1988). Thus, vitality is a morphostructural manifestation of the vital state of plants (Zlobin et al., 2013).

The purpose of this study was to determine the vitality state of coenopopulations (CPs) of Colchicum bulbocodium subsp. versicolor (Ker Gawl.) K. Perss. in the Lower Volga region.

C. bulbocodium subsp. versicolor is a perennial plant with a height of 5–15 cm. It belongs to the ephemeral group of plants characterized by a very short cycle of the aboveground development. The presence of storage compounds in bulbotubers of such plants allows them to quickly form aboveground organs, which, within a short time, realize their photosynthetic, flowering, and fruiting functions and then die off (Artyushenko, 1970). The species grows in steppes, dry meadows, forest glades, and shrubs (Krasnaya..., 2008). Being a Balkan–Eastern European subspecies, it grows in the Caucasus, eastern Mediterranean, and southeastern Middle Europe (Sagalaev, 2004). The Lower Volga region covers the southeastern and eastern borders of its habitat (Sagalaev and Shantzer, 2006), while the northern border partially includes the Saratov region (Kashin et al., 2020).

In Russia, C. bulbocodium subsp. versicolor is known mainly in the Central Russian and Volga Uplands. It is observed sporadically and seems to van-
ish in many localities (Tsvelev, 1979; Krasnaya..., 2008). The subspecies was included in the Red Book of the Russian Federation as Bulbocodium versicolor (Ker-Gawler) Spreng. (Krasnaya..., 2008) with the status 2a (a species decreasing because of a disturbance of its habitats), as well as in the Red Books of all regions of its occurrence.

Irrespective of the location and geographical confinement, plants of *C. bulbocodium* subsp. versicolor grow and flower under similar ecological conditions, which include no moisture deficiency, relatively low soil and air temperatures, and a low competition with other species (due to the almost complete lack of actively vegetating other species observed in the coenoses in this period). If these conditions are changed (especially in the case of a stable decrease in the biotope moisture level and an increase in the total projective cover of herbaceous vegetation), *C. bulbocodium* subsp. versicolor will rapidly disappear from the coenosis (Kulicova et al., 2019).

The earlier analysis of changes in the ontogenetic structure and the density of a spatial distribution of *C. bulbocodium* subsp. versicolor plants in CPs showed that, in the absence of any changes of external factors influencing the CPs, their ontogenetic spectra remain relatively stable and are characterized by a low variability (Kashin et al., 2020). At the same time, if external factors change, the subspecies demonstrates the lability of both the above-mentioned population characteristics. *C. bulbocodium* subsp. versicolor is capable of active development on territories characterized by a drastically reduced (because of mowing, fires, poorly developed soil, etc.) total projective cover; due to a good reserve of seeds and dormant bulbotubers in the soil, plants can rapidly occupy vacant areas. When displaced by competitive species, it also quickly vacates occupied territories because of the weak competitive ability of plants at the pregenerative stage and the transition of bulbotubers into a long dormancy period. In other words, *C. bulbocodium* subsp. versicolor manifests explerrent properties in terms of the variability of its ontogenetic structure and the density of the spatial distribution of plants (Kashin et al., 2020).

When changes in external conditions result in an increased total projective cover, plants from the early ontogenetic groups become the most vulnerable. At the same time, unfavorable conditions (drought) in the summer and autumn seasons of the preceding year cause plants of the generative state to transit into a prolonged dormancy period (Kashin et al., 2020).

**MATERIALS AND METHODS**

Within the period of 2014–2019, 23 CPs of *C. bulbocodium* subsp. versicolor were studied in six areas of the Saratov region and ten areas of the Volgograd region (Fig. 1). These areas included the Tatishchevo (Tat-1, Tat-2), Krasnoarmeisk (Krm-2), Engels (Eng-1, Eng-2, Eng-3), Saratov (Srt), Balashov (Bls-1, Bls-2), and Rovnove (Rvn) districts of the Saratov region, as well as the Elan (Eln), Zhirkovsk (Gm), Kamshin (Kmsh), Staraya Poltavka (Strp), Nekhaevskaya (Nech-1, Nech-2), Danilovka (Dnl), Kotovo (Kot), Kletskaya (Klt), Ilovlya (Ivl, Sir), and Svetly Yar (Otr) districts of the Volgograd region (Kashin et al., 2020; Kulicova et al., 2019).

