*Bulletin of Botanical Gardens, **15**: 79–86, 2006*

FLOWERING PHENOLOGY OF SOME MOUNTAIN PLANTS IN THE COLLECTION OF THE BOTANICAL GARDEN IN LUBLIN

Fenologia kwitnienia niektórych roślin górskich w kolekcji Ogrodu Botanicznego w Lublinie

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STRESZCZENIE

Obserwacje nad fenologią kwitnienia oraz modyfikacją pokroju roślin górskich w warunkach Ogrodu Botanicznego Uniwersytetu Marii Curie-Skłodowskiej w Lublinie prowadzono w 2004 i 2005 roku. Obiektami badań było 17 rodzimych taksonów roślin naczyniowych, w tym 16 zielnych i 1 pnącze o zdrewniałych pędach – *Clematis alpina* (L.) Mill. Jedynie u *Alyssum saxatile* L. i *Sedum acre* L. var. *calcigenum* nie zaobserwowano większych różnic w okresach kwitnienia i pokroju roślin w porównaniu z warunkami naturalnymi. Następujące gatunki zakwitają znacznie wcześniej niż w górach: *Hieracium aurantiacum* L., *Dianthus nitidus* Waldst. & Kit., *D. compactus* Kit., *Centaurea kotschyana* Heuff. ex W.D.J. Koch, *C. alpestris* Hegetschw. & Heer, *Mutellina purpurea* (Poir.) Thell. i *Solidago alpestris* Waldst. & Kit. Znaczne opóźnienie kwitnienia obserwowano u *Erysimum wittmannii* Zaw., *Jovibarba hirta* (L.) Opiz subsp. *glabrescens*, a szczególnie u *Dendranthema zawadzkii* (Herb.) Tzvelev. Powszechne jest skracanie okresu kwitnienia, czasem nawet trzykrotnie, jak w przypadku *Clematis alpina, Erysimum pieninicum* (Zapał.) Pawł., *Aster alpinus* L. czy *Dendranthema zawadzkii*. Natomiast u *Centaurea mollis* Waldst. & Kit. i *Hieracium aurantiacum* w obu sezonach badawczych obserwowano dwukrotne kwitnienie. U większości badanych gatunków rozmiary kwitnących pędów i rozet liściowych są znacznie większe (niekiedy 1,5-2-krotnie).

SUMMARY

The observation of flowering phenology and shape modification in some mountain plants was carried out in the Botanical Garden of the Maria Curie-Skłodowska University in Lublin, in the years 2004–2005. The object of the study were 17 taxa of native vascular flora: 16 taxa of herbaceous plants and 1 creeper with lignifying stem – *Clematis alpina* (L.) Mill. Only in the case of *Alyssum saxatile* L. and *Sedum acre* L. var. *calcigenum* no major difference was found in the flowering and architecture of plants in respect to their natural conditions. The following species flower considerably earlier than in the mountains: *Hieracium aurantiacum* L., *Dianthus nitidus* Waldst. & Kit., *D. compactus* Kit., *Centaurea kotschyana* Heuff. ex W.D.J. Koch, *C. alpestris* Hegetschw. & Heer, *Mutellina purpurea* (Poir.) Thell. and *Solidago alpestris* Waldst. & Kit. On the other hand, a considerably later flowering was observed in *Erysimum wittmannii* Zaw., *Jovibarba hirta* (L.) Opiz subsp. *glabrescens* and especially in *Dendranthema zawadzkii* (Herb.) Tzvelev. A shortening of the flowering period was commonly observed, sometimes it is even three times shorter, as is the case of *Clematis alpina, Erysimum pieninicum* (Zapał.) Pawł., *Aster alpinus* L. or *Dendranthema zawadzkii*. In contrast, during both seasons of study the second flowering of *Centaurea mollis* Waldst. & Kit. and *Hieracium aurantiacum* was observed. For most of the analysed taxa, the size of flowering shoots and leaf rosettes are considerably bigger (sometimes 1.5-2 times).

