Humidity and temperature influence on anthocyan coloring of flowering plants corolla

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Abstract. The influence of the number of abiotic factors (soil acidity, soil fertility, soil humidity, temperature, climatic continentality, light availability and month of flowering) on anthocyan corolla coloring was studied on 272 species of flowering plants of C-layer. It was established, that the leading factors in color formation are temperature, humidity and soil fertility. For dicots plants the main factor is temperature.
Key Words: temperature, humidity, soil enrichment with nutritional chemicals, anthocyans, season, corolla coloring.

Introduction. G. Ellenberg's ecological scales are very useful instruments for ecological conditions evaluation. These scales were developed for the European vegetation (Ellenberg 1974) and are considered the most complete and perfect ones. They include 2.5 thousand species of vascular plants and are constantly elaborated and discussed (Ellenberg 1988; Ellenberg et al 1991; Wamelink et al 2002; Witte & von Asmuth 2003; Wamelink et al 2003). In this paper we made an attempt with their help, basing on the ecological factor manifestation, to evaluate its input in the formation of the convergent character of the unrelated species - the corolla coloring of herbaceous plants. The correlation analysis of the indices, received basing on the scales, and those received by their direct measurement, that was performed (Wamelink et al 2002), has shown that the best results of comparison within one type of the vegetation are given by the Ellenberg's scales. For our purposes the most convenient was the herbaceous level, while the separate analysis would allow to reveal if there are any differences in the dominating role of the coloring formation factor of corolla coloring of the dicots and unicotyledonous plants and in case the differences exist, which they are.

Material and Method. As an object of the investigation the flowering plants of C level were taken, represented in the ecological scales (Ellenberg 1974). Basing of 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 coloring into five color classes: red, blue, green (including corollaless plants), yellow and white. With the help of the identification guides (Ciocărlan 2000; Geideman 1986) the flower coloring range of each species, the flowering beginning, and the belonging to the unicotyledonous or dicot plant class were specified. The expected anthocyan corolla coloring (red and blue classes) was evaluated basing on the fractionary scale (1 through 8 points, where the meanings from 1 through 4 showed red color shades, while the meanings from 5 through 6 corresponded to blue color shades). The data statistical processing was performed by «Excel 2003» program.

Results and Discussion. According to the Ellenberg's scales, the evaluation of the ecological living environment is based on the species regional distribution. In compliance with Ellenberg's decoding, the temperature scale evaluates the species thermal resistance and cold rigor and is based on their distribution from the polar zone (or high mountain region - 1, 2, 2 scale steps) to the Mediterranean basin (7, 8, 9 scale steps). Although originally N number was interpreted as a measure of the plant supply with mineral nitrogen (NH_4^+ and NO_3^-) (Ellenberg 1974), according to the new data, the scale of nitrogen abundance is rather a nutritional chemicals scale, as it shows the general store of the nutritional chemicals in soil – nitrogen, potassium, phosphorus, magnesium - and depends on the soils type. The soil humidity scale is based on the species distribution from dry cliffs to swamplands and bodies of water. However, the living environment of the

majority of organisms, including the vegetational ones, is exposed to the deep seasonal changes. The exceptional stability of the periodicity changes of light availability, temperature, humidity, geomagnetical field and other environmental parameters, that are determined by the Earth and the Moon movement around the Sun, let the living systems in the process of evolution develop the time programs, stable and resistant to external influence. The organisms adaptation to the environment in the process of evolutionary development went in the direction of their structural organization perfection and in the direction of coordination in time and space of different functional systems activity. That is why, while considering the abiotic special factors we took into account a time factor - the flowering season (the first month) as well.

The analysis of the European vegetation list, represented in Ellenberg's ecological scales, revealed the existence of 892 herbaceous flowering plants (Table 1). The species with presumably anthocyanin corolla coloring made up 30 per cent, the group of species with yellow-green corolla coloring – 51 per cent, and with white corolla coloring – 19 per cent. Out of 272 herbaceous flowering plants with presumably anthocyanin corolla coloring the unicotyledonous plants class was made up by 34 species, and the dicot plants class – by 238 species.

