FLOWERING AND POLLEN PRODUCTION OF SEVERAL *f.* BRASSICACEAE ORNAMENTALS

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Received 07 May 2008; accepted 23 October 2008

S u m m a r y

Observations of blooming biology and pollen output were carried out in 2002-2004 in Lublin, Poland. Several perennial Brassicaceae ornamentals were chosen: *Arabis caucasica* Wild. ex Schltdl., *Arabis procurrens* Waldst. et Kit, *Aubrieta* x *hybrida* Bergm ('Gloriosa' and 'Blue Emperor'), *Iberis sempervirens* L., *Alyssum saxatile* L. (= *Aurine saxatilis* (L.) Desf.).

Methods accepted in bee botany were applied (Jabłoński and Szklanowska 1997, Warakomska 1972, Szklanowska 1995). The studied ornamentals bloomed between the second decade of April till the first days of June. Most flowers opened in the early morning. By 8:00 (GMT + 2 h) approx. 50% of *Arabis* spp. flowers had bloomed. Over 85% of *Aubrieta x hybrida* flowers had opened before 11:00 h. *Alyssum saxatile, Arabis procurrens* and *Iberis sempervirens* bloomed the most abundantly. Under good weather conditions these three species developed over 60 thousands flowers per 10 m^2. In all the species studied the number of flowers decreased considerably if the average air temperature during winter or early spring dropped significantly. The water content of the anthers depended primarily on the amount of rainfall before and during blooming. *Iberis sempervirens* had 1.16 mg of pollen per 100 anthers. *Aubrieta x hybrida* 'Blue Emperor' produced 6.68 mg of pollen per 100 anthers. Anthers of *Arabis procurrens* and *A. caucasica*, are comparable in size but produced a significantly different percentage of pollen, thus deliver 1.16 mg and 2.97 mg of pollen per 100 anthers, respectively. The average pollen efficiency was from 2.72 g (*Arabis procurrens*) to 8.86 g (*Aubrieta* x *hybrida* 'Blue Emperor') per 10 m^{-2}.

Keywords: flowering, pollen production, Brassicaceae.

INTRODUCTION

Urban honeybee food supplies can be improved through the propagation and growing of different nectariferous and polliniferous species. Small garden plots which have been joined, can grow to cover large areas. This makes them worth considering when planning to improve a generally poor supply of honeybee forage (Lipiński 1982, Jabłoński 2000). Rock gardens have become quite popular. These gardens provide an opportunity to use perennial groundcover ornamentals of the Brassicaceae family. For a long time, such ornamentals have been reported as nectar or pollen-yielding in the beekeeping literature (Rawski 1948, Demianowicz 1953, Gluchov 1958, Howes 1979, Lipiński 1982). Until now the Brassicaceae family has been studied mainly for the blooming, nectar and pollen output of major crops (McGregor 1976, Kołtowski 2002, Masierowska 2003) and of some ruderal taxa (Denisow 2004, 2005).

The need observations of the flowering biology and the evaluation of the pollen efficiency of some frequently planted,

perennial, garden-ornamentals, were the reason for this study.

MATERIAL AND METHODS

The observations and measurements were done in the UMCS Botanical Garden, Lublin, Poland, in the years 2002-2004. The species singled out for the study were *Arabis caucasica* Wild. ex Schltdl., *Arabis procurrens* Waldst. et Kit, *Aubrieta x hybrida* Bergm ('Gloriosa' and 'Blue Emperor'), *Iberis sempervirens* L., and *Alyssum saxatile* L. (syn. *Aurinia saxatilis* (L.) Desf.). The plants grew in different parts of an alpinary situated on a loess-covered, rather steep slope. The alkaline soils contained large amounts of rocks and gravel fractions. The plants were well insolated and formed dense stands. All observations on the flowering biology were done according to the methods of Jabłoński and Szklanowska (1997).