INTRODUCTION

The Botanical Garden of the Maria Curie-Skłodowska University in Lublin was founded in 1965, in the valley of the Czechówka River (Chmielewski, Sawicki 1989; Łukasiewicz, Puchalski 2002). It comprises a flat inundation terrace with two ponds, a steep loess slope reclining to a valley with several ravines, and a fragment of a rolling loess plateau. The garden occupies 23 ha; the prevailing soils are of loess origin; the slopes are covered with soils lessivés and brown eroded soils and in the depression one may find alluvial soils. The differences of levels exceed 30 m (180-212 m a.s.l.).

The Alpinarium is situated on a high loess slope with the gradient of 5–30° and the relative height up to 25 m, occupying the area of 0.4 ha. It houses a rich floristic collection of mountain plants of Poland and the neighbouring countries. In order to create alkaline substratum, more than 100 ton of limestones was brought here: dolomitic, Jurassic, Cretaceous and Tertiary. The group of limestone rocks was separated from the acidic ones by a clear basalt ridge; beyond the ridge, 20 ton of quartzites and 30 ton of big granite erratic boulders were put. The rocks were brought partly from the Sudety Mts., and partly form different regions of the Lublin and Kielce voyvodships (Chmielewski, Sawicki 1989).

Two elevations with in-built limestone, situated on an escarpment in the eastern part, are used for collecting species coming from the Pieniny Mts. Their flora is represented, among others, by *Dentranthema zawadzkii, Jovibarba hirta* subsp. *glabrescens, Alyssum saxatile, Erysimum pieninicum, E. wittmannii, Sedum acre* var. *calcigenum*. Moving towards the centre of the Alpinarium, the next two elevations, built of limestones, too, are devoted to the collecting of species appearing on limestone rock of the Tatra Mts. We may find here such species as *Clematis alpina* and *Dianthus nitidus*. *Centaurea kotschyana, C. mollis, Solidago alpestris* and *Hieracium aurantiacum* trace their origin to the Bieszczady Mts. (Chmielewski, Sawicki 1989; Franszczak-Być et al. 2000).

STUDY AIM, MATERIALS AND METHODS

The aim of this study is to find answers to the following questions:

1. do mountain plants preserve their morphological and physiological features when moved into lowland conditions?
2. do they modify the shape (architecture) of an individual and its life cycle, especially in the case of its generative phase?

In the Botanical Garden of UMCS, a systematic observation of flowering phenology and shape modification was carried out on 17 taxa of native flora: 16 taxa of herbaceous plants and 1 creeper with lignifying stem. All of them had already exhibited phenological differences in comparison to the natural conditions. 13 of them had been brought to the Garden from their natural sites in the Carpathians (the Pieniny, Tatry and Bieszczady Mountains); 4 had been obtained from other botanical gardens. The study was conducted during two vegetative seasons:

Table 1. Monthly and annual means of air temperature and precipitation in 2004–2005. Data from the Meteorological Observatory of Maria Curie-Skłodowska University in Lublin.
Tabela 1. Średnie miesięczne i roczne wartości temperatury powietrza i opadów atmosferycznych w latach 2004–2005. Dane z Obserwatorium Meteorologicznego Uniwersytetu Marii Curie-Skłodowskiej w Lublinie.

	Mean air temperature (°C)												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
2004	-4.9	-0.3	3.6	9.3	12.6	16.7	19.0	19.4	13.7	10.7	3.6	2.1	8.8
2005	0.6	-3.3	0.4	9.9	14.2	17.2	21.1	18.2	16.1	9.4	3.4	0.1	8.9
	Sum of atmospheric precipitation (mm)												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
2004	27.7	50.9	29.0	50.7	26.8	57.9	102.2	37.2	12.0	24.4	66.6	17.0	502.4
2005	39.0	34.7	39.7	20.9	85.8	41.1	68.6	96.7	19.0	3.1	21.1	55.0	524.7

Table 2. Modifications of size and architecture of flowering mountain plants in the UMCS Botanical Garden in compared to natural conditions. Nomenclature of species according to Mirek et al. (2002).
Tabela 2. Modyfikacje wielkości i architektury kwitnących roślin górskich w Ogrodzie Botanicznym UMCS w Lublinie w porównaniu z warunkami naturalnymi. Nomenklatura gatunków według Mirek i in. (2002).

