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Floral abnormality in plants of the genera *Colchicum* and *Crocus*

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The article presents the results of the study of abnormal flowers in representatives of the genera *Colchicum* L. and *Crocus* L. *ex situ*. The research was conducted in the M. M. Gryshko National Botanical Garden of the National Academy of Science of Ukraine, Kyiv. Observations were made in 2019–2022 for 18 representatives of the genera *Colchicum* and *Crocus*. The research was carried out using the methods of comparative morphology and photofixation. Data on the phenology of plant flowering in Kyiv are presented. Photos and descriptions of 38 abnormal flowers are provided. A decrease or increase in the number of perianth segments, stamens, styloids (or stigmas) of gynoecium, floral virescence, and cuts on perianth segments was revealed. 26 types of abnormal flowers were found (16 for *Colchicum* species and 10 for *Crocus* species). Pearson correlation coefficients (R) for *Colchicum* flowers revealed negligible, and for *Crocus* flowers – moderate and strong correlation. A comparative analysis of the normal and abnormal number of *Colchicum* flowers' organs revealed that the widest range of percentage difference is characterized by the gynoecium. For *Crocus*, corolla are characterized by the widest percentage difference range. Among the studied taxa of the genus *Colchicum*, the largest number of abnormal flowers was recorded in *C. bulbocodium* Ker Gawl. and *C. autumnale* L. Among representatives of the genus *Crocus* – in *C. heuffelianus* Herb. The described flower anomalies are generally similar to those recorded by other researchers in natural conditions and in culture. For *Colchicum* and *Crocus*, the appearance of individual atypical flowers in inflorescences is characteristic and is caused by external factors, in particular, temperature changes, phytoplasma, damage to buds. Teratological changes in flowers occur as temporary developmental abnormalities and have no taxonomic or adaptive significance. In general, the resettlement of plants and their cultivation outside the natural range did not cause significant permanent changes in the flowers of *Colchicum* and *Crocus*.

Keywords: plant teratology; Iridaceae; colchicine; adaptation; anomalies; teratomorphs.

Introduction

A change in habitat conditions for plants is a stress factor, which is expressed by a complex of physiological changes in the body, which is reflected in anatomical and morphological aberrations, a shift in phenological dates, a violation of biological rhythms, neoteny, etc. Often such changes are adaptive and are considered preadaptations or adaptations, but some aberrations have no proven adaptive significance. These include, in particular, teratological changes in plants (Likhonov, 2002).

There is evidence that abnormal (in particular, double) flowers arise as a result of gene expression or suppression and hormonal regulation disorders in plants (Gao et al., 2022). Researchers have proven that the abnormal development of flowers can occur due to the influence of drought, temperature fluctuations, altitude above sea level, anthropogenic pollution, the content of trace elements in the soil, radiation or chemical exposure, diseases or pests (Kondratyuk, 1986; Hoffman et al., 2009; Cam et al., 2022). The study of the teratological variability of plants is interesting from a theoretical and practical point of view, in particular for learning morphogenesis, phylogeny of species and larger taxonomic units (Fedorov, 1958a; Meeuse, 1986; Meyerowitz et al., 1989). Books (Wordsell, 1915–1916; Tutayuk, 1969; Gluhov et al., 2005) as well as scientific articles are devoted to teratological changes in plants (Ortiz-Hernández et al., 2012; Ivashchenko, 2014; Srivastava et al., 2016).

The morphological features of the flower and their changes directly affect the success of pollination, fertilization of plants and adaptation of the flower to a certain method and mechanism of pollination. Flower development usually results from the controlled division of the floral meristem, followed by its differentiation and organization. The type and number of cell divisions for a particular species determine the number, shape and

orientation of the flower and its parts. According to Meyerowitz et al. (1998), the pattern of cell division and their number are strictly controlled by genes and any changes in expression or mutations in these genes can lead to flower abnormalities.

The classical foliar theory says that the flower is a shortened vegetative shoot, and all parts of the flower developed from the fertile leaf. The following studies on the theory of the origin of the flower indicate that the main reproductive parts of the flower (stamens and carpels) come from the sporogenous organs of the ancestors of flowering plants, and the corolla was formed at the early stages of the ontogenetic development of sterile stamens, which, growing wide, acquire a petal-like shape (Takh-tadzhyan, 1982). The transformation of stamens into petals is a characteristic of many decorative plants with double flowers. Atypical flowers, which are characterized by excessive development of petals or their unusual shape, are important in selection for creating cultivars, because they are considered more attractive in gardens than their usual counterparts (Rubtsova et al., 2023). Of special interest are the changes that occur in plants that are taxonomically or morphologically related.

The genera *Colchicum* L. and *Crocus* L. include perennial herbs, geophemmeroids with a shortened underground stem thickened at the base into a corm. The flowers of representatives of the genera *Colchicum* and *Crocus* appear almost simultaneously with the leaves in winter-spring, or the flowers appear in late summer or autumn, and the leaves and fruits appear in the spring of the following year. The gynoecium is three-membered. The pistil is syncarpous. Ovary – superior, three-carpellate, three-locular, belowground. The perianth is simple, corolla-like, mostly sympetalous, with six perianth segments joined for the majority of their length at the base of the flower into a long tube that surrounds the ovary. In some members of the genus *Colchicum*, the petals of the corolla can be separate,

or apopetalous. In typical *Colchicum* flowers perianth segments or petals – 6 (3 outer and 3 inner), 6 stamens, are attached to the base of perianth segments in two rows, of which three inner ones are longer. The anthers are linear or oblong, attached to a thread near the base or in the middle (oscillating). The stamen filaments are thin, slightly thickened at the base. Nectaries in *Colchicum* are staminal, located at the base of the stamen filaments, orange or yellow, secrete nectar into the groove of the corresponding perianth segment (Sterling, 1973; Oganezova, 2016; Odemir et al., 2011). The flowers are single or collected in an umbel-like inflorescence or a dense raceme (Persson, 1993) in the upper part of an annual shoot, have a small bract and sit on a short peduncle, mostly 1–8, different in size and color. In *Colchicum*, they are purple, pink, lilac, white or yellow, often with a pleasant aroma.

In *Crocus*, the range of corolla colors is wider: from blue and purple-pink to yellow and white. *Crocus* flowers also have 3 outer and 3 inner circles of perianth segments and a long tube, which in some species differ not only in shape but also in color. Anthers are yellow, orange or white, linear with an arrow-shaped base, not oscillating, mostly extrorse (in *C. banaticus* – introrse, nectaries are septal). Three stamens are attached at the base of the outer perianth segments or petals. Many *Crocus* species are

highly prized as garden plants for their colorful flowers, horticultural varieties, for industrial applications and as unique collector's items (Ruksans, 2010; Siracusa et al., 2022).

Colchicum flowers are often protogynous (stigmas ripen earlier than anthers), partial dichogamy, homogamy or proterandry is observed, and heterostyly occurs (Felbaba-Klushyna, 2001). In autumn-flowering species, pollination and fertilization occur in the fall (Jung et al., 2011). These plants are known for their decorative properties and are quite popular for decoration of gardens in spring and autumn. Plants belonging to the Colchicaceae family have been used as ornamental plants in parks and gardens due to their medicinal (they contain, in particular, colchicine) and aromatic properties as well as their elegant and beautiful appearance (Metin et al., 2014; Ozcakir, 2021). Among the cultivars of *Colchicum*, there are well-known ones with double flowers: the varieties of *C. autumnale* 'Flore pleno', 'Pleniflorum' or 'Roseum plenum' – with purple-pink, 'Alboplenum' or 'Album plenum' – with white, and the 'Waterlily' – with purple-pink flowers (Fig. 1). The presence of stable double flowers plants in *Colchicum* indicates the possibility of genetic changes in individuals and the occurrence of a persistent mutation (Gnatiuk, 2023). Double flowers varieties are not known in *Crocus*.