In order to rate the abundance of pollen production, the method of Warakomska (1972) as modified by Szklanowska (1995) was used. Well developed flower buds were collected. The stamen heads were dissected and placed in tarred vessels (n = 100) prepared for this purpose. Measurements were repeated in four replications for each species and cultivar. Stamen heads were assayed for their fresh and dry weight. The mass of dry pollen was established. Pollen was washed out of the anthers with ether and ethyl alcohol. Pollen viability was tested using standard acetocarmine-stained slides.

In 2002, the weather pattern was very advantageous. Spring was early. During the blooming period of the perennials the temperatures were above the norm and rainfall was 40% lower than the long-term average. January and February of 2003 turned out to be very cold. Average temperatures were twice as low as the long-term average. The beginning of 2004 was slightly warmer with the temperatures of February, March and April higher by ca. 2ºC than the long-term average and with intensive rain and snowfalls. Cold spells and deficient rainfall occurred at blooming time.

The results were analyzed statistically using two-way ANOVA. The Duncan's test at a significance level of α=0.05 was used to measure the significance of differences between means.

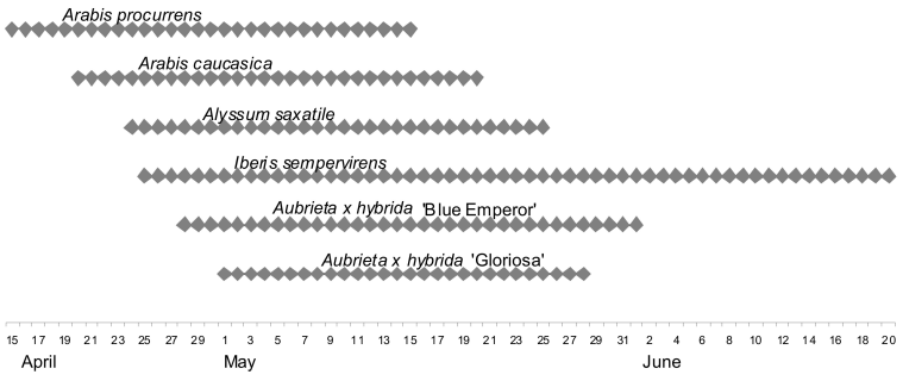

Fig. 1. The time and period of blooming of some ornamentals from Brassicaceae in Lubllin (averages from 2002-2004).

RESULTS

Blooming of the studied species and cultivars took place from the second decade of April to the second decade of June. In all study years the first species to bloom was *Arabis procurrens.* It bloomed in mid-April and it was followed within a few days by *Arabis caucasica* (Fig. 1). *Alyssum saxatile* and *Iberis sempervirens* started to bloom towards the end of the month. During the first couple of days of May the two cultivars of *Aubrieta x hybrida* were in flower. The blooming period of the majority of the perennials lasted about a month. Only *Iberis sempervirens* stayed in bloom for seven to nine weeks.

The flowers of the *Arabis* spp. opened mainly in early morning hours. An average of 50% of the *Arabis* flowers had opened by 8:00 h (Fig. 2). By 17:00 h the remaining flowers opened with an hourly installment of 2 to 8% of the day's total. More than 85% of *Aubrieta x hybrida* flowers had opened by 11:00 h. After 11:00 h the process ceased completely. It recurred after 15:00 h and lasted with little intensity until 17:00 h. In average, in weather conditons the life-span of the flowers was 2.5 days (*Alyssum saxatile*), ca. 4 days (two cultivars of *Aubrieta* x *hybrida* and *Iberis sempervirens*) or 6 day (*Arabis procurrens*). The flowers of *Arabis caucasica* and *A. procurrens* tended to be protogynous. At the bud stage the pistil protruded distinctly above the stamen heads (Fig. 3). It is only when pollen was released that the stamens grew high above the stigma (Fig. 4). This was not the case in the remaining species.