An individual generative plant was considered as a statistical unit of this study. Such a choice of the ontogenetic state of plants was intended to maintain a uniformity in the assessment of the morphological parameters (Sharma and Pandit, 2011). In total, 2044 individuals were analyzed in 2014–2019. All measurements were carried out during the mass flowering of *C. bulbocodium* subsp. versicolor using plants with overblown flowers.

The parameters of the aboveground plant parts were measured in living plants without their damage (Kashin et al., 2015, 2016). Thirteen morphometric traits of both the generative and vegetative plant parts were measured in 30 randomly selected generative plants per sample area; if the CP size was fewer than 30 plants, then all flowering individuals were included in the study. The measured traits included the following: plant height; plant diameter (the maximum distance between leaf tips in a cross section of the plant); number of leaves; bottom leaf length and width; lamina thickness measured in the central part of a leaf; number of flowers; height of the perianth (height of the upper perianth part consisting of the perianth lobe bendings); perianth diameter; the length and width of the perianth lobe bending; claw length; and the diameter of the perianth “tube” formed by non-accrete perianth leaves and measured at half of the distance between the ground level and the bend of the perianth lobe (Fig. 2).

Vitality analysis is a comparative method; therefore, the more local CPs are included into the analysis, the more accurate the evaluation is. One of the main tasks of viability evaluation is the selection of traits (at either the organism or population level), which are the most informative and convenient for measurement. The main interest, especially during route surveys, is aimed at finding the smallest number of such traits, sometimes even up to a single trait (Blinova, 2008). In order to select the key traits for calculating the vitality index, correlation and factor analyses were carried out, as well as an analysis of the total variability of traits, expressed through the coefficient of variation.

Correlations between morphological traits were evaluated using Spearman’s rank correlation coefficient. No parameter averaging was carried out. The studied sampling included each trait measured separately for each individual plant and for each year of observation. A correlation pleiad was built using the GRAPHS software package (Novakovsky, 2006). Correlation relationships were divided into three
groups according to their strength: \( r = 0.31–0.50 \) (weak); \( r = 0.51–0.69 \) (medium); and \( r \geq 0.70 \) (strong).

In order to identify traits providing the greatest load on the first two principal components, factor analysis was performed for quantitative traits using principal component analysis (PCA) and the correlation matrix (Shitikov and Zinchenko, 2019; Podani, 2000).

The total variability was expressed by the coefficient of variation of traits (Cv). The trait variability level was evaluated according to Mamaev and Chuyko (1975): if the coefficient of variation is <7, 7–15, 16–25, 26–35, 36–50, or >50%, than the trait variability is very low, low, medium, heightened, high, or very high, respectively.

The vitality structures of CPs were assessed according to Zlobin (1989) using the individual vitality index (IVI). The series of individual plants ranked by the vitality index was divided into three vitality classes: high (a), medium (b), and low (c) (Parkhomenko and Kashin, 2012). The boundaries of the b class were determined within the limits of the confidence interval for the mean (\( x_{\text{m}} \pm \sigma \)). The vitality structure was characterized by the population vitality index (IVC) (Ishbirdin et al., 2005; Zlobin et al., 2013). The gradient of the worsening of living conditions was constructed based on IVC calculated by the results of monitoring in 2018, since the majority of populations (18 of 23) with the maximum possible sampling size (30 plants each) were studied in this year. The size plasticity index (ISP) was calculated as the ratio between the maximum and minimum IVC values (Ishbirdin et al., 2005).

The vitality type of CPs was determined using the \( Q \) criterion (\( Q = 1/2(a + b) \)); for prosperous CPs \( Q > c \); for equilibrium CPs \( Q = c \); and for depressive CPs \( Q < c \) (Zlobin, 2009).