Fig. 1. *Colchicum autumnale* 'Flore pleno' (a) and *Colchicum* 'Waterlily' (b) in collection of the M. M. Gryshko National Botanical Garden of the National Academy of Sciences of Ukraine

All species of *Colchicum* and *Crocus* genera of the natural flora of Ukraine are protected and listed to the Red Book of Ukraine (Didukh, 2009). Plants of the *Colchicum* and *Crocus* genera have useful properties (Boyko et al., 2020; Pourbagher-Shahri & Forouzanfar, 2023; Sevindik et al., 2023), are well introduced and have good prospects for introduction into mass culture (Mykhailenko, 2019; Kaysarov & Akhmedov, 2021; Babaie et al., 2023; Zahorodnia et al., 2023). Representatives of the genera *Colchicum* and *Crocus* are in the collections of many botanical institutions of Ukraine and the world, in particular in the M. M. Gryshko National Botanical Garden of the National Academy of Sciences of Ukraine in Kyiv (Lebeda et al., 2011). Protection of natural flora species ex situ by introducing them to botanical gardens for the purpose of reproduction and repatriation is an additional method of plant conservation (Gaponenko, 2001). The purpose of this work was to find out and analyze the anomalies of flowers of various representatives of the genera *Colchicum* and *Crocus* in the conditions of the M. M. Gryshko National Botanical Garden of the National Academy of Sciences of Ukraine.

Material and methods

The plants used in the research were grown in culture and were not collected from natural habitats. All requirements of the Law of Ukraine on the Red Book of Ukraine (<https://zakon.rada.gov.ua/laws/show/3055-14#Text>) were met. The study did not involve damaging or harvesting the plants. No approval is required for this study.

The research was conducted in the M. M. Gryshko National Botanical Garden of the National Academy of Sciences of Ukraine (NBG). NBG is located in the Pechersk District of Kyiv in South-Eastern part of city. Kyiv is located on the border of the forest and forest-steppe physio-

graphic zones. The climate is moderately continental, with mild winters and warm summers (Osadchiy et al., 2010). Data of Kyiv wather conditions, daytime and night air temperatures in 2019–2022 are given by internet resource Meteopost (2024) <https://meteopost.com>. Observations were carried out from 2019–2022 on representatives of genera available in the collection (Table 1).

In the Department of Natural Flora of the NBG representatives of the genera *Colchicum* and *Crocus* have been grown since the second half of the 20th century mainly on the collection site "Rare plants of the flora of Ukraine"; some taxa are represented on botanical and geographical areas "Steppes of Ukraine", "Ukrainian Carpathians", "Crimea" and "Caucasus", which represent the vegetation of different regions of Eurasia. Thus, the NBG has had a sufficient opportunity to simultaneously observe the flowers of various representatives of the genera *Colchicum* and *Crocus* for a long time. Plant species names are presented according to the POWO (2024) <https://powo.science.kew.org/database>.

The study of flowers was carried out using the methods of comparative morphology and photofixation. The data of phenological observations contain the dates of the beginning and end of flowering of all studied taxa. The place of abnormal flowers with number of floral parts in the field was marked to recognise the next year abnormal situation of flowers. The floral formulae were used for representing the structure of flowers. The following notations are used in the formulas: \square – polysymmetry flower (actinomorphic); σ – male (staminate); $\sigma\text{♀}$ – hermaphrodite (bisexual) flower; P – sympetalous simple perianth; A – stamens (androecium); G – carpels (gynoecium); 0–9 – the number of flower members; + – placement of homogeneous members of the flower, marked by numbers, in two circles; () – members of the flower that have grown together; [] – P and A have grown together. We used tools of correlation analysis to inves-

tigate connections between different parts of abnormal flowers to reflect their relations. As the correlation measure, we used Pearson's correlation test. Results (correlation coefficients – R) were interpreted using the Chaddock scale: 0.00–0.30 negligible correlation; 0.30–0.50 weak correlation; 0.50–0.70 moderate correlation; 0.70–0.90 strong correlation; 0.90–1.00 very strong correlation. The percentage difference (PD) between the

normal and abnormal number of flower parts in Figure 9–10 was calculated by the formula: $PD = 100 - y \times 100 / x$, where x – normal number of flower parts, y – abnormal number of flower parts. Negative percentage difference values show that the normal number of flower parts is less than the abnormal number.

Table 1

The representatives of genera *Colchicum* and *Crocus* involved in the study

No.	Taxon	Native range	Flowering period	Number of individuals ¹
I				
Genus <i>Colchicum</i>				
1	* <i>C. autumnale</i> L.	Europe	autumn	100
2	* <i>C. bulbocodium</i> Ker Gawl.	Europe from the Pyrenees to the Caucasus	spring	20
3	<i>C. cilicicum</i> (Boiss.) Damme	S. Turkey to NW. Syria	autumn	20
4	<i>C. hungaricum</i> Janka	Central Europe (Hungary), Balkan Peninsula	spring	10
5	<i>C. kesselringii</i> Regel	Central Asia, North Afghanistan and Pakistan	spring	10
6	<i>C. luteum</i> Baker.	Central and S. Asia, Afghanistan, Pakistan, W. Himalayas, Tibet.	spring	10
7	<i>C. soboliferum</i> (C.A.Mey.) Stef.	Turkey, Syria, Iran, Afghanistan, Balkan Peninsula	spring	15
8	<i>C. speciosum</i> Steven	N. Turkey, Caucasus, N. Iran	autumn	50
9	<i>C. trigynum</i> (Steven ex Adam) Steam.	Turkey, Iran, Caucasus	spring	15
10	* <i>C. triphyllum</i> Kunze	Medit. incl. S. Ukraine, Crimea to NW. Iran	spring	20
11	* <i>C. umbrosum</i> Steven	Crimea, N. Turkey to Caucasus	autumn	15
II				
Genus <i>Crocus</i>				
1	* <i>C. angustifolius</i> Weston	Balkan Peninsula (Greece), Asia Minor, Crimea, S. Ukraine	spring	100
2	* <i>C. banaticus</i> J. Gay	Carpathians (Romania, NE Serbia), Transcarpathia	autumn	20
3	* <i>C. heuffelianus</i> Herb.	SE. Alps, E. Hungary to Carpathians, Transcarpathia	spring	50
4	* <i>C. reticulatus</i> Steven ex Adams	CS. Europe, N. Caucasus, Crimea; CS. Turkey, SW. Asia	spring	100
5	* <i>C. speciosus</i> M. Bieb.	SW Asia (S-E Turkey, Mon Iran), Caucasus, Crimea	autumn	100
6	<i>C. tommasinianus</i> Herb.	Central and E. Balkan Peninsula	spring	20
7	<i>C. veluchensis</i> Herb.	S. Balkan Peninsula	spring	10

Note: 1 – the number of generative individuals studied each year; * - species listed in to the Red Book of Ukraine (2009); # – species listed in to the IUSN Red List of Threatened Species.

Results

The occurrence of phenological phases in plants is closely related to the temperature indicators. The development of the studied plants in the years of observation in Kyiv usually began at the end of February and in March. Among the studied species, the earliest onset of vegetation occurs in *Colchicum triphyllum*. In a few days, due to the trend of a steady increase in temperature, other representatives of the genera *Colchicum* and *Crocus* with spring flowering begin their vegetation, and later flowering.

In 2019, the average air temperature during the calendar spring was +10.9 °C, which is slightly higher than the climatic norm. During the flowering period of the studied plants, the temperature difference was more than 26 units: from –6.3 °C (March 3) to +20 °C (April 30, Fig. 2). The amount of precipitation this year was significant and amounted to 161 mm in the spring. The meteorological spring of 2020 came to Kyiv in February. After a long period of positive temperatures, and its increase to +10 °C caused flowering in *Colchicum triphyllum*. The difference between the day and night temperatures during the flowering period was 15 units: from –7 at the beginning to +18 °C at the end of flowering period.

The spring of 2021 turned out to be colder than the previous one. The average air temperature for the season was +8.4 °C. The coldest temperatures were recorded on March 10 and 11, when the minimum temperature dropped to –8.5 °C, and the warmest was on April 1, when the maximum temperature rose to +20.1 °C. The difference between day and night temperatures during the flowering period reached 28.6 units. The amount of precipitation in the spring was 136 mm. The average air temperature during the calendar spring in 2022 was +8.4 °C, the same as the previous year. The coldest was March 11, when in the morning the minimum temperature dropped to –8.6 °C, the maximum temperature during the flowering period of plants reached 20 °C in April. The temperature difference during the flowering period was 28.6 units. The amount of precipitation in the spring was small and amounted to 87 mm (Fig. 2).

