Modificational variability and physiological foundation of herbaceous plants corolla colouring in Central Europe

Irina Kolomiets, Nikolay Platovsky

Institute of Ecology and Geography, Academy of Sciences of Republic of Moldova, Chişinău, Republic of Moldova. Corresponding author: I. Kolomiets, mihailov-me@mail.ru

Abstract. Corolla colouring modificational variability of 272 herbaceous plants species of Central Europe has been studied basing on Ellenberg ecological scales. It was found that the corolla colouring of 209 species out of 272 varied. The moisture regime was observed to change one position of the corolla colouring. The temperature regime changed the colouring within three positions.
Key Words: temperature, humidity, corolla colouring, color transitions, modificational variability, ecological scales.

Introduction. At present special attention is paid to studying of plants, resistant to the extreme values of abiotic factors. Living organisms have a wonderful characteristic to combine the resistance under changing environmental conditions and the adaptiveness to these conditions (Zolotukhin & Zanina 2015). The interaction of ecological factors and plants manifests itself in definite modificational variations. Usually, when we speak about modificational variations, we mean morphological changes, but quite often this group also includes physiological reactions. These modificational variations have a pronounced adaptive character, thus they are often named physiological adaptations (Grodnitsky 2001). In our opinion, it is not reasonable to separate physiological and morphological adaptations, as morphological adaptations are the results of physiological adaptations. In this work we will try to demonstrate the thesis by the example of modificational variability of herbaceous plants corolla colouring in Central Europe.

Material and Method. As an object of investigation the lowering plants species of C layer, given in ecological scales (Ellenberg 1974) were taken. Based on the data of http://www.plantarium.ru/ site, a colored atlas of the herbaceous flowering plants was compiled. All the species were subdivided according to the corolla colouring into five color classes: red, blue, green (including corollaless), yellow and white. The modificational variability ranges of each species corolla colouring were specified according to Geideman field guide (Geideman 1986). Red and blue classes were evaluated based on a fractionary scale (points from 1 through 4 denoted red color shades, and those from 5 through 8 corresponded to blue color shades). The data statistical processing was made basing on «Excel 2003» program.

Results and Discussion. Out of 272 herbaceous plants species from Central Europe and the Alps that are supposed to have anthocyan corolla colouring 63 species are marked out with stable colouring. Out of them 36 species had red scale colouring, while 27 had blue scale colouring. Corolla colouring of the rest 209 species varied and they were of special interest in the investigation of the species phenotypic variability (Table 1).

Table 1

Corolla colouring variation of herbaceous plants from Central Europe and the Alps

P, %	*N, units*	*D, %*
0.4	1	50.0
5.0	13	37.5
16.2	44	25.0
55.2	150	12.5
23.2	63	0

Explanatory legend: P – the species proportion from the sample of herbaceous plants of Central Europe and the Alps; N – the species number in the group; D – the variation range of the corolla anthocyan colouring character, where 12.5% of variation is within two color classes.

From the definition of the modificational variability term it follows that the studied character stability is connected with the stability of the ecological factor, participating in this character formation. The sample analysis of the plants with the stable corolla colouring (63 species) has shown, that according to Ellenberg (1974), for the temperature factor the scale indices are in the moderate range (3 through 7 steps). The Pearson correlation coefficient (rft) between the corolla colouring (F) and the thermophilicity (T) for the species with stable colouring is equal to 0.43, with the significance level $p > 0.001$ (Dospekhov 1985). For the whole sample of herbaceous plants from Central Europe and the Alps the correlation coefficient (rft) is equal to 0.18 with $p > 0.01$. Thus, the temperature factor stability determines the corolla colouring stability, that is typical for the endemics, the species, the representatives of which grow in rather restricted areal, presented by not large geographical region. The intraspecific corolla colouring variation results from the species large habitat areal and the variation of the main ecological factors such as temperature and humidity. In the first place corolla colouring depends on the pigment concentration in the enchylema. A plant cell is a complex self-regulating osmolytic system, which main organ, a vacuole, deposits the anthocyan pigments. The saturation degree of the cell with water is determined by the water potential value: the less the cell is saturated with water, the more negative its water potential is. The cell water potential, in its turn, depends on the osmolytic potential, that is determined by Vant-Goff equation (Detlaf & Yavorsky 1989):

$$\Psi = - R\ t\ c\ i\ 101.3 \quad (1)$$

where Ψ is the osmolytic potential, kPa; R – the universal gas constant (0.082 L × atm/gradus × mol); t – absolute temperature (273 + t°C); c – the enchylema concentration in moles; i – Vant-Goff coefficient, that characterizes the solution ionisation, 101.3 - the coefficient for conversion atm. in кPa.