Fig. 1. Localities of the studied Colchicum bulbocodium subsp. versicolor cenopopulations.

Fig. 2. Measurable morphological traits of Colchicum bulbocodium subsp. versicolor plants: 1, plant height; 2, plant diameter; 3, number of leaves; 4, bottom leaf length; 5, bottom leaf width; 6, lamina thickness; 7, number of flowers; 8, perianth height; 9, perianth diameter; 10, perianth lobe bending length; 11, perianth lobe bending width; 12, claw length; 13, flower tube diameter.
To evaluate the level of CP prosperity or depression, the $I_Q = (a + b)/2c$ index was used (Ishbirdin et al., 2005). In this case, $I_Q > 1$ corresponded to the prosperous state, while $I_Q < 1$ indicated the depressive state. The degree of deviation from one (equilibrium state) indicated the degree of prosperity or depression. In the case of the lack of individuals referred to any state, the $I_Q$ index was examined. The population vitality indices ($IVC$) were calculated using four traits selected by the results of correlation and factor analysis, as well as the analysis of the general variability of traits. According to the data of the factor analysis, the maximum positive load (0.6–0.7) on the first two components, which provided 44% of the total dispersion, was determined by the plant height, plant diameter, leaf length and width, perianth height, clay length (for the first component), and the flower tube diameter (for the second component; Table 2). The calculated coefficients of variation revealed six highly variable traits: plant diameter (46.41%), leaf length and width (35.98 and 39.39%, respectively), number of flowers (40.01%), diameter of the cyathiform perianth (37.18%), and the diameter of the perianth tube (43.92%). Four traits characterized by a heightened variation level included the plant height (26.95%), lamina thickness (31.07%), perianth lobe bending width (29.90%), and the length of the perianth lobe claw (31.45%). The medium variability level was revealed for two morphometric traits, the height of the cyathiform perianth (20.48%) and the perianth lobe bending length (25.27%). Such a trait as the number of leaves was characterized by a low variability level (9.27%).

Thus, following the recommendations of Zlobin et al. (2013), the vitality structure of CPs was studied using the most varying traits and taking into account the greatest contribution of traits in the first two main components and the correlation between the traits. The chosen traits included the plant diameter and height as well as the length and width of the bottom leaf. These traits completely characterize the development of $C.~bulbocodium$ subsp. $versicolor$ plants.

The population vitality indices ($IVC$) were calculated using four traits selected by the results of correlation and factor analysis, as well as the analysis of the general variability of traits. In general, CP vitality within the whole region studied and the study period varied within a wide range (from 0.37 to 1.55; Table 3).
In the left-bank area, a high vitality level (1.29–1.55) was observed in four CPs: Rvn (2015, 2019), Eln (2017), Eng-1 (2016), and Eng-2 (2016, 2018). The maximum value of this parameter was registered for the Eng-2 CP in 2016.

Among CPs of the right-bank area, the highest vitality level (sometimes reaching 1.28–1.37) was observed in three CPs: Tat-1 (2015), Tat-2 (2015, 2017), and Kmsh (2018).

Low vitality was revealed in the Tat-1 and Tat-2 CPs in 2016 and in the Srt, Eng-3, Nech-1, Nech-2, and Sir CPs in 2018.

The maximum instability of this index within the period studied was revealed in the Tat-1 (0.64–1.37), Tat-2 (0.65–1.32), and Srt (0.37–1.16) CPs located mainly in the northeastern part of the territory studied.

The most stable values of this index in the Saratov region were registered for the Krm-2 CP representing one of the southernmost CPs in the right-bank area; in the Volgograd region, similar data were obtained for the Eln, Grn, Strp, and Kot CPs.

Three CPs from the Volgograd region (Kot, Grn, and Eln) and one CP from the Saratov region (Eng-2) were characterized by a stably high viability (>1.00) within the whole monitoring period.

For all CPs studied, the lowest vitality was observed in 2014. In this year, no CPs had $IVC > 1.00$. At the same time, $IVC > 1.00$ was observed in seven out of 11 CPs in 2015, eight out of 16 CPs in 2016, nine out of 12 CPs in 2017, five out of 17 CPs in 2018, and five out of six CPs in 2019.