The beginning of the flowering phase of the studied species is associated with a decrease in soil temperature (in autumn or after rains). A temperature drop of 10–15 °C provokes the growth and development of flower buds. Already, in the middle of August, *C. umbrosum* begins to bloom. The main flowering of the studied species occurs in September,

and only in *C. autumnale* are individual flowers observed in October or before frost.

The flowering period of various types and varieties of *Colchicum* and *Crocus* lasts about 1.0–1.5 months. Flowers open under conditions of sufficient lighting: on clear, sunny, warm days. Typical flowers of *Colchicum* and *Crocus* plants are open, actinomorphic, bisexual, and entomophilous. The species of the genera have certain peculiarities in their flower structure. The difference in the structure of gynoecium and androecium is significant. There are 3 stamens in *Colchicum* gynoecium, they are free or fused in the lower part into a style and branch only at the top. Stigmas of rounded (point) or elongated (descending) form are solid. The gynoecium of *Crocus* flowers has a single style divided at the top into 3 parts with a branched stigma, the shape of which is specific to each species. In general, the typical structure of flowers within the modern genus *Colchicum* can be described by the following formulae: ♀ □ [P₍₃₊₃₎, A₃₊₃]G₃, ♀ □ [P₃₊₃, A₃₊₃]G₍₃₎ and ♀ □ [P₃₊₃, A₃₊₃]G₃, which correspond to the genera *Colchicum* L. *sensu stricto*, *Bulbocodium* L. and *Merendera* Ramond. The typical floral formula of *Crocus* is ♀ □ [P₍₃₊₃₎, A₃]G₍₃₎ (Fig. 3).

During the observations, we found unusual flowers in *Colchicum bulbocodium*, *C. luteum*, *C. soboliferum*, *C. hungaricum*, *C. autumnale*, *C. umbrosum*, *C. speciosum*, *C. cilicicum* and in *Crocus angustifolius*, *C. heuffelianus*, *C. speciosus*, *C. tommasinianus*, *C. veluchensis* (Fig. 4–6). An increase or decrease in the number of perianth segments (petals), stamens, and stamens (stigmas) was mainly observed.

In *Colchicum*, the reduction of perianth segments to 3, 4 or 5 occurred in some cases due to their growth, and the increase to 7, 8 or 9 – due to splitting, full or partial petalization of stamens, or by fusion of flower buds (Fig. 4–8). The number of stamens varied from 3 to 8, and the number of stamens in the gynoecium from 0 to 4 (Table 2). In *C. bulbocodium*, an interesting specimen with double stamens, which arose as a result of paired growth of petals, was found (Fig. 6.2). Cuts were observed on the perianth segments of the corolla (Fig. 5; Fig. 8.8), but they were caused by external damage to the buds during emergence above the soil surface. In some specimens of *C. autumnale* and *C. speciosum*, flowers with floral virecence (with green stripes on the corolla) were found (Fig. 9). The number of stamens varied from 3 to 8, and stamens from 0 to 4. Sixteen types of abnormal flower combinations were identified (Fig. 10) in representatives of the genus *Colchicum*.

In representatives of the *Crocus* genus, we also observed an increase (up to 7–9) and a decrease (up to 5–3) in the number of perianth segments. The number of stamens and stigmas increased to 4 or decreased to 2 (Table 2). Most often, a decrease in the number of flower parts (3–4 perianth segments, 2 stamens) is observed in young generative individuals that bloomed for the first time. An increase in the number of flower parts was characteristic of adult generative plants.

In the conditions of Kyiv, we found 10 abnormal flowers types of combinations in representatives of the genus *Crocus* (Fig. 11).

A comparative analysis of the normal and abnormal number of flower organs of representatives of the genus *Colchicum* revealed that the widest range of percentage difference is characterized by styloids of the gynoecium: from negative values (when the normal number of styloids is –33.3% less than the abnormal number) to the complete absence of styloids and the formation of male (staminate) flowers (when the normal number of styloids is 100% greater than the abnormal number, Fig. 12), this was found in *Colchicum autumnale*, *C. cilicicum*, *C. hungaricum*, *C. soliferum* (Fig. 12). For the corolla, the percentage difference is in the range from –50.0% (the normal number of perianth segments or petals is less than the abnormal) to 33.3% (the normal number of perianth segments or petals is greater than the abnormal, Fig. 12). For the androecium, the per-

centage difference is in the range of –33.3% (normal number of stamens is less than abnormal) to 50.0% (normal number of stamens is greater than abnormal, Fig. 12). For representatives of the genus *Crocus*, the widest range of percentage difference is characterized by perianth segments: from –50.0% to 50.0% (Fig. 13). For the androecium and gynoecium, the percentage difference ranges from –33.3% (the normal number of stamens and styloids is less than the abnormal number) to 33.3% (the normal number of stamens and styloids is greater than the abnormal number, Fig. 13). Anomalies of the gynoecium in representatives of the genus *Crocus* were observed less often (4 anomalies, Fig. 13) than in representatives of the genus *Colchicum* (18 anomalies, Fig. 12).

Correlation analysis shows positive connections between number of different parts in abnormal flowers. Connections between number of perianth segments / stamens of androecium, stamens / styloids and perianth segments and styloids of gynoecium in *Colchicum* flowers turned out to be negligible ($R(PA) = 0.15$; $R(AG) = 0.19$; $R(PG) = 0.24$). Connections between number of perianth segments / styloids and stamens of androecium / styloids show moderate correlation ($R(PG) = 0.54$; $R(AG) = 0.64$) in *Crocus* flowers. Strong correlation ($R(PA) = 0.81$) has been found between number of perianth segments / stamens of androecium in abnormal *Crocus* flowers.