Species	Natural station		Botanical Garden			
	Height of flowering shoots [cm]	Other features	Height of flowering shoots [cm] 2004	Height of flowering shoots [cm] 2005	Other features 2004	Other features 2005
Clematis alpina (L.) Mill. ■	up to 400	ø fructification >4 cm	over 300	over 300	ø fructification 4 cm	ø fructification 4 cm
Centaurea mollis Waldst. & Kit. ●	40–100		1) 126–140 2) 16–30	1) 57–113 2) 19–36	two flowering periods the second weaker	two flowering periods the second weaker
Erysimum wittmannii Zaw. ❑	15–50		37–51	46–73		
Hieracium aurantiacum L. ●	15–60		1) 13–15 2) 50–70	1) 24–59 2) 43–68	two flowering periods	two flowering periods
Erysimum pieninicum (Zapał.) Pawł. ❑	50–120		114–142	71–118		
Aster alpinus L. ▼	5–15		12–35	25–42		
Dianthus nitidus Waldst. & Kit. ▼	15–30		35–43	22–42		
Centaurea kotschyana Heuff. ex W. D. J. Koch ●	64–80		25–60	55–78		
Centaurea alpestris Hegetschw. & Heer ▼	30–60		52–95	72–83		
Dianthus compactus Kit. ●	20–40	calyx length 14–17 mm, corolla petals length 5–6 mm	40–67	31–44	calyx length 17–20 mm corolla petals length 9–10 mm	calyx length 14–19 cm corolla petals length 8–11 mm
Mutellina purpurea (Poir.) Thell. ▼	15–30	27–45	29–52			
Solidago alpestris Waldst. & Kit. (station I) ●	5–50	48–67	29–67		stem height 34–41 cm inflorescence length 14–26 cm flower capitula bigger	stem height 7–50 cm inflorescence length 13–28 cm flower capitula bigger
Solidago alpestris Waldst. & Kit. (station II) ●	5–50	62–90	39–73		stem height 45–58 cm inflorescence length 17–30 cm flower capitula smaller	stem height 26–35 cm inflorescence length 13–40 cm flower capitula smaller
Jovibarba hirta (L.) Opiz subsp. *glabrescens* ❑	15–30	ø leaf rosettes up to 4 cm	10–21	10–23	ø leaf rosettes 5–10 cm	ø leaf rosettes 5–10 cm
Dendranthema zawadzkii (Herb.) Tzvelev. ❑	25–60	trailing stem slightly erect	48–60	47–63	erect stem lack of fertile fruits	erect stem lack of fertile fruits

Plant origins: ■ – Tatry Mountains; ● – Bieszczady Mountains; ❑ – Pieniny Mountains; ▼ – other botanical gardens