The pollen of all taxa was vivid yellow. The process of pollen release in perfect, six-stamen and tetradynamic flowers lasted for an average of 8-10 hours. The pollen release continued for 2 days when there was a drop in temperature or a rise in air humidity. During dry and sunny weather pollen was released once the corolla lobes expanded. The first to release pollen were always the stamen heads which were attached to long filaments. The pattern of pollen release in the flowers of the *Arabis* spp. was always dependent on the time of flower expansion. In flowers opening in the morning, pollen release proceeded stably throughout the day. A slightly higher intensity occurred during the peak hours of sunshine from 10:00 - 15:00 h. In flowers

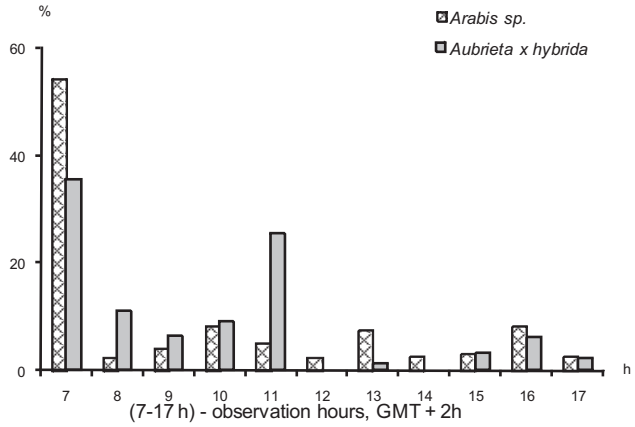

Fig. 2. Diurnal dynamics of blooming *Arabis* sp. and *Aubrieta* x *hybrida* pillars - number of flowers opened in 1-hour intervals shown as %.

expanding in the afternoon the majority of stamens released their pollen the next day. Once the pollen was released the stamen heads withered or dropped off the filaments (*Iberis sempervirens*) – (Fig. 5).

The species differed substantially in corolla colour and size. The corollas of *Aubrieta* x *hybrida* are pink ('Gloriosa') or light violet ('Blue Emperor'). The onset of pollen release is associated with a subtle change in corolla colour and the route to the food is signaled with contrast markers. In flowers void of pollen the lack of pollen is manifested by pigments concentrated in the marginal parts of the corolla and the lessening of pigment at the corolla base. The white flowers of *Arabis caucasica* take on a pink hue as they grow older. In the case of the remaining species the change in the colour of corolla petals is less distinct or does not occur at all (*Alyssum saxatile*).

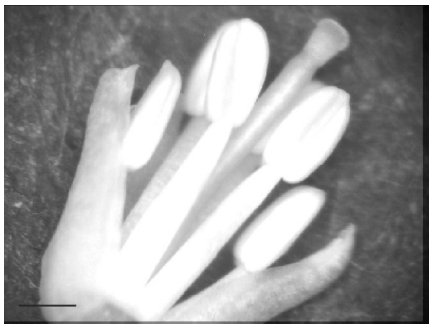

Fig.3. Protogynous flower of *Arabis procurrens* at the bud stage (Bar = 1 mm).

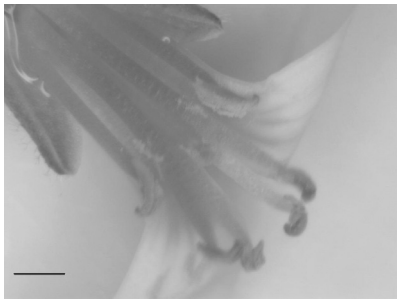

Fig. 4. The process of pollen release in the *Arabis caucasica* flower (Bar = 2 mm).

The abundance of blooming differed from species to species and also from year to year (Fig.6). *Alyssum saxatile, Arabis procurrens* and *Iberis sempervirens* were classified among the most abundantly blooming species. They had an average of more than 60,000 flowers per 10 m^2. In 2003 the winter and early spring temperatures were much lower than the long-term average. All the studied species responded with a significant reduction in the number of developed flowers per unit area.