The value of the osmolytic potential is influenced by the concentration (c) of the substances, dissolved in the enchylema (organic acids, salts, amino acids, sugar, pigments). The fermentative transformation of complex insolubles into solubles (starch into sugar, proteins into amino acids) results in the increase of enchylema concentration and the growth of the osmolytic potential negative value. In such a way a plant to some extent regulates the osmolytic potential value by itself. Many physiologists consider the osmolytic potential value one of the species characteristics, that makes it possible to determine the plant maximum ability to absorb water from soil and retain it in spite of the drying influence of atmosphere. The osmolytic potential value of different ecological groups varies. The desert plants are characterized by its more negative value in comparison with the steppe plants. The steppe plants osmolytic potential value is more negative than the one of the meadow plants. The osmolytic potential value of the plants from the helobious and water habitats is still less (Fedulov et al 2015. We have grouped the plants with variable corolla colouring according to the hydrophily classes (Table 2) and then made a correlation analysis between the hydrophily scale value and the average corolla colouring value of the classes (F). The data statistical processing has revealed the high degree of correlation (rfм = -0.79, $p > 0.001$) between the hydrophility scale steps that are proportional to the osmolytic potential (Ψ) and the corolla colouring (F).

Along with the osmolytic potential there are matrix, gravitation and electric potentials in a cell. Water movement can be induced by the accumulation of K+, Na+ cations, that, in its turn, take place under the influence of the electric potentials difference. It is known, that K^+ and Na^+ cations lead to the anthocyan pigments reddening, while Ca^{2+}, Mg^{2+} cations bring about blue coloring (Shoeva 2013). As for inorganic substances, potassium, sodium, calcium phosphates accumulate in the vacuolar sap, organic acids salts (oxilates, citates, et al.) may accumulate too. It gives the vacuolar sap a definite acidic reaction (pH from 1 through 6). Based on the above stated, the water potential value depends on the combination of osmolytic, gravitational, matrix, electrical potentials (Na^+, K^+, H^+, Ca^{2+}, Mg^{2+}) and a cell wall pressure. But in the process of water entrance into a cell the osmolyric potential plays the leading role, that depends on the dilution and temperature of the vacuolar sap according to Vant-Goff equation. Predominantly (95% of the species, presented in Ellenberg scales) the dilution increases

1 through 100 times with the modificational variability that includes three color positions out of eight (Table 1). This result corresponds to the specific features of plants ontogeny. In the aging process the vacuole volume changes from 5 through 95% of the cell volume, that may result in the colouring variability of a bud, a blossoming flower and a fading flower within three positions. The "plasmolysis-turgor" condition is determined by the cell volume variation within 10-29%, so the modificational variability will be limited by the tenfold dilution of the enchyloma and one position colouring change. But it's impossible to transform the acidic enchylema into the alkaline one by simple delution. Thus position 8, corresponding to the alkaline reaction of enchylema, becomes possible only with the tonoplast depolarisation, and position 7 is possible only with the enchylema neutralization. One of the mechanisms, leading to the tonoplast depolarization, is the opening of calcium canals. It is necessary to note, that the calcium concentration increase in the enchylema may depend on the calcium income not only from the outside environment, but also from the intracellular organelles. It is not known, how the signal from the tonoplast is transmitted to these organelles (Vereninov & Marakhova 1986). The temperature factor influence on the modificational variability of corolla colouring is well explained from the point of view of the electrolytic dissociation theory. Contrary to common belief, pH may change not only within the range from 0 through 14, but can go beyond these limits. For example, at hydrogen ions concentration $[H^+]$ = 10-15 mol L^{-1}, pH = 15, at hydroxide ion concentration 10 mol L^{-1} pOH = -1. As at 25°C (standard conditions) $[H^+] \cdot [OH^-]$ = 10-14, it is clear, that at this temperature pH + pOH = 14. As in acidic solution $[H^+]$ > 10-7, so in acidic solutions pH < 7. Similarly, the main solutions have pH > 7, and pH of neutral solutions = 7. But at higher temperature the constant of the electrolytic dissociation of water increases, consequently the ion production of water increases too. Thus pH < 7 turns to be neutral (this corresponds to simultaneously increased concentrations of both H^+ and OH^-). Vice versa, at temperature reduction the neutral pH increases (Beits 1972). Consequently, the corolla may have blue color (position 8) at low temperatures, when neutral pH > 7.