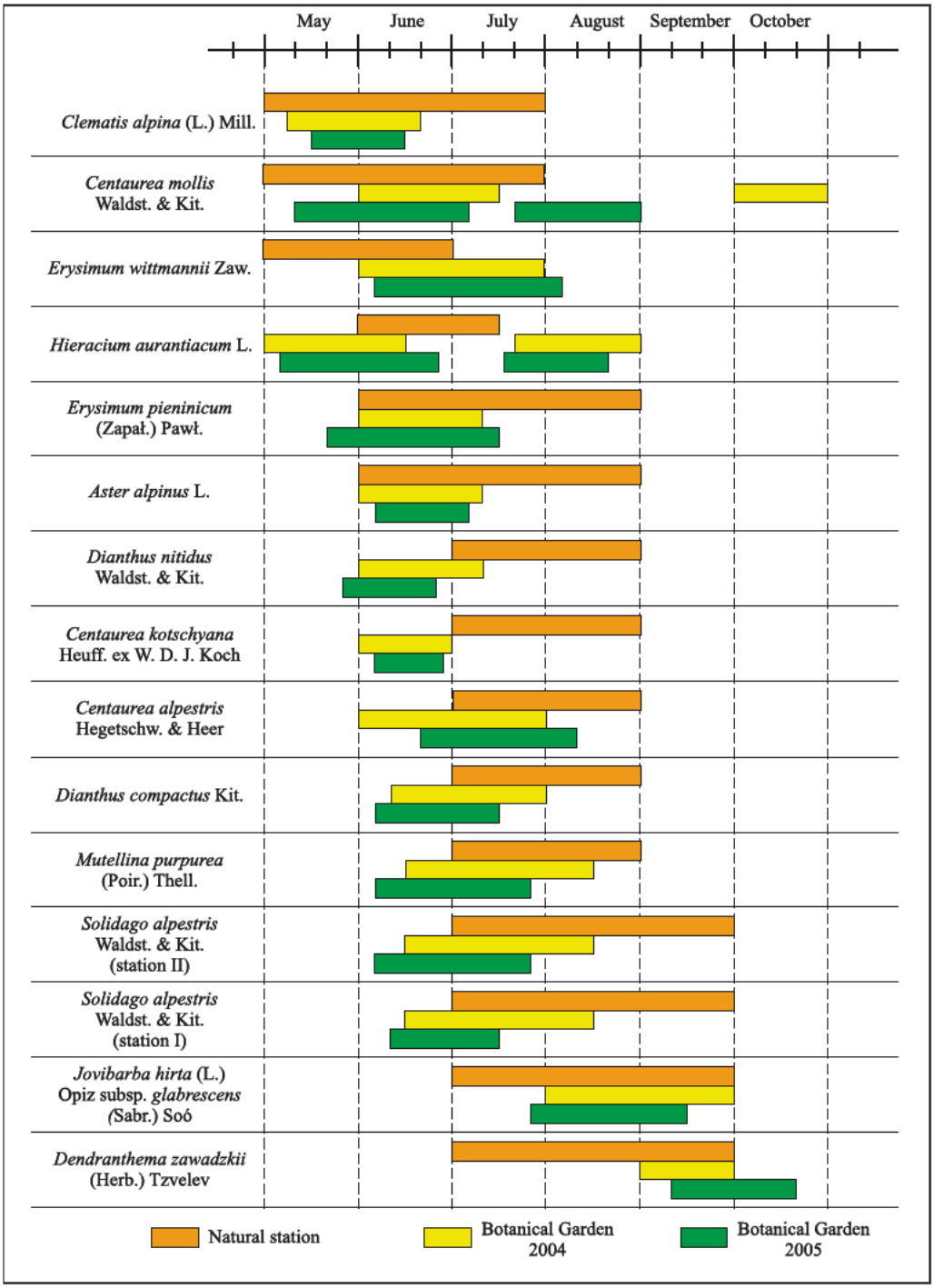

Fig. 1. Flowering calendar of mountain plants in the UMCS Botanical Garden in Lublin. Species are ordered according to term of the beginning of the phase in natural conditions.
Ryc. 1. Kalendarz kwitnienia roślin górskich w kolekcji Ogrodu Botanicznego UMCS w Lublinie. Gatunki uporządkowano zgodnie z terminem początku fazy w warunkach naturalnych.

Fig. 2. *Mutellina purpurea* (POIR.) THELL. (Photo M. Władyka)

Fig. 3. *Erysimum wittmani* ZAW. (Photo M. Władyka)

Fig. 4. *Dendranthema zawadzkii* (HERB.) TZVELEV (Photo M. Franszczak-Być)

Fig. 5. *Clematis alpina* (L.) MILL. (Photo M. Topyło)

Fig. 6. *Erysimum pieninicum* (ZAPAŁ.) PAWŁ. (Photo M. Władyka)

Fig. 7. *Centaurea mollis* WALDST. & KIT. (Photo M. Topyło)

of 2004 and 2005. The course of flowering was confronted with the range of temperatures and precipitation in the successive months (Table 1). Apart from phenological observation, biometrical measurements of plants during the generative phase were taken. Several factors were taken into consideration, among others such as: stem height, length of inflorescence, diameter of leaf rosettes, calyx length, length of corolla petioles, diameter of fructification (Table 2).

The characteristics of species in their natural sites was based on the following sources: Pawłowski (1956), Pałczyński (1962), Tutin et al. (1964–1980), Jasiewicz (1965), Hess et al. (1968), Franszczak-Być, Petrowicz (1984), Szafer et al. (1986), Kaźmierczakowa, Zarzycki, eds. (2001), Zarzycki et al. (2002), Mirek, Piękoś-Mirkowa (2003), Piękoś-Mirkowa, Mirek (2003).