The stamen heads of the investigated species differed considerably (Table 1). The fresh weight of 100 anthers varied, depending on species, from 6.69 to 28.10 mg. The dry weight of the same number of anthers was accordingly lower and ranged from 3.79 to 14.92 mg. The water content of anthers depends on the pattern of some weather factors, primarily on the amount of rainfall before and during blooming. In 2002, with a particularly dry spring (rainfall lower by 40% than the long-time average) the weight of 100 anthers was the lowest and averaged 18.72 mg. In May of 2003 during the full blooming period, rainfall was comparable to the long-time average and the weight of 100 fresh anthers turned out to be higher than that in the remaining years of study by an average of 8-10% (*Aubrieta* x *hybrida*) and by 40-50% (*Iberis sempervirens*).

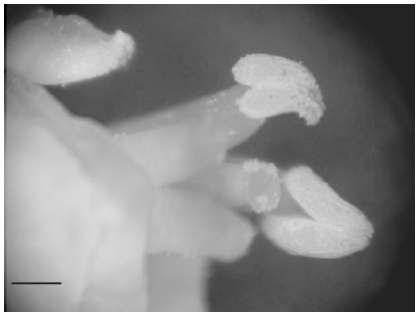

Fig. 5. The process of pollen release in the *Iberis sempervirens* flower (Bar = 1 mm).

Table 1.

The mass of anthers and pollen of ornamentals (f. Brassicaceae) in the years 2002-2004.

Species	Year	Mass of 100 anthers with pollen (mg)		H_2O (%)	Pollen per 100 anthers		Pollen per 100 flowers	Viability %
		Fresh	Dry		mg	%	mg	
Arabis procurrens	2002	21.99 $_a$	11.61 $_a$	47.20	1.0 $_a$	8.61	6.00	91.7 $_a$
	2003	25.33 $_b$	12.12 $_b$	52.15	1.3 $_b$	10.72	7.80	97.6 $_b$
	2004	23.83 $_{ab}$	11.84$_a$	50.31	1.17$_a$	9.88	7.02	87.1 $_a$
	mean	23.72 $_C$	11.86 $_{BC}$	49.89	1.16 $_B$	9.74	6.94	92.13 $_C$
Arabis caucasica	2002	18.82 $_a$	6.56 $_a$	65.14	2.10 $_a$	32.01	12.60	67.3 $_b$
	2003	25.33 $_b$	12.17 $_b$	51.95	4.20 $_b$	34.51	25.20	64.0 $_b$
	2004	24.08 $_b$	7.82 $_a$	67.52	2.62 $_a$	33.5	15.72	53.4 $_a$
	mean	22.74 $_B$	8.86 $_B$	61.54	2.97 $_C$	33.34	17.84	61.57 $_A$
Iberis sempervirens	2002	14.02 $_a$	5.82 $_a$	58.48	0.90 $_a$	15.46	5.40	90.2 $_c$
	2003	21.28 $_b$	6.55 $_b$	69.22	1.51 $_b$	23.05	9.06	86.6 $_b$
	2004	18.92 $_b$	6.56 $_b$	65.33	1.08 $_a$	16.46	6.48	74.3 $_a$
	mean	18.07 $_B$	6.31 $_B$	64.34	1.16 $_B$	18.32	6.98	83.70 $_B$
Aubrieta x *hybrida* 'Gloriosa'	2002	23.03 $_a$	11.03 $_a$	52.11	2.41 $_a$	21.84	14.46	84.1 $_a$
	2003	24.17 $_a$	10.75 $_a$	55.52	3.71 $_b$	34.51	22.26	90.0 $_b$
	2004	22.92 $_a$	11.12 $_a$	51.48	2.82 $_a$	25.36	16.92	90.2 $_b$
	mean	23.37 $_C$	10.97 $_{BC}$	53.04	2.98 $_C$	27.24	17.88	88.10 $_B$
Aubrietax *hybrida* 'Blue Emperor'	2002	27.30 $_a$	14.66 $_a$	46.30	6.54 $_a$	44.61	39.24	76.3 $_b$
	2003	29.50 $_b$	15.00 $_a$	49.15	6.70 $_a$	44.67	40.02	93.0 $_c$
	2004	27.5 $_a$	15.10 $_a$	45.09	6.80 $_a$	45.03	40.80	64.9 $_a$
	mean	28.10 $_D$	14.92 $_C$	46.85	6.68 $_D$	44.77	40.02	78.07$_{AB}$
Alyssum saxatile	2002	7.21 $_b$	3.96 $_a$	45.07	0.87 $_{ab}$	21.96	5.22	91.5 $_b$
	2003	8.13 $_b$	4.31 $_b$	46.99	1.07 $_b$	24.83	6.42	90.0 $_b$
	2004	4.72 $_a$	3.11 $_a$	34.11	0.55 $_a$	17.68	3.30	68.6 $_a$
	mean	6.69 $_A$	3.79 $_A$	42.06	0.83 $_A$	21.49	4.98	83.37 $_B$
Means in years	2002	18.72 $_X$	8.94 $_X$	52.38	2.30$_X$	24.09	13.82	83.52 $_Y$
	2003	22.29 $_Y$	10.15 $_Y$	54.16	3.08 $_Y$	28.72	18.46	86.87 $_Y$
	2004	20.33$_{XY}$	9.26 $_X$	52.31	2.51 $_{XY}$	24.64	15.04	73.08 $_X$