Within 2016–2018 (a period during which the state of the maximum number of CPs in both regions was

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**Table 1.** Correlation relationships between morphological traits of *C. bulbocodium* subsp. *versicolor*

| Number of trait | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|-----------------|---|---|---|---|---|---|---|---|---|----|----|----|----|
| 1               |   |   | 0.32 | 0.17 | **0.71** | **0.54** | 0.23 | 0.23 | 0.42 | 0.31 | 0.45 | 0.27 | **0.65** | 0.00 |
| 2               |   | 0.15 | **0.63** | **0.53** | 0.33 | 0.31 | 0.28 | 0.24 | 0.23 | 0.24 | 0.25 | **−0.01** |   |
| 3               |   |   | 0.14 | 0.19 | 0.09 | 0.20 | 0.16 | 0.12 | 0.12 | 0.11 | 0.08 | 0.02 |   |
| 4               |   |   | 0.61 | 0.34 | 0.22 | 0.29 | 0.27 | 0.33 | 0.18 | **0.55** | **−0.06** |   |
| 5               |   |   |   | 0.34 | 0.42 | 0.35 | 0.29 | 0.37 | 0.46 | 0.39 | 0.09 |   |
| 6               |   |   |   |   | 0.14 | 0.17 | 0.13 | 0.22 | 0.20 | 0.20 | 0.12 |   |
| 7               |   |   |   |   |   | 0.19 | 0.16 | 0.18 | 0.38 | 0.10 | 0.18 |   |
| 8               |   |   |   |   |   |   | 0.34 | **0.65** | 0.30 | 0.24 | **0.00** |   |
| 9               |   |   |   |   |   |   |   | 0.44 | 0.28 | 0.17 | **0.04** |   |
| 10              |   |   |   |   |   |   |   |   | 0.36 | 0.29 | 0.06 |   |
| 11              |   |   |   |   |   |   |   |   |   | 0.21 | 0.31 |   |
| 12              |   |   |   |   |   |   |   |   |   |   | 0.05 |   |
| 13              |   |   |   |   |   |   |   |   |   |   |   |   |

1. plant height; 2. plant diameter; 3. number of leaves; 4. bottom leaf length; 5. bottom leaf width; 6. lamina thickness; 7. number of flowers; 8. perianth height; 9. perianth diameter; 10. perianth lobe bending length; 11. perianth lobe bending width; 12. claw length; 13. flower tube diameter. Values of correlation relationships equal or exceeding 0.50 are indicated in bold. Statistically insignificant traits ($p ≤ 0.05$) are indicated in italics.

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**Table 2.** Factor analysis of morphological traits of *C. bulbocodium* subsp. *versicolor*

| Number of trait | PC 1   | PC 2   |
|-----------------|--------|--------|
| 1               | **0.78** | −0.34  |
| 2               | **0.64** | −0.06  |
| 3               | 0.27   | 0.17   |
| 4               | **0.78** | −0.37  |
| 5               | **0.78** | 0.13   |
| 6               | 0.32   | 0.17   |
| 7               | 0.45   | 0.54   |
| 8               | **0.62** | −0.01  |
| 9               | 0.49   | 0.07   |
| 10              | 0.56   | −0.03  |
| 11              | 0.51   | 0.54   |
| 12              | **0.61** | −0.38  |
| 13              | 0.14   | **0.64** | 11.34 |