RESULTS

Only in the case of two out of 17 taxa, *Alyssum saxatile* and *Sedum acre* var. *calcigenum*, no major difference was found in the flowering and shape of plants in respect to their natural conditions. In the case of the remaining plants, clearly visible were the changes in the seasons and/or the number of flowering episodes, as well as in the size and shape of flowering shoots (Table 2, Fig. 1).

In the Botanical Garden of UMCS, several species flower considerably earlier than in the mountains; these are: *Hieracium aurantiacum, Dianthus nitidus, Centaurea kotschyana, C. alpestris, Dianthus compactus, Mutellina purpurea* (Fig. 2) and *Solidago alpestris*. Definitely smaller is the group of species flowering considerably later than in natural conditions; these are: *Erysimum wittmannii* (Fig. 3) and *Jovibarba hirta* subsp. *glabrescens* (ca. 1 month later), and especially *Dendranthema zawadzkii* (Fig. 4) – even up to 2 months later. The latter species is the latest flowering mountain perennial; moreover, it does not produce fertile seeds.

A considerable shortening of the flowering period is commonly observed, sometimes it is even three times shorter (one month in comparison to three in natural conditions), as is the case of *Clematis alpina* (Fig. 5), *Erysimum pieninicum* (Fig. 6), *Aster alpinus* or *Dendranthema zawadzkii*. In contrast, during both seasons of study the second flowering of *Centaurea mollis* (Fig. 7) and *Hieracium aurantiacum* was observed (Table 2, Fig. 1). For most of the analysed taxa, the size of flowering shoots and leaf rosettes are considerably bigger (sometimes 1.5-2 times bigger).

DISCUSSION

In the rich collection of the UMCS Botanical Garden, apart from numerous representatives of native flora including rare, protected and endangered species, coming mostly from the sites located in the Lublin Upland and the Roztocze Region (Kwiatkowski et al. 2004), one can find 116 taxa of Poland's mountain flora. They include both common species of wide ecological range such as *Centaurea mollis, Hieracium aurantiacum* or *Solidago alpestris*, and species representing more specific habitats, including such endemic species as *Erysimum pieninicum* and *Jovibarba hirta* subsp. *glabrescens*, both under strict protection. Protected, too, is *Dianthus compactus* and the following three species, included in the Polish Red Data Book (Kaźmierczakowa, Zarzycki, eds. 2001, Piękoś-Mirkowa, Mirek 2003): *D. nitidus* (EX – extinct) *E. pieninicum* (VU – vulnerable) and *C. kotschyana* (LR – low risk).

Lowland alpinaria are subject to different climatic conditions: the amount of precipitation and the air and soil moisture resulting from it are considerably different. These are thermal conditions, however, that depart most radically from those of the mountains, with their considerable differences of temperature between day and night. Long snow coverage shortens vegetative period of plants; therefore, in mountain conditions the prevailing species are persistent: herbaceous perennials and dwarf shrubs (Pawłowski 1956; Mirek, Piękoś-Mirkowa 2003). Strong solar radiation, with ensuring large amount of UV rays coming through the rarified air, condition the meagre size and compact shape of plants. Strong winds additionally result in mechanical damage of unprotected individuals. Mountain conditions, therefore, favour plants of small size and numerous adaptive strategies, mostly miniaturisation and geofitisation (Falińska 2004).

Generally, differences in flowering phenology result from those between the climatic conditions of lowlands and mountains, that is, from

the difference between the optimum altitude of a given taxon and the altitude of the garden. The greater the difference, the bigger the changes in flowering phenology.

The highest peaks of the Tatra Mts. have the annual mean temperature of –4°C (Obrębska-Starklowa et al. 1995). For Zakopane, the long-period average air temperature in the years 1961–1990 was +5.1°C, for Kasprowy Wierch –0.8°C (Kossowska-Cezak 2000). In the same period, the mean precipitation reached the values of 1122 mm and 1801 mm, respectively. The mean annual precipitation for the whole region of the Tatras is 1200–1600 mm, with the maximum reaching up to 2500 mm (Kossowska-Cezak 2000).