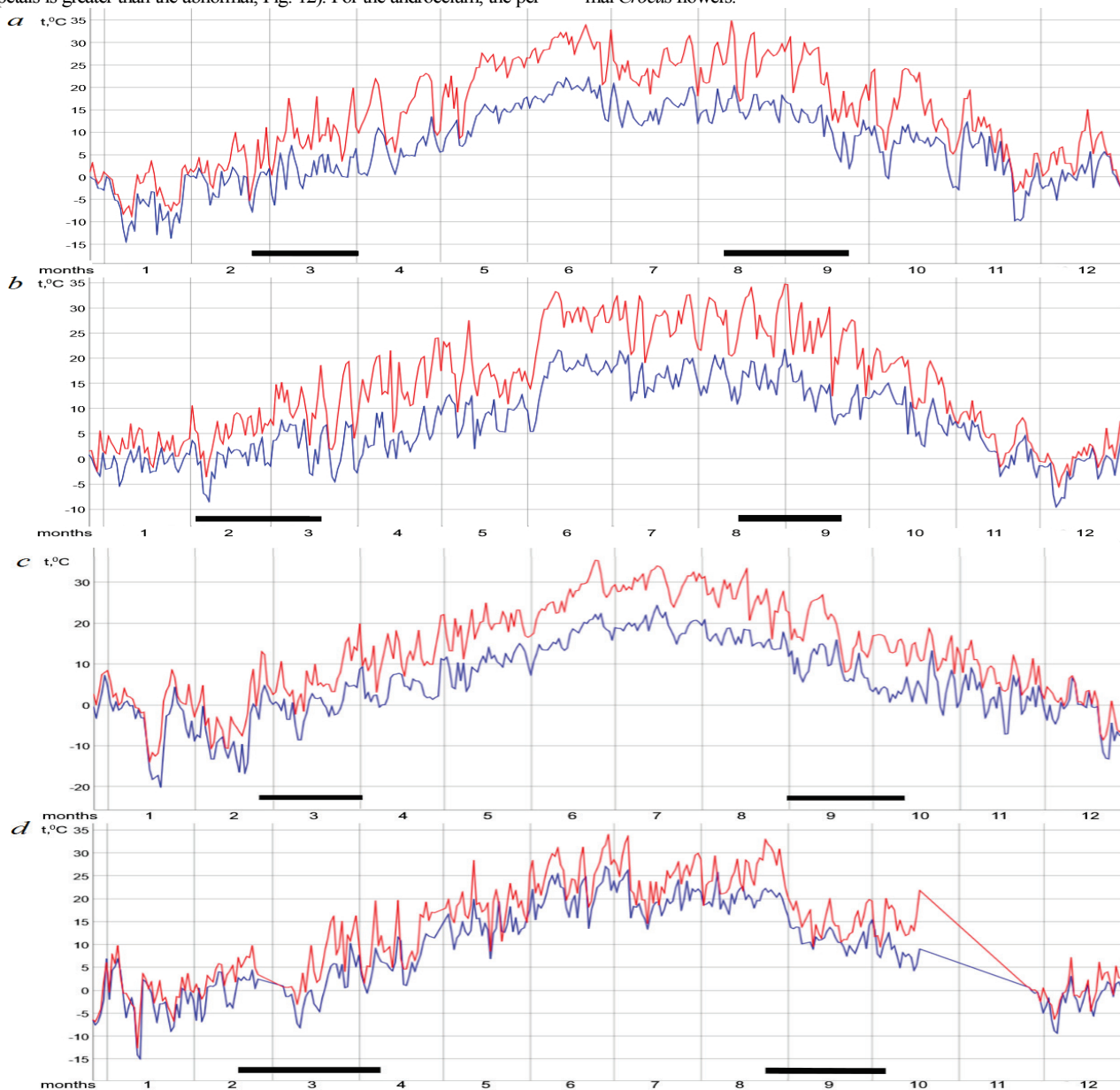


Fig. 2. Dynamics of daytime (red line) and night (blue line) air temperatures in years of research (a – 2019, b – 2020, c – 2021, d – 2022) and the flowering time of *Colchicum* and *Crocus* species (shows black horizontal lines) in Kyiv: data air temperatures given by internet resource Meteopost (<https://meteopost.com>)

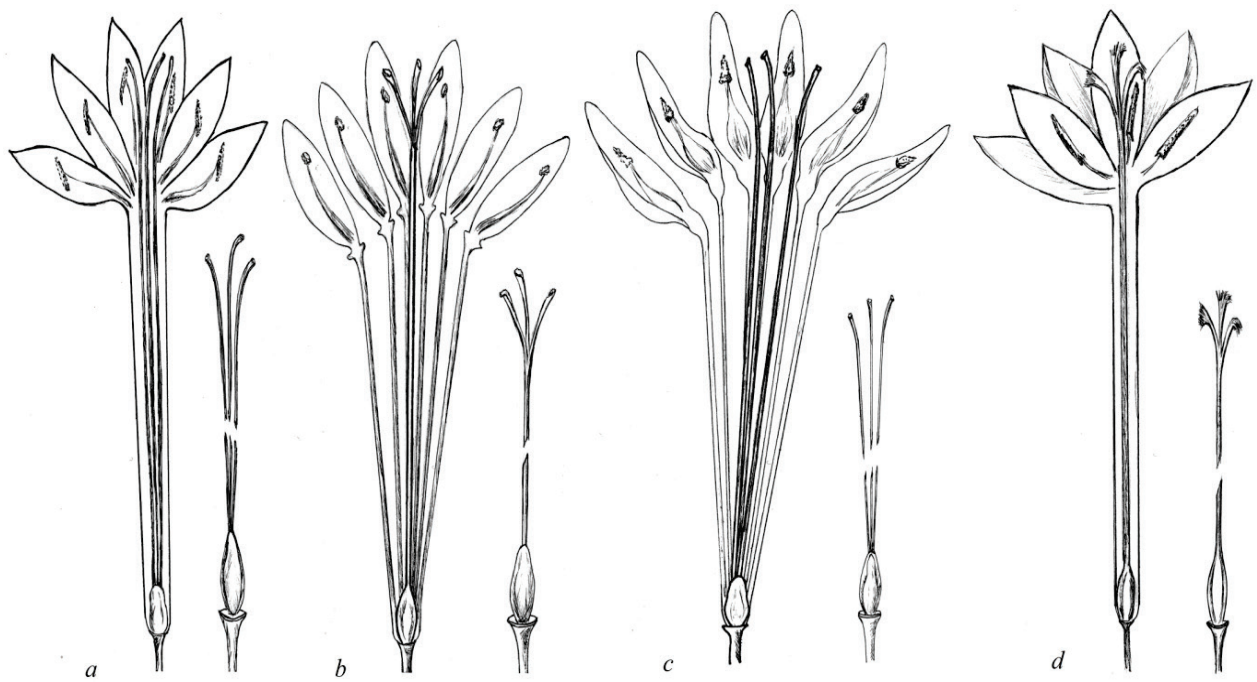


Fig. 3. Normal flowers of *Colchicum* s.l. (a – *Colchicum* s.s., b – *Bulbocodium*, c – *Merendera*) and *Crocus* L. (d)

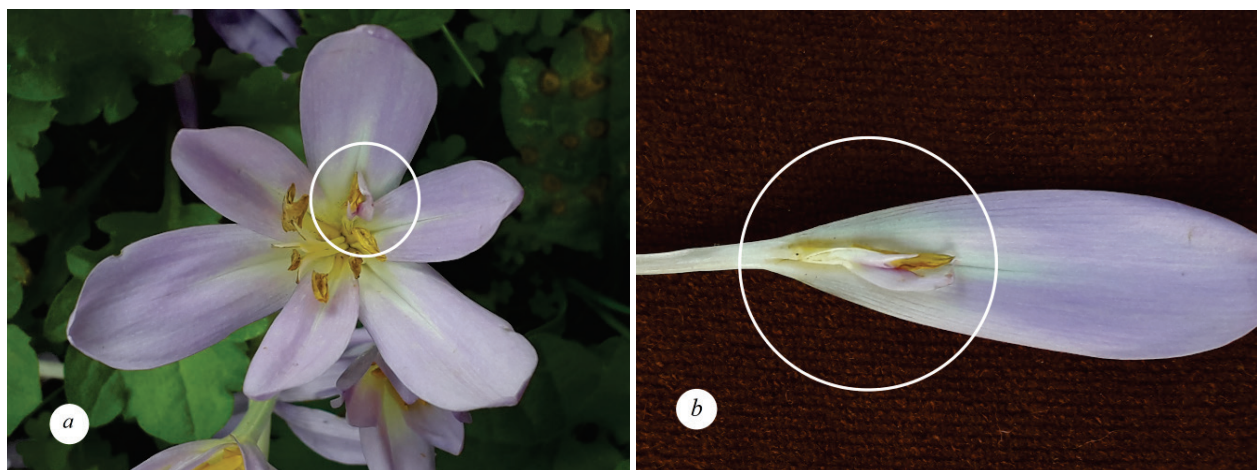


Fig. 4. Petalody (the metamorphosis one of stamen into petal) in the *Colchicum autumnale* flower (a, b)



Fig. 5. Cuts on perianth segments of corolla in *Crocus speciosus* (a) and *Crocus angustifolius* (b) flowers