Table 2

Influence of ecological factors on corolla colouring of herbaceous plants in Central Europe and the Alps

Number of species	*Average value of factor (x) within the classa*						
	M~Ψ	*S*	*F*	*T*	*K*	*pH*	*N*
12	2	5.14	4.43	7.86	5.71	7.00	1.57
29	3	5.53	4.55	7.25	5.03	7.28	2.75
49	4	5.36	4.13	6.91	4.00	7.06	3.50
39	5	5.44	3.91	6.36	3.50	6.49	4.78
28	6	5.44	4.19	4.81	4.00	6.94	6.61
9	7	5.43	3.21	6.50	4.50	6.64	5.67
27	8	5.74	3.84	7.32	4.50	6.61	4.64
12	9	5.80	3.80	7.53	4.27	5.33	3.67
2	10	5.67	3.67	7.00	2.67	6.33	4.67
1	11	7.00	3.50	6.00	-	6.00	4.00
2	12	5.30	3.50	7.00	4.00	6.10	5.10
average	7,00	5.00	3.50	7.00	5.00	6.00	5.50
correlation (F)	-0.79***	0.01	1.00	-0.09	0.34	0.62**	-0.63**

Explanatory legend: S – the first month of flowering; F – corolla colouring; L – lighting/shading (9); T – thermophilicity (9); K – climate continentality (9); M – soil moisturisation (12 classes); pH – soil acidity (9); N – soils rich level of nitrogen (9), Ψ – thr osmolytic potential, significance levels $p < 0.05$ - *, $p < 0.01$ - **, $p < 0.001$ - ***.

Conclusions. The species variation of anthocyan colouring of herbaceous plants from Central Europe is distributed as follows: 23.2% have stable colouring, 55.2% have the corolla colouring within two color transitions, 16.2% - within three color transitions and 0.4% of species are able to change the corolla colouring within five color transitions.

The change of the moisture regime in the area of distribution results in one position colouring change.

The enchylema acidity change may be induced by the membrans depolarization and the calcioum ions entrance into cytoplasm.

According to the theory of electrolytic dissociation, the corolla colouring modificational variability shifts to the red side with temperature increase, and to the blue one with temperature decrease.

References

Beits P., 1972 [Definition of pH. Theory and practice]. Translation from English under the editorship of acad. B. P. Nikolsky and prof. M. M. Shults. 2nd edition, L.: Chemistry. [in Russian]

Detlaf A. A., Yavorsky B. M., 1989 [Course of physics. Study guide of higher school]. M.: Higher school, 113 pp. [in Russian]

Dospekhov B. A., 1985 [Methods of field experiment]. M.: Agropromizdat, 351 pp. [in Russian]

Ellenberg H., 1974 Zeigerwerte der Gefasspflanzen Mitteleuropas. Göttingen, Goltze, 97 pp.

Fedulov Y. P., Kotlyarov V. V., Dotsenko K. A., 2015 [Sustainability of plants to adequate environmental factors]. Krasnodar, 64 pp. [in Russian]

Geideman T. S., [Field guide of higher plants of MSSR]. Kishinev: Shtiintsa, 637 pp. [in Russian]

Grodnitsky D. L., 2001 [Epigenetic theory of evolution as a possible basis for a new evolutionary synthesis]. Available at: http://www.macroevolution.narod.ru/grodnitsky.htm. [in Russian]

Shoeva O. J., 2013 [Anthocyans, secrets of color]. Chemistry and Life 1:13-17. [in Russian]

Zolotukhin A. I., Zanina M. A., 2015 [The adaptations of woody plants after a thermal stress in the Khopior River region]. Proceedings of the Saratov University, Series Chemistry, Biology, Ecology, pp. 93-98. [in Russian]

Vereninov A. A., Marakhova I. I., 1986 [Ions transportation in cells in culture]. L.: Science, 292 pp. [in Russian]

Received: 30 July 2017. Accepted: 18 September 2017. Published online: 30 September 2017.

Authors:
Irina Kolomiets, Institute of Ecology and Geography, Academy of Sciences of Republic of Moldova, Chişinău, Republic of Moldova, e-mail: mihailov-me@mail.ru
Nikolay Platovsky, Institute of Ecology and Geography, Academy of Sciences of Republic of Moldova, Chişinău, Republic of Moldova, e-mail: Nik.Plat@hotmail.com

This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

How to cite this article:
Kolomiets I., Platovsky N., 2017 Modificational variability and physiological foundation of herbaceous plants corolla colouring in Central Europe. Ecoterra 14(3):40-43.