In the Bieszczady Mts. the average air temperatures measured at the height of 450 and 470 m a.s.l. range from +7.0 to +7.1 and +6.3°C (Niedźwiedź 1983; Michna, Paczos 1987/1988). The mean annual precipitation is estimated at 1000–1300 mm, ranging from 900 mm in lower parts to 1135 mm in Wetlina, and exceeding 1200 mm in highest parts (Michna, Paczos 1987/1988; Obrębska-Starklowa et al. 1995).

The climate of the Pieniny Mts. is considerably milder in comparison to the neighbouring mountain ranges. More important, however, are the microclimatic differences: at the bottom of the southern slopes, up to the altitude of 520 m a.s.l., the mean annual temperature stretches from +6 to +8°C (moderately warm belt), while at the northern slopes above 521 m a.s.l. up to 1050 m a.s.l. it assumes values between +4 to +6°C (moderately cold belt). The region is characteristic of low precipitation whose annual average ranges from 700 to 900 mm (Obrębska-Starklowa et al. 1995; Perzanowska 2004).

The long-period average (1951–1990) precipitation measured for Lublin was only 550 mm with the mean air temperature +7.4°C (Kaszewski et al. 1995). In the recent seasons the precipitation was even lower with the considerably higher average temperature.

Another reason for the differences in the flowering phenology of mountain plants growing in their natural habitats, and those from the UMCS Botanical Garden, can be attributed to the length of vegetative period, i.e. to the number of days with the air temperature exceeding +5°C. In the Tatra Mts., on average, it lasts 180 days, in the Bieszczady Mts. – 190–200 days, and in the Pieniny Mts. – 180–190 days. In the case of the Lublin Upland it is 200–210 days long (data for the years 1931–1960; Atlas... 1973), or even 210–215 days (the years 1961–1995; Koźmiński, Michalska 2001). Longer vegetative period in the lowlands, together with higher air temperature, usually make plants to flower earlier and for a shorter period of time, sometimes 2- or even 3-times shorter. A reverse tendency, that is, the delaying of the flowering, could be observed in the case of several rock, termophilous, calciphilous plants coming from the Pieniny Mts. (*Erysimum wittmannii, Jovibarba hirta, Dendranthema zawadzkii*, and, to a smaller extent, in the case of *E. pieninicum*). This delay can be explained by the different character of the soil substratum and slope exposition. In the case of *D. zawadzkii* it is probably the delay in flowering that results in the lack of fertile seeds.

The initiation of flowering in the garden can be different than that in the natural conditions, too; in successive seasons this difference could reach even 3 weeks, depending on meteorological conditions. Smaller differences were observed in the length of this phase. Despite the fact, that the vegetative season of 2004 started in Lublin considerably earlier than that of 2005, and in spite of its exceptional length (March 15 – November 13 = 244 days; and April 2 – November 13 = 226 days, respectively), due to lower average air temperatures in spring and at the beginning of summer, earlier flowering was observed only in the case of 5 of the observed species. The greatest differences between the two seasons, as far as the beginning of flowering is concerned, were observed for *Centaurea mollis* and *C. alpestris*; as for the length of the vegetative phase – in the case of *Solidago alpestris, Erysimum pieninicum* and *Clematis alpina*.

Mountain plants growing in the lowlands are also different in size, shape and the proportions between their generative and vegetative parts, favouring the latter; the difference resulting from greater abundance of pollinators in respect to the natural conditions. Moreover, it is caused by different climatic conditions, especially thermal, and some features of the substratum whose specificity cannot be possibly recreated in the lowland conditions. The measures taken by the UMCS Garden, such as seed crops or plant trimming, make some plants repeat the flowering, even up to two months after the 'proper' generative phase is over: this was the case of *Centaurea mollis* in 2004.

It is difficult to unambiguously account for all the reasons for the differences in the flowering phenology and in the morphology of the mountain taxa collected in the UMCS Botanical Garden. It is definitely a combined result of climatic and lithological conditions, as well as little adaptive physiological adjustments produced and preserved by plants over successive years and successive generations.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to professor B.M. Kaszewski from Department of Meteorology and Climatology of the Maria Curie-Skłodowska University for his kind sharing of the meteorological data for the years 2004–2005.

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