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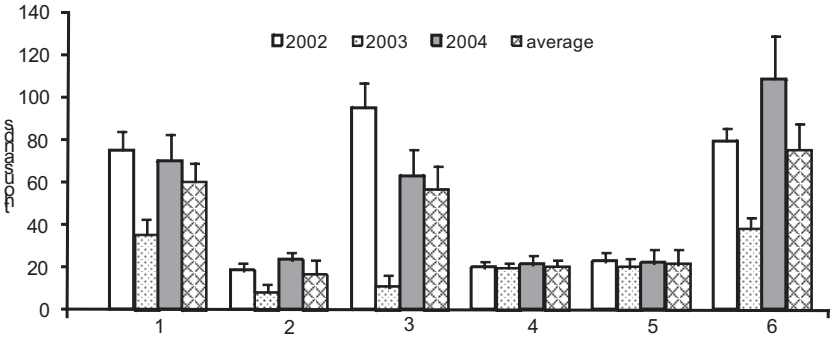

1- *Arabis procurrens*, 2- *Arabis caucasica*, 3- *Iberis sempervirens*, 4- *Aubrieta x hybrida* 'Gloriosa', 5- *Aubrieta x hybrida* 'Blue Emperor', 6- *Alyssum saxatile*

Fig. 6. The comparison of abundance of flowering per 10 m^2 in 3 years of study (±SD is given).

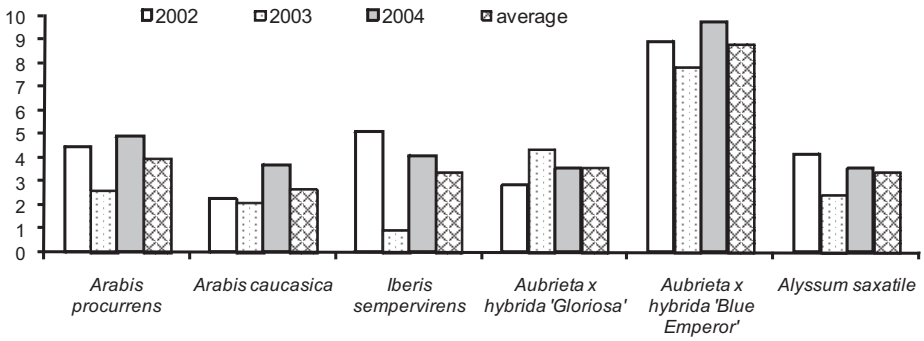

Fig. 7. Pollen efficiency (g per 10 m^2) of investigated ornamentals from Brassicaceae in years 2002-2004.