Dispersion, % 32.47

Factor loading values equal or exceeding 0.70 are indicated in bold. PC is the principal component. The trait numbering corresponds to that in Table 1.
| CP     | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|--------|------|------|------|------|------|------|
| Bls-1  | *    | 1.09 | *    | *    | *    | *    |
| Bls-2  | *    | *    | *    | 0.81 | *    | *    |
| Tat-1  | 0.99 | 1.37 | 0.64 | 1.19 | 0.78 | 1.03 |
| Tat-2  | 0.94 | 1.32 | 0.65 | 1.28 | 0.76 | 1.07 |
| Srt    | 0.84 | 0.75 | 1.16 | 0.75 | 0.37 | 0.75 |
| Krm-1  | 0.68 | 0.85 | 0.97 | 1.13 | 1.01 | *    |
| Krm-2  | 0.90 | 0.94 | 0.96 | 1.16 | 0.99 | *    |
| Eng-3  | *    | 0.95 | 0.98 | *    | 0.59 | 1.11 |
| Eng-1  | 0.88 | 1.15 | 1.35 | *    | *    | *    |
| Eng-2  | *    | 1.01 | 1.55 | *    | 1.36 | *    |
| Rvn    | 0.94 | 1.34 | 0.76 | 1.22 | *    | 1.31 |
| Eln    | *    | *    | 1.21 | 1.29 | *    | *    |
| Grn    | *    | 1.01 | 1.09 | *    | 1.08 | *    |
| Kmsh   | *    | *    | 0.99 | 1.18 | 1.28 | *    |
| Strp   | *    | *    | 0.94 | 1.13 | 0.97 | 1.18 |
| Nech-1 | *    | *    | *    | *    | 0.68 | *    |
| Nech-2 | *    | *    | *    | *    | 0.66 | *    |
| Dnl    | *    | *    | *    | *    | 1.01 | *    |
| Kot    | *    | *    | 1.18 | 1.05 | 1.17 | *    |
| Klt    | *    | *    | 1.19 | *    | 0.77 | *    |
| Sir    | *    | *    | *    | 0.85 | 0.49 | *    |
| Iv     | *    | *    | 1.08 | *    | *    | *    |
| Otr    | *    | *    | *    | *    | 0.88 | *    |

Asterisks (*) mean that the CP was not studied in this season or plants were faded.

During the period studied, the vitality spectra of the majority of *C. bulbocodium* subsp. *versicolor* CPs were characterized by the prevalence of medium-class individuals (Table 4). The prevalence of plants of the lower class was observed for the Krm-1 in 2014, Tat-1 and Tat-2 in 2016, and Eng-3, Srt, Sir, and Nech-2 in 2018. The Nech-1 CP was characterized by an equal ratio of individuals between the lower and medium vitality classes. The plants of the higher vitality class dominated in the following CPs: Eng-1 (2016), Eng-2 (2016, 2018), and Rvn (2015, 2019). An equal ratio between the individuals of the medium and higher vitality classes was observed in the Tat-1 and Tat-2 in 2015. The absence of lower-class individuals in the vitality composition of CPs was observed in Eng-1 (2015, 2016), Eng-2 (2016, 2018), Krm-1 (2017), Krm-2 (2014, 2015, 2017, 2018), Rvn (2015, 2017, 2019), Srt (2016), Tat-1 (2015, 2017, 2019), Tat-2 (2015, 2017), Bls-1 (2015), Iv (2016), Klt (2016), Kmsh (2017, 2018), Kot (2016, 2018), and Eln (2016).

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**Table 3.** *IVC* (vitality index) values of the studied *C. bulbocodium* subsp. *versicolor* coenopopulations (CPs) monitored. *IVC* values equal or greater than 1.00 were registered in ten out of 23 cases for the Saratov region and in 13 out of 23 cases for the Volgograd region. Thus, in general, Volgograd CPs were characterized by a higher vitality than those in the Saratov region.

Based on these facts, one can conclude that, compared to the CPs growing on the southwestern part of the Lower Volga (Volgograd region), CPs growing in the northeastern part of this area (Saratov region) are characterized by greater instability and a greater variability in the range of this parameter. Therefore, CPs growing on the northeastern part of the subspecies habitat are more vulnerable.