Table 1

Distribution of herbaceous plants with different corolla coloring according to Ellenberg's scales

Corolla coloring of herbaceous flowering plants									
red		*blue*		*white*		*green*		*yellow*	
N	%	N	%	N	%	N	%	N	%
117	13	155	17	164	19	279	31	177	20

The analysis results (Table 2) have shown that the corolla coloring (C) slightly, but reliably correlates with the flowering season (S), temperature (T) humidity (F) and the soil nitrogen abundance. The season of the plants flowering reliably correlates with light availability, temperature and the soil enrichment with nutritional chemicals. The intercrossing of many factors, influencing the season and influencing the corolla coloring, is the temperature and the soil enrichment with nutritional chemicals. Basing on Table 2 data, the factor, determining the season, is the solar radiation, because the temperature and the light availability are in fact its derivatives. Both the flowering periods and the corolla coloring equally depend on the soil enrichment with nutritional chemicals and this dependence has an inverse character, as when the soil enrichment with nutritional chemicals increases, the proportion of the species with blue corolla coloring decreases.

Table 2

Dependence between anthocyan corolla coloring of unicotyledonous and dicot herbaceous plants and abiotic factors manifestation according to Ellernberg's ecocenotic scales

	S	*C*	*L*	*T*	*K*	*F*	*R*	*N*
S	1	-0.26***	0.24***	-0.18**	0.05	0.11	0.05	-0.12*
C	-0.26***	1	-0.03	0.18**	0.03	-0.14*	0.06	-0.12*
L	0.24***	-0.03	1	0.13*	0.25***	-0.03	0.01	-0.22***
T	-0.18**	0.18**	0.13*	1	0.20**	-0.30***	0.29***	-0.0424
K	0.05	0.03	0.25***	0.20**	1	-0.21***	0.28***	-0.21***
F	0.11	-0.14*	-0.03	-0.30***	-0.21***	1	-0.21***	0.27***
R	0.05	0.06	0.01	0.29***	0.28***	-0.21***	1	0.19**
N	-0.12*	-0.12*	-0.22***	-0.0424	-0.21***	0.27***	0.19**	1

Legend: S – the first month of flowering; C – corolla coloring; L – luminance/shading (9 classes); T – climate temperature (9); K – climate continentality (9); F – soils moisture content (12); R – soils acidity (9); N – soils nitrogen abundance (9), * - $P \leq 0.05$, ** - $P \leq 0.01$, *** - $p \leq 0.001$.

The similar analysis of the dicot plants group (Table 3) has shown that the corolla coloring of dicots depends on the season, the soil enrichment with nutritional chemicals and humidity. With that, the increase of humidity and the soil enrichment with nutritional

chemicals results in the increase of the species with red corolla coloring. The dicots season of flowering reasonably correlates with the light availability, temperature and humidity. So, the humidity is an interlink between the corolla coloring and the dicots flowering season.

Table 3

Dependence between anthocyan corolla coloring of dicot herbaceous plants and abiotic factors manifestation according to Ellenberg's scales

	S	*C*	*L*	*T*	*K*	*F*	*R*	*N*
S	1	-0.24***	0.28***	-0.15*	0.07	0.13*	0.10	-0.02
C	-0.24***	1	-0.05	0.12	0.02	-0.19	0.03	-0.19*
L	0.28	-0.05	1	0.10	0.25	-0.08	0.03	-.22***
T	-0.15*	0.12	0.10	1	0.18**	-0.34***	0.29***	-0.08
K	0.07	0.02	0.25***	0.18**	1	-0.22***	0.31***	-.23***
F	0.13*	-0.19**	-0.08	-0.34***	-0.22	1	-.21***	0.30***
R	0.10	0.03	0.03	0.29***	0.31***	-0.21***	1	0.17*
N	-0.02	-0.19*	-0.22***	-0.08	-0.23***	0.30***	0.17*	1

Legend: S – the first month of flowering; C – corolla coloring; L – luminance/shading (9 classes); T – climate temperature (9); K – climate continentality (9); F – soils moisture content (12); R – soils acidity (9); N – soils nitrogen abundance (9), * - $P \leq 0.05$, ** - $P \leq 0.01$, *** - $p \leq 0.001$.