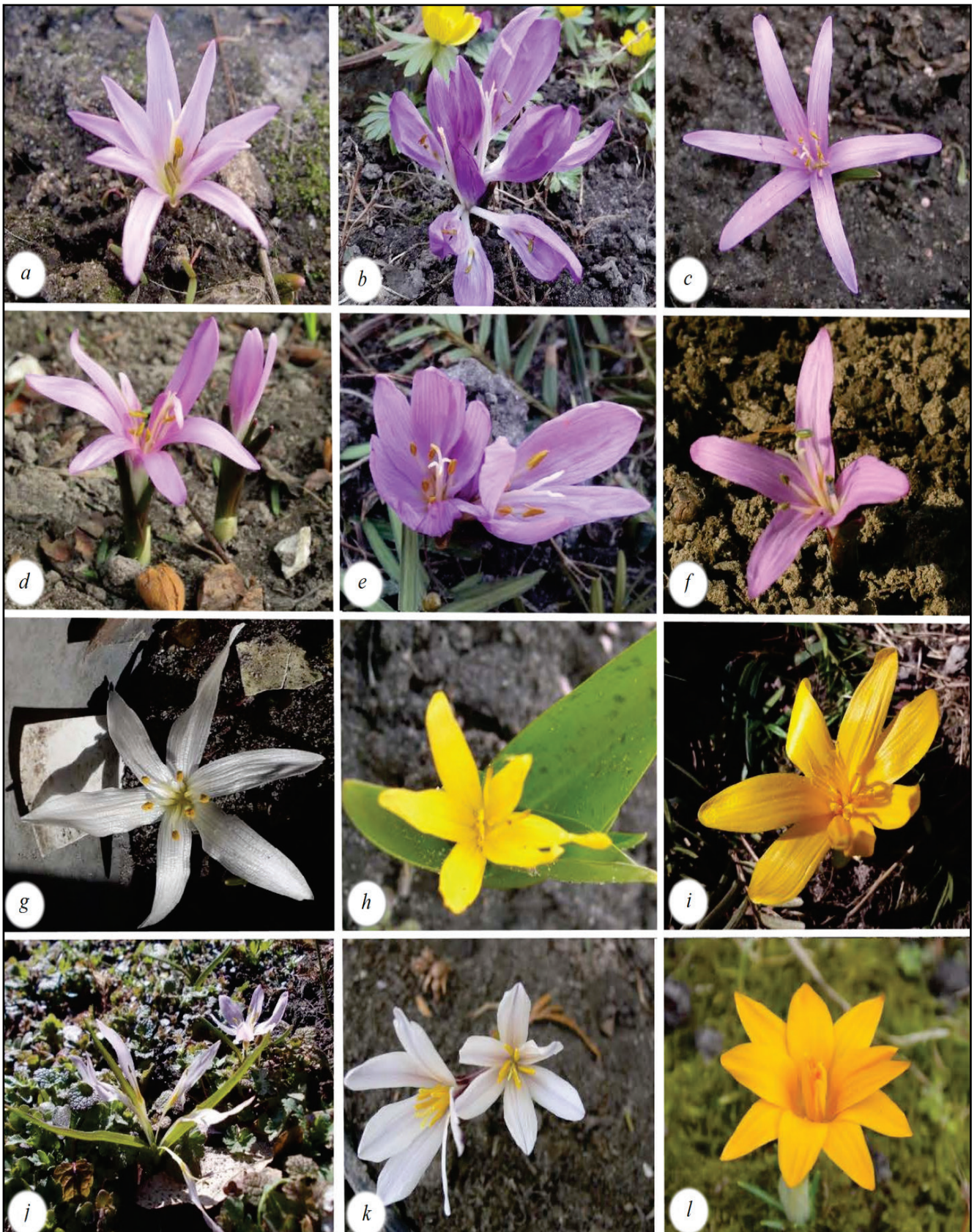


Fig. 6. Floral abnormality in spring-flowering plants of *Colchicum* (a – *C. bulbocodium* \square [P₅₊₄A₃]G₍₃₎; b – *C. bulbocodium* \square [P₄A₈]G₍₄₎, c – *C. bulbocodium* \square [P₃₊₃A₃₊₃]G₍₂₎, d – *C. bulbocodium* \square [P₄₊₄A₃₊₃]G₍₃₎, e – *C. bulbocodium* \square [P₃₊₃A₃₊₃]G₍₄₎ & \square [P₂₊₂A₂₊₂]G₍₂₎, f – *C. bulbocodium* \square [P₍₂₊₂₎A₂₊₂]G₍₃₎; g – *C. hungaricum* \square ♂ [P₍₃₊₃₎A₃₊₃]G₍₀₎, h – *C. luteum* \square [P₍₂₊₃₎A₃₊₂]G₍₂₎, i – *C. luteum* \square [P₄₊₄A₄₊₄]G₍₄₎, j – *C. soboliferum* \square ♂ [P₃₊₃A₃₊₃]G₍₀₎, k – *C. kesselringii* \square [P₍₃₊₃₎A₃₊₃]G₍₂₎) and *Crocus* L. (l – *C. angustifolius* \square [P₍₅₊₄₎A₄]G₍₃₎)

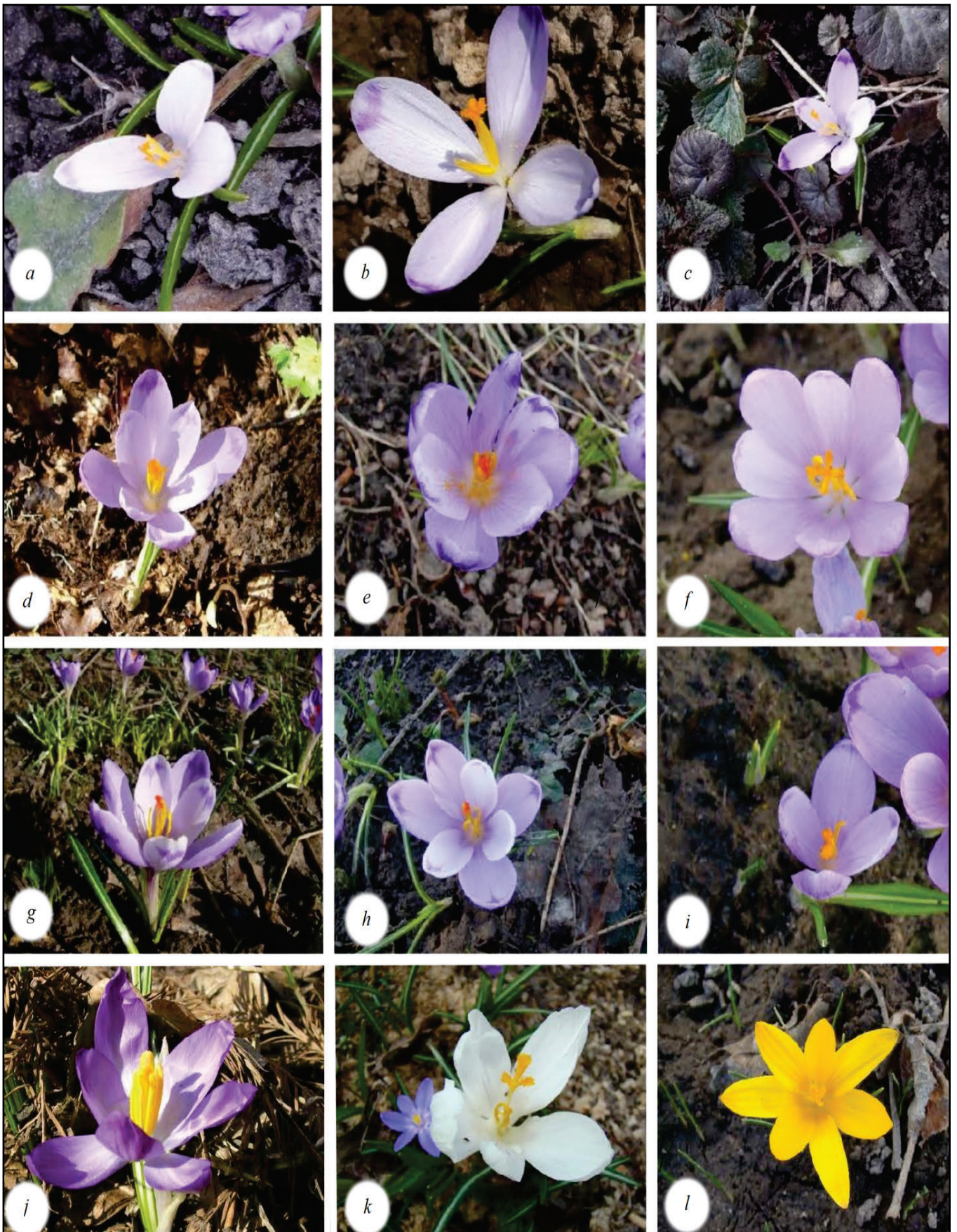


Fig. 7. Floral abnormality in plants of spring-flowering *Crocus*: *C. heuffelianus* Herb.: *a* – □ [P₍₃₎, A₃]G₍₃₎; *b* – □ [P₍₄₎, A₂]G₍₃₎; *c* – □ [P₍₂₊₃₎, A₂]G₍₂₎; *d* – □ [P₍₄₊₄₎, A₄]G₍₃₎; *e* – □ [P₍₇₎, A₃]G₍₃₎; *f* – □ [P₍₄₊₄₎, A₄]G₍₄₎; *g*, *h* – □ [P₍₄₊₃₎, A₄]G₍₃₎; *i* – □ [P₍₂₊₂₎, A₂]G₍₂₎; *j* – *C. tommasianus* □ [P₍₃₊₄₎, A₄]G₍₃₎; *k* – *C. veluchensis* □ [P₍₃₊₂₎, A₂]G₍₃₎; *l* – *C. angustifolius* □ [P₍₄₊₃₎, A₃]G₍₃₎