According to the vitality indices of the studied *C. bulbocodium* subsp. *versicolor* CPs calculated for 2018, a series was constructed that reflected the gradient of worsening of their growing conditions: Eng-2 → Kmsh → Kot → Grn → Krm-1 → Dnl → Krm-2 → Strp → Otr → Tat-1 → Klt → Tat-2 → Nech-1 → Nech-2 → Eng-3 → Sir → Srt.
Table 4. Vitality structure of *Colchicum bulbocodium* subsp. *versicolor* coenopopulations (CPs)

| CP | Year | Share of individuals of different ontogenetic states per 1 m², % | Q   | Iₐ | CP type         |
|----|------|---------------------------------------------------------------|-----|----|----------------|
|    |      | *a*       | *b*       | *c*       |     |                |
|    |      | 6 | 7 | 8        |     |                |
| Bls-1 | 2015 | 26.67 | 73.33 | 0.00 | 50.00 | 50000.00 | Prosperous |
| Bls-2 | 2017 | 0.00 | 83.33 | 16.67 | 41.67 | 2.50 | The same as above |
| Tat-1 | 2014 | 10.00 | 76.67 | 13.33 | 43.33 | 3.25 | " |
| Tat-1 | 2015 | 50.00 | 50.00 | 0.00 | 50.00 | 50000.00 | " |
| Tat-1 | 2016 | 0.00 | 30.00 | 70.00 | 15.00 | 0.21 | Depressive |
| Tat-1 | 2017 | 33.33 | 66.67 | 0.00 | 50.00 | 50000.00 | Prosperous |
| Tat-1 | 2018 | 0.00 | 66.67 | 33.33 | 33.33 | 1.00 | Equilibrium |
| Tat-1 | 2019 | 10.00 | 90.00 | 0.00 | 50.00 | 50000.00 | Prosperous |
| Tat-2 | 2014 | 0.00 | 96.67 | 3.33 | 48.33 | 14.50 | The same as above |
| Tat-2 | 2015 | 50.00 | 50.00 | 0.00 | 50.00 | 50000.00 | " |
| Tat-2 | 2016 | 0.00 | 36.67 | 63.33 | 18.33 | 0.29 | Depressive |
| Tat-2 | 2017 | 43.33 | 56.67 | 0.00 | 50.00 | 50000.00 | Prosperous |
| Tat-2 | 2018 | 0.00 | 60.00 | 40.00 | 30.00 | 0.75 | Depressive |
| Srt | 2014 | 0.00 | 86.67 | 13.33 | 43.33 | 3.25 | The same as above |
| Srt | 2015 | 0.00 | 80.00 | 20.00 | 40.00 | 2.00 | " |
| Srt | 2016 | 30.00 | 70.00 | 0.00 | 50.00 | 50000.00 | " |
| Krm-1 | 2014 | 0.00 | 43.75 | 56.25 | 21.88 | 0.39 | " |
| Krm-1 | 2015 | 0.00 | 73.33 | 26.67 | 36.67 | 1.38 | Prosperous |
| Krm-1 | 2016 | 0.00 | 93.33 | 6.67 | 46.67 | 7.00 | The same as above |
| Krm-1 | 2017 | 13.33 | 86.67 | 0.00 | 50.00 | 50000.00 | " |
| Krm-1 | 2018 | 6.67 | 90.00 | 3.33 | 48.33 | 14.50 | " |
| Krm-2 | 2014 | 0.00 | 90.00 | 0.00 | 50.00 | 50000.00 | " |
| Krm-2 | 2015 | 0.00 | 100.00 | 0.00 | 50.00 | 3.45 | " |
| Krm-2 | 2016 | 3.33 | 93.33 | 3.33 | 48.33 | 14.50 | " |
| Krm-2 | 2017 | 20.00 | 80.00 | 0.00 | 50.00 | 50000.00 | " |
| Krm-2 | 2018 | 0.00 | 100.00 | 0.00 | 50.00 | 50000.00 | " |
| Eng-3 | 2015 | 3.33 | 90.00 | 6.67 | 46.67 | 7.00 | " |
| Eng-3 | 2016 | 10.00 | 83.33 | 6.67 | 46.67 | 7.00 | " |
| Eng-3 | 2018 | 0.00 | 20.00 | 80.00 | 10.00 | 0.13 | Depressive |
| Eng-3 | 2019 | 16.67 | 80.00 | 3.33 | 48.33 | 14.50 | Prosperous |
| Eng-1 | 2014 | 0.00 | 92.59 | 7.41 | 46.30 | 6.25 | The same as above |
| Eng-1 | 2015 | 20.00 | 80.00 | 0.00 | 50.00 | 50000.00 | " |
| Eng-1 | 2016 | 53.33 | 46.67 | 0.00 | 50.00 | 50000.00 | " |
The calculated $I_Q$ values and the $Q$ criterion showed that the absolute majority of CPs were prosperous during the whole monitoring period (Table 4). The Tat-1 CP was found to be equilibrium in 2018. A depressive state was registered only for some CPs and only in individual years: Eng-3 (2018), Krm-1 (2014), Srt (2018, 2019), Tat-1 (2016), Tat-2 (2016, 2018), Sir (2018), Nech-1 (2018), and Nech-2 (2018). Obviously, such a state of the CP was typical mainly for 2018. This fact may be most likely explained by the...
Fig. 4. Average temperatures in *Colchicum bulbocodium* subsp. *versicolor* habitats, located on the studied territory, within the period from March 1 to May 31.