For the group of unicotyledonous plants the reduction of the number of reliable correlation connections and the transition of weak correlations into the category of intermediate ones are typical. So, according to Table 4 data, the corolla coloring of unicotyledonous plants reasonably depends on the temperature and the flowering season. The flowering season, in its turn, also depends on the temperature, that correlates with the continentality and the availability of light. Consequently, the corolla coloring of the unicotyledonous species depends on the solar radiation.

Table 4

Dependence between corolla anthocyan coloring of unicotyledonous herbaceous plants and abiotic factors manifestation according to Ellenberg's ecocetotic scales

	S	*C*	*L*	*T*	*K*	*F*	*R*	*N*
S	1	-0.39**	-0.07	-0.37*	-0.14	-0.00	-0.20	-0.17
C	-0.39**	1	0.14	0.61**	0.05	0.21	0.21	0.26
L	-0.07	0.14	1	0.42*	0.27	0.22	-0.04	-0.33
T	-0.37*	0.61**	0.42*	1	0.44*	-0.07	0.20	0.13
K	-0.14	0.05	0.27	0.44*	1	-0.14	0.16	-0.18
F	-0.00	0.21	0.22	-0.07	-0.14	1	-0.23	0.28
R	-0.20	0.21	-0.04	0.20	0.16	-0.23	1	0.33
N	-0.17	0.26	-0.33	0.13	-0.18	0.28	0.33	1

Legend: S – the first month of flowering; C – corolla coloring; L – luminance/shading (9 classes); T – climate temperature (9); K – climate continentality (9); F – soils moisture content (12); R – soils acidity (9); N – soils nitrogen abundance (9), * - $P \leq 0.05$, ** - $p \leq 0.01$.

The diagram of the changes of the precipitation sum and the average monthly air temperatures for the continental climate has the form of the sinewave with the maximum point in July and the minimum point in January (for average temperatures) and in February (for the precipitation sum). By the method of the seasonal intervals selection, it was determined that the correlation coefficient changes its sign for the opposite one within the period from July through February. The studying of the distribution dependency of the corolla coloring within the period from January to June and from July to February has shown, that the soils humidity increase results in the increase of the proportion of the red corolla species in the sample of the dicot plants (K = -0.20), while the temperature increase leads to the increase of the proportion of the blue corolla species. The increase of the numerical order of the first flowering month correlates with the increase of the proportion of the red corolla species (K = -0.36).

Consequently, among the dicot plants the red corolla species will be more adapted to the humid environment conditions than the blue corolla species. Under the arid conditions among the species with the anthocyan coloring the blue corolla species get the advantage.

The unicotyledonous plants on the rising part of the temperature curve are characterized by the increase of the proportion of the blue corolla species with the temperature rise (K = 0.65), and the increase of the first flowering month number correlated with the increase of the proportion of the red corolla species (K = -0. 46). On the descending part of the precipitation curve the reasonable humidity decrease results in the increase of the proportion of the eudicots plants species with blue corolla coloring (K = -0.20). With the increase of the first flowering month number there is a tendency of increasing of the proportion of blue corolla species (K = 0.21). As for the unicotyledonous plants, on the descending part of the average monthly temperatures and the average precipitation sum the reliable data were not received due to a very small sample (3 species). So, taking into consideration the Ellenberg's scales decoding, it is possible to conclude, that the plants cold endurance increase in the polar and the high mountain regions (1, 2, 3 scale steps) is connected with the increase of the proportion of the red corolla species, while the increase of the thermal resistance of the Mediterranean plants is connected with the increase of the proportion of the blue corolla species (7, 8, 9 scale steps). According to the humidity scale, the species with presumably anthocyan corolla coloring are distributed in such a way, that on the dry cliffs with nutritional chemicals deficit the proportion of the blue corolla species is higher, than on the wet souls, rich with nutritional chemicals and located near the swamplands and bodies of water. These specific features in the regional distribution are determined by the Alps, the most extended mountain chain on the territory of Central Europe. The climate of the north part of the Alps is colder and more humid, and that of the south part vice versa is warmer and drier (Diagrams 1, 2). The average temperature of July is lower than +14 °C, the temperature of January is to -15 °C. The precipitation makes up to 1 000 mm a year. The snow on the valleys lies from one to six month a year. The main part of winter on the valleys is foggy (Giorgio et al 2003).