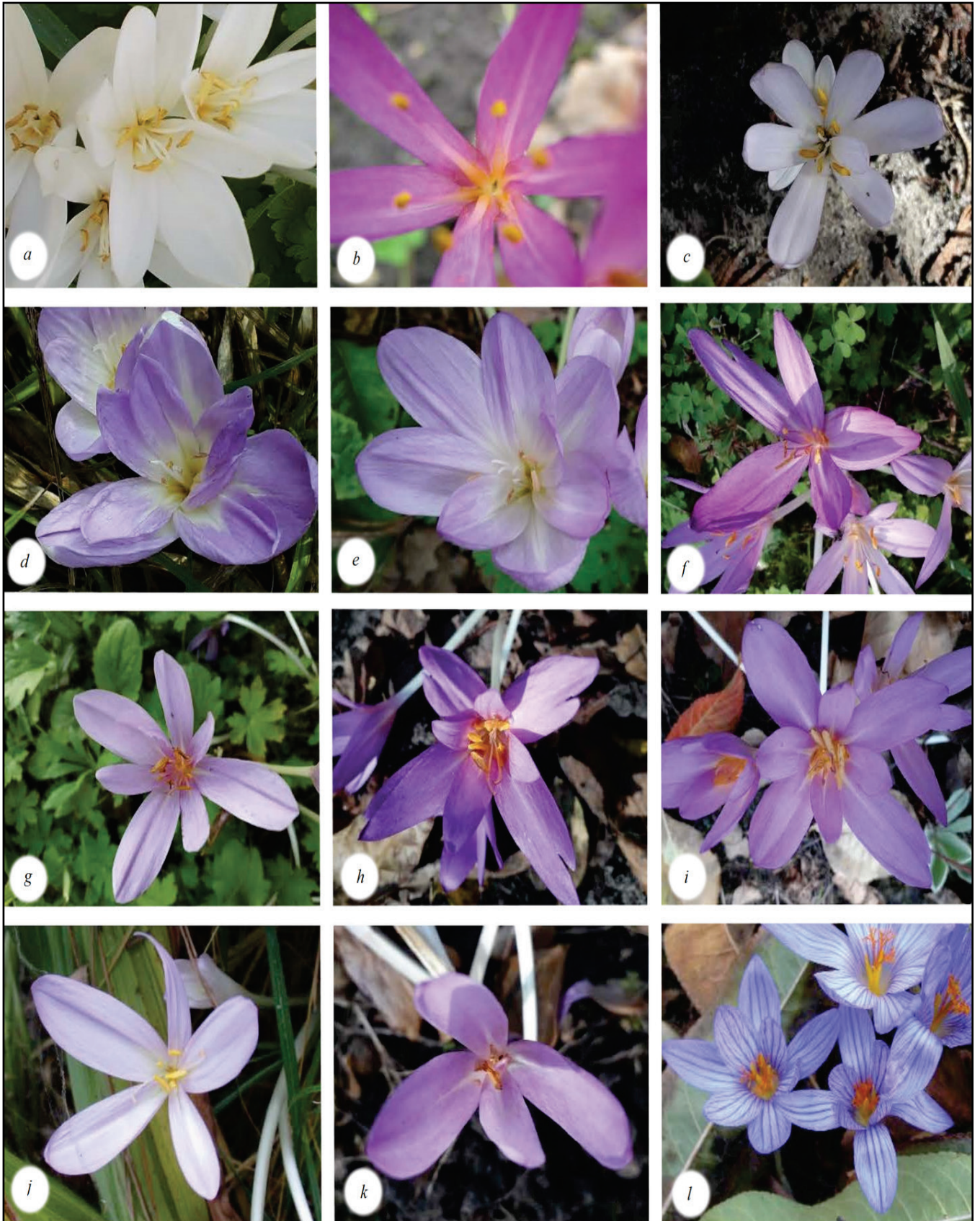


Fig. 8. Floral abnormality in autumn-flowering *Colchicum* and *Crocus*: *a* – *C. autumnale* ‘Album’ $\square [P_{(3+3)}, A_{3+3}]G_4$; *b* – *C. cilicicum* $\square \text{♂} [P_{(3+3)}, A_{3+3}]G_0$; *c* – *C. umbrosum* $\square [P_{(4+3)}, A_{3+2}]G_3$; *d* – *C. speciosum* $\square [P_{(5+4)}, A_4]G_2$; *e* – *C. speciosum* $\square [P_{(4+4)}, A_4]G_4$; *f* – *C. cilicicum* $\square [P_{(3+2)}, A_{3+2}]G_2$; *g* – *C. autumnale* $\square [P_{(4+4)}, A_{4+4}]G_3$; *h* – *C. autumnale* $\square [P_{(4+4)}, A_{4+4}]G_2$; *i* – *C. autumnale* $\square [P_{(4+4)}, A_{4+4}]G_4$; *j* – *C. autumnale* $\square [P_{(3+2)}, A_3]G_1$; *k* – *C. autumnale* $\square [P_{(2+2)}, A_4]G_2$; *l* – *Crocus speciosus* $\square [P_{(4+4)}, A_{2+2}]G_{(4)}$



Fig. 9. Floral virescence in plants of *Colchicum speciosum* (a) and *Colchicum autumnale* (b)

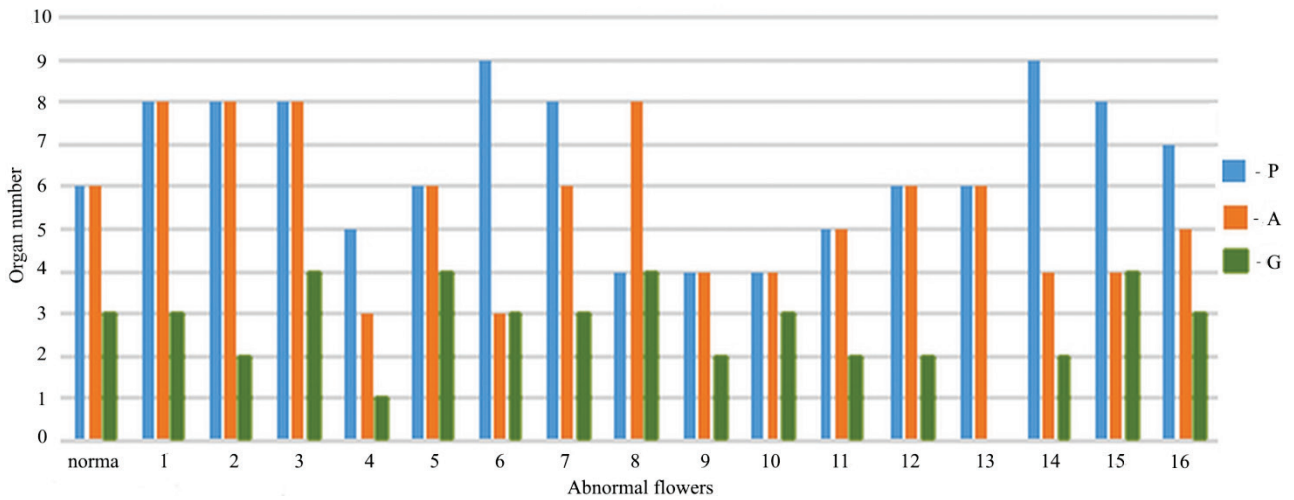


Fig. 10. Diversity of organs number in flowers (*P* – perianth segments or petals; *A* – stamens of androecium; *G* – styloids (stigmas) of gynoecium) in representatives of the genus *Colchicum* in Kyiv