Fig. 5. Dependence of the dimensional indices of some *Colchicum bulbocodium* subsp. *versicolor* traits and their coefficients of variation on the vitality of cenopopulations: (a) plant height; (b1) plant diameter; (b2) coefficient of variation for the plant diameter; (c) leaf length; (d1) leaf width; (d2) coefficient of variation for the leaf width; (e1) claw length; (e2) coefficient of variation for the claw length; (f) flower tube diameter; (g) coefficient of variation for the perianth height.
unfavorable weather conditions of the early spring period formed in certain years of this study (mainly in 2018).

In the early spring of 2018, the average temperatures during the period of active vegetation and flowering of plants in the region studied were extremely low compared to other years of monitoring (Fig. 4). In the case of some CPs, this may result in extreme growing conditions due to the later and prolonged melting of snow, severe overwetting and frosts, temporary soil icing, etc. The highest relative number of individuals of the lower vitality class in 2018 was registered for the following CPs: Srt (100%, northern hillside), Sir (96.67%; northeast gully slope on the hill), and Eng–3 (80%, gully bottom). All three CPs received less heat than the other ones due to their exposure (Srt and Sir) or overwetting of the gully bottom (Eng–3). Exceptional local conditions may have also formed for those few CPs, which were characterized by a depressive state during other years of monitoring.

At the same time, the plant response to stress conditions is manifested at the morphological level through miniaturization of vegetative and generative traits (Fig. 5). For example, according to the results of a simple regression analysis, worsening of growing conditions correlates with reliable \((p \leq 0.05)\) reduction of the average values of the plant height \((a)\) and diameter \((b_1)\), leaf length and width \((c \text{ and } d_1)\), and claw length \((e_1)\). For the flower tube diameter \((f)\), the character of changes in the average value of this trait was indeterminate. For the plant diameter \((b_2)\) and leaf width \((d_2)\), there was a reliable increase in the variability of these traits, while for generative traits such as the key length \((d_3)\) and the perianth height \((g)\), an indeterminate variation within the ecocline was observed. This fact indicates a significant response of individuals of the subspecies to changes in the environmental conditions (in the case they occur).

CONCLUSIONS

In comparing CPs of *C. bulbocodium* subsp. *versicolor* growing in the southwestern area of the Lower Volga, northeastern CPs are characterized by greater instability and greater variability range of this parameter.

The depressive state of some CPs observed in some years is probably associated with unfavorable weather conditions during early spring (mainly with low temperatures).

In the Lower Volga area, *C. bulbocodium* subsp. *versicolor* is characterized by relatively low ecological plasticity, which can be explained by uniform growing conditions of the subspecies in the studied part of their habitat during the active vegetation and flowering period. The morphological response of plants to stress conditions is manifested through miniaturization of their traits.

**COMPLIANCE WITH ETHICAL STANDARDS**

The authors declare that they have no conflict of interests. This article does not contain any studies involving animals or human participants performed by any of the authors.

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