An attempt to study the specific features of the species distribution according to the corolla coloring results in one-type answer – with the increase of the flowering month number (from January to July) the proportion of the red corolla species increases. The possible cause of such a conclusion is the predominance of the species, growing on the north side of the Alps, where the proportion of the red corolla species is higher, than on the other territory of Central Europe in Ellenberg's list of flora. It should be noted, that the correlations registered between the corolla coloring and the ecological factors, refer to weak and average categories and are not the exclusive ones.

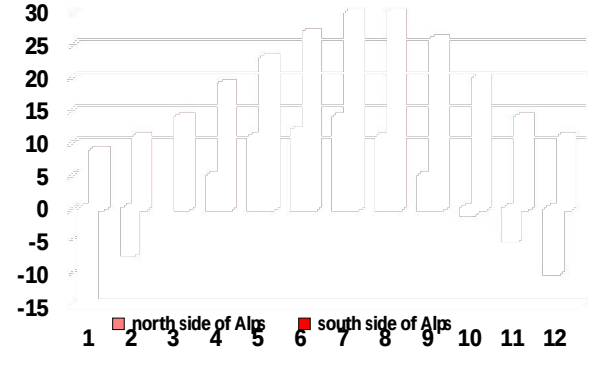

Diagram 1. Average monthly air temperature sums in the Alps (°C).

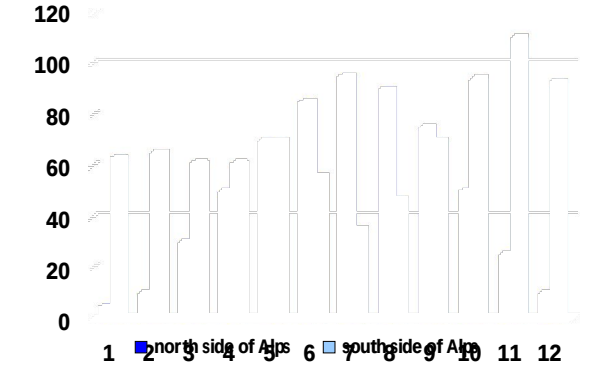

Diagram 2. Average monthly precipitation in the Alps (mm).

Such regional species distribution according to the corolla coloring can also be explained by the fact, that the south side of the Alps belongs to the Mediterranean Center of the

cultivated plants origin. The more evolutionally advanced the taxon is, the more species with the blue corolla coloring it includes.

Conclusions. Among the main abiotic factors, presented in G. Ellenberg's ecologica scales (light availability, temperature, continentality, humidity, the soil reaction, the soil enrichment with nutritional chemicals), the leading role in the formation of the character of herbaceous plants corolla coloring with anthocyan pigments is played by the temperature, humidity and the soil enrichment with nutritional chemicals.

The leading factor in the formation of the character of the dicot plants corolla coloring is humidity.

The leading factor in the formation of the character of unicot plants corolla coloring is temperature.

With the increase of the soil enrichment with nutritional chemicals the proportion of red corolla species increases.

The humidity increase makes larger the proportion of the red corolla species, while the temperature increase makes larger the proportion of the blue corolla species.

Among the dicot plants the red corolla species are more adapted to the over moisturization conditions, than the blue corolla species.

Under arid weather conditions among the plants with the anthocyan coloring the blue corolla species get the advantage.

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