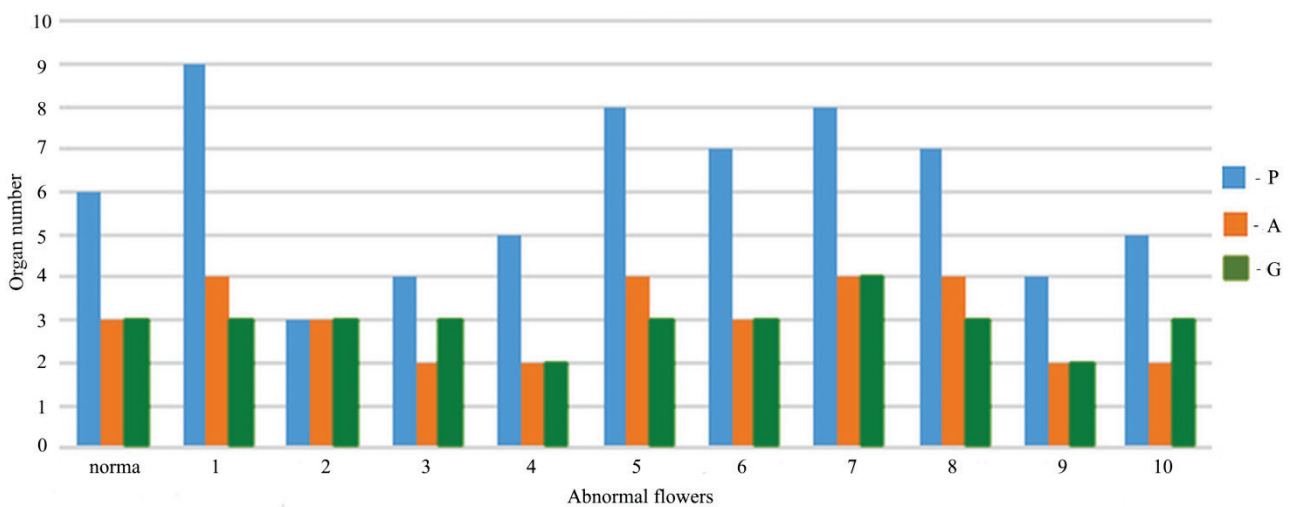


Fig. 11. Diversity of organ number in flowers (*P* – perianth segments; *A* – stamens of androecium; *G* – styloids (stigmas) of gynoecium) in representatives of the genus *Crocus* in Kyiv

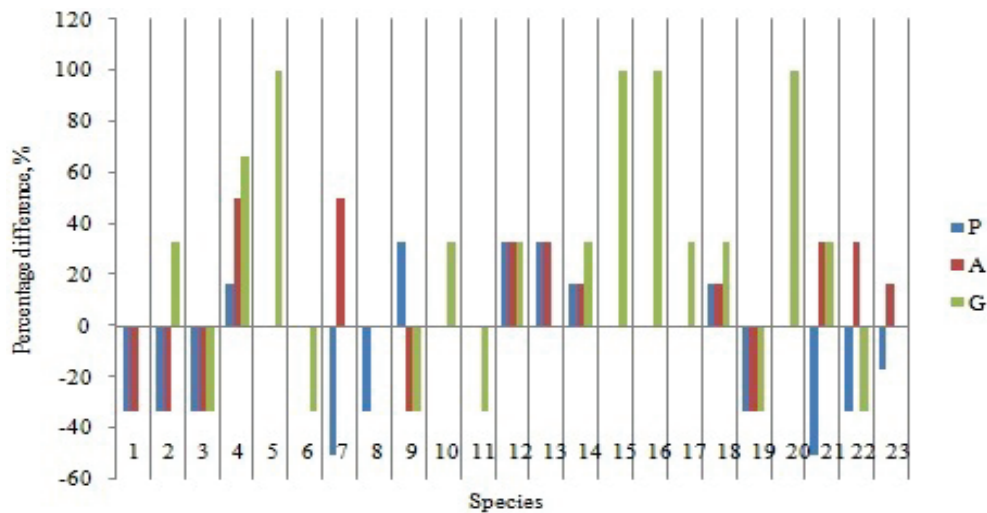


Fig. 12. Percentage difference between normal and abnormal number of *Colchicum* flower organs (*P* – perianth segments; *A* – stamens; *G* – styloids (stigmas) of gynoecium) in representatives of the genus *Colchicum* in NBG: 1–6 – *C. autumnale*, 7–13 – *C. bulbocodium*, 14–15 – *C. cilicicum*, 16 – *C. hungaricum*, 17 – *C. kesselringii*, 18–19 – *C. luteum*, 20 – *C. soboliferum*, 21–22 – *C. speciosum*, 23 – *C. umbrosum*

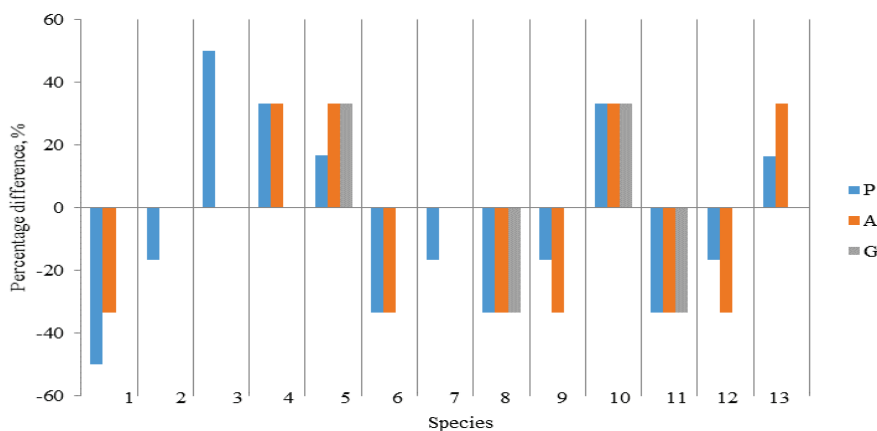


Fig. 13. Percentage difference between normal and abnormal number of *Crocus* flower organs (*P* – perianth segments; *A* – stamens; *G* – styloids (stigmas) of gynoecium) in representatives of the genus *Crocus* in Kyiv: 1–2 – *C. angustifolius*, 3–10 – *C. heuffelianus*, 11 – *C. speciosus*, 12 – *C. tommasianus*, 13 – *C. veluchensis*

Discussion

It is known that frequent teratological changes are characteristic of the *C. autumnale* flower. There is an increase or a decrease in the number of parts of the flower: the splitting of the corolla parts (horiza), the fusion of two flowers (fasciation), as well as the transformation of stamens into petals (petalization). In the Carpathians, according to researchers, there are plants with 4, 5, 7 perianth segments with 2, 4 styloids (Artemchuk, 1960; Felbaba-Klushyna, 2001). During observations in the botanical garden of Syktyvkar University in 2009, T. V. Novakovska also recorded the variability of flowers, which in *Colchicum autumnale* was manifested in the fluctuation of the number of perianth segments (flowers with 7 and 5 perianth segments were recorded), the number of styloids (from 2 to 4), and the number of stamens (5, 4 and 7 stamens were recorded). Plants with 2 styloids and conglutination of stamens were found in *C. speciosum* (Novakovskaya, 2013). We observed similar changes in *Colchicum* flowers an increase and decrease in the number of segments of corolla (or petals) from 4 to 9 due to their fusion or splitting in the conditions of Kyiv.

Atypical flowers are also described for representatives of the genus *Crocus* in the scientific literature. Skvortsova (1970) observed abnormal deviations in *Crocus* flowers, which consisted of changes in the shape and number of perianth elements. She notes that dissection of the corolla occurs most often (in all species, both in nature and in culture). Seven, eight and nine perianth segments were found in *Crocus pallasii* Goldb., *C. heuffelianus*, *C. tauricus* (Trautv.) Puring, *C. reticulatus*. An increase and decrease in the number of stamens, their complete reduction and petalization were also noted. Four stamens were observed in *C. heuffelianus*, *C. pallasii*, *C. reticulatus*; decrease to 2 – in *C. heuffelianus* and *C. tauri-*

cus. During the long-term studies of *C. reticulatus* in NBG (Gritsenko, 2020), no abnormalities in flower development were detected. The greatest increase in flower parts was noted in *C. angustifolius* – 9 perianth segments, 4 stamens (Skvortsova, 1970). In *C. angustifolius* Pupova (1974) noted the presence of flowers with 7 perianth segments in the culture. Konovalova (2001) notes that in particularly favorable conditions, the number of perianth segments increases in some varieties, but this feature is not hereditary and appears only once. Mihaly & Kricsfalusy (1997) conducted studies in nature and also noted the polymorphism of *C. heuffelianus* flowers and described flowers with 9, 8, 7, 5 perianth segments and different numbers of stigmas and stamens. In the flower structure they noted some anomalies, which are described as follows: " $*P_{4+4}A_{4+0}G_{(4)}$, $*P_5A_{3+0}G_{(3)}$, $*P_{2+2}A_{(1+1)}G_{(2)}$, $*P_9A_{3+0}G_{(3)}$ ". They observed cuts occur on the petals (mainly external ones). Kushnir (2010) found a large natural population of *C. heuffelianus* in Borshevik district, Temopil region (Ukraine), in which a significant portion of flowers had 8 perianth segments. It was established that individuals from this population and in culture periodically form 8-segmented flowers.

Ghaffari & Bagheri (2009) on *C. sativus* showed that no change in the chromosome number of the abnormal plants had occurred. Usually, abnormal plants are found in the fields which have received plenty of compost. In the case of the abnormal flowers, the flowering buds merge completely so that the pedicels and floral parts combine with each other. When two or more flowering buds combine, parts of the flowers unite, so that in the resulting flowers the floral parts are not always present in multiples of three. There can be flowers with 4 stigmas, 5 stigmas and 6 stigmas, their occurrence being due to fusion of two flowering buds. This phe-

nomenon is observed more than occurrence of fusing in other stages (fusion of 3 or more bud flowers).

Table 2

Structure of floral anomalies in plants of genera *Colchicum* and *Crocus*

No.	Taxon	Number of floral parts		
		perianth segments (petals)	stamens	styloids of gynoecium (stigmas)
Genus <i>Colchicum</i>				
1	<i>C. autumnale</i>	8	8	3
2	<i>C. autumnale</i>	8	8	2
3	<i>C. autumnale</i>	8	8	4
4	<i>C. autumnale</i>	5	3	1
5	<i>C. autumnale</i>	6	6	0
6	<i>C. autumnale</i>	6	6	4
7	<i>C. bulbocodium</i>	9	3	3
8	<i>C. bulbocodium</i>	8	6	3
9	<i>C. bulbocodium</i>	4	8	4
10	<i>C. bulbocodium</i>	6	6	2
11	<i>C. bulbocodium</i>	6	6	4
12	<i>C. bulbocodium</i>	4	4	2
13	<i>C. bulbocodium</i>	4	4	3
14	<i>C. cilicicum</i>	5	5	2
15	<i>C. cilicicum</i>	6	6	0
16	<i>C. hungaricum</i>	6	6	0
17	<i>C. kesselringii</i>	6	6	2
18	<i>C. luteum</i>	5	5	2
19	<i>C. luteum</i>	8	8	4
20	<i>C. soboliferum</i>	6	6	0
21	<i>C. speciosum</i>	9	4	2
22	<i>C. speciosum</i>	8	4	4
23	<i>C. umbrosum</i>	7	5	3
Genus <i>Crocus</i>				
1	<i>C. angustifolius</i>	9	4	3
2	<i>C. angustifolius</i>	7	3	3
3	<i>C. heuffelianus</i>	3	3	3
4	<i>C. heuffelianus</i>	4	2	3
5	<i>C. heuffelianus</i>	5	2	2
6	<i>C. heuffelianus</i>	8	4	3
7	<i>C. heuffelianus</i>	7	3	3
8	<i>C. heuffelianus</i>	8	4	4
9	<i>C. heuffelianus</i>	7	4	3
10	<i>C. heuffelianus</i>	4	2	2
11	<i>C. speciosus</i>	8	4	4
12	<i>C. tommasianus</i>	7	4	3
13	<i>C. veluchensis</i>	5	2	3

We never observed the full fusion of two *Crocus* flowers buds (complete doubling of flower parts). However, there was no fertilization of plants with humus or mineral fertilizers. The development of abnormal flowers for *C. heuffelianus* can be related to the age of individuals. For other species, no such regularity was found, although we observed "multi-petal" flowers in *C. angustifolius* and *C. speciosus* only in adult generative individuals.

The temperature regime definitely has a certain effect on the rate of cell division in the floral meristem. The period of active growth and formation of *Colchicum* and *Crocus* flowers occurs at the time of temperature fluctuations from significant drops in temperature and frost at night to warm temperatures during the day. This explains the presence of a higher number of atypical flowers at the very beginning and at the end of the flowering period. Atypical flowers occur mainly at the beginning of flowering of "spring" species, but the largest number of them was observed in autumn-flowering species at the end of the flowering period among the last flowers. The appearance of a significant number of flowers, where there is a partial or complete reduction of parts (especially the gynoecium) can theoretically reduce seed production and the intensity of generative reproduction in some unfavorable years. However, in our observations, their number was not significant, and the main amount of abnormal flowers was concentrated in periods of the lowest pollinator activity.

Among the studied taxa of the *Colchicum* genus, the largest number of abnormal flowers was recorded in *C. bulbocodium* and *C. autumnale*. At the same time, no abnormal flowers were detected in *Colchicum triphyllum* and *C. trigynum* during the observations. Among representatives

of the genus *Crocus*, the most anomalies were registered in *Crocus heuffelianus*, and none were found in *C. banaticus* and *C. reticulatus*.

Viruses cause different degrees of floral abnormalities in plants (Malyarenko & Gaydarzhi, 2014). The plants infected by phytoplasma exhibited floral discoloration, virescence, small flowers, and occasionally full floral reversion (Lee, 2011; Su et al., 2011; Madhupriya et al., 2017). Therefore, virus can also be considered as a factor in teratogen formation in the studied plants.

The presence of green *Colchicum* flowers is evidenced by the data of various researchers. Some clones of *C. autumnale* produce virescent flowers and flower both in fall and spring (Harder & Lorenzen, 1965). Green-flowered forms have been described for *C. autumnale* (Ascherson & Graebner, 1896; Wierdak, 1925; Hegi, 1939). Stecki and Biernacki (1961) describe it as a phenomenon – freak of nature and pathological (insects, viruses).

Singular flowers of *Colchicum* with green stripes on the corollas that we discovered were a one-time phenomenon and were not observed in plants in subsequent years. This, obviously, testifies in favor of the viral nature of this phenomenon.

Conclusion

For the genera *Colchicum* and *Crocus*, the appearance of some atypical flowers in inflorescences is characteristic. Anomalies of flowers consist of reduction or increase in the number of their parts. Such anomalies in the structure of the flower most often occur as a violation of the differentiation of cells in the floral meristem due to certain external factors, in particular, the abrupt change of temperature during the formation and growth of the flower. Teratological changes in flowers that occur as temporary developmental abnormalities have no taxonomic or adaptive significance. The appearance of some anomalies, in particular, green pigmentation on flower petals, can be caused by infection with phytoplasma. Other deformations (such as cuts on the perianth) are caused by external injuries to the buds. In general, the introduction of plants outside the natural range did not cause significant persistent changes in the flowers of *Colchicum* and *Crocus*. The anomalies in the development of flowers revealed in the conditions of Kyiv are generally similar to those recorded by other researchers in natural conditions and in culture.

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The authors declare that they have no conflict of interest.

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