The percentage participation of pollen per 100 anthers turned out to be species-related, correlated with anthers proportions, and dependent on hydration of anther tissues. The tiny stamens of *Iberis sempervirens* yielded 1.16 mg of pollen per 100 anthers. The largest stamen heads of *Aubrieta x hybrida* 'Blue Emperor' yielded 6.68 mg of pollen per 100 anthers. The *Arabis procurrens* and *A. caucasica* yielded 1.16 and 2.97 mg of pollen per 100 anthers, respectively, due to a large difference in the percentage amount of pollen that they contained. In the years 2002 and 2004 the rainfall was lower than the long-term average. This resulted in the anthers of all investigated species and cultivars containing significantly less pollen than they did in 2003.

Pollen production varied with the species. It also varied from year to year and was correlated with blooming abundance (Fig.7). The highest pollen yield per unit area was delivered by *Aubrieta* x *hybrida* 'Blue Emperor' averaging 8.86 g per 10 m^2. The lowest pollen efficiency, a mere 2.82 g per 10 m^2 was found in *Arabis caucasica.*

The pollen grains of the species and cultivars under investigation were tricolpate and their viability varied between species. The lowest number of grains with a viable protoplast was found in *Arabis caucasica* with an average of 61.57% of the total. The highest was found in *A. procurrens* – 92.13%. Drops in temperature with deficient rainfall caused the majority of the species and cultivars to respond with a reduction in the percentage of viable pollen grains.

DISCUSSION

In south-eastern Poland the average blooming time of groundcover ornamentals of the Brassicaceae family occurs in the springtime. In the Lublin area, the first to bloom is *Arabis procurrens*. The date is actually later than that reported by Marcinkowski (2004) who found the perennial to bloom as early as March. The blooming dates of the remaining species are in agreement with those reported in literature where those species are classified as pollen-yielding perennial ornamentals (Lipiński 1982).

There are slight differences in the diurnal blooming pattern of the investigated species. Generally, like other Brassicaceae the investigated taxa opened the majority of their flowers early during the day. More than 50% of the flowers of *Arabis* spp. opened by 8:00 (GMT +2h) as did the flowers of mustard cultivars investigated by Masierowska (2003). The buds of *Aubrieta x hybrida* fail to expand altogether at some hours, the process being resumed after a break of a few hours. The same was observed earlier by Denisow (2004) in *Bunias orientalis*.

The flowers of all the species and cultivars are typically entomophilous offering both pollen and nectar rewards to pollinators. The feature is characteristic of the plants of the Brassicaceae family (Warakomska 1972, Proctor et al. 1996, Kołtowski 2002, Masierowska 2003).

The life-span of the flowers of the investigated species is 2-4 days, on average. This period is longer than in the mustard, rape or ruderal species belonging to the same family (Kołtowski 2002, Masierowska 2003, Denisow 2004). It can be related to the diurnal pattern of air temperatures. The diurnal pattern of air temperatures varies substantially during the spring blooming period of the studied ornamentals. The flowers of *Arabis procurrens* retained the freshness of their corolla petals for up to 5 – 6 days. That species is south European in origin. Probably with the temperatures prevailing during the experiment, the flowers prolonged their blooming in the expectation of optimum thermal conditions for pollination and fertilization. Likewise, the efficiency of the archesporial tissue in *Arabis procurrens* in south-eastern Poland turned out to be much lower than that in the remaining species. This is an additional piece of evidence in support of a substantial impact of abiotic conditions, diurnal temperature variations, rainfall and relative air humidity in particular, on pollen release, a key process for pollination. In the case of some of the species (e.g. *Arabis caucasica*, *Arabis procurrens*) the stigma was observed to protrude above the anthers as early as at the bud stage. It indicates protogyny which is extensively described in Brassicaceae representatives (Mc Gregor 1976, Faegri and van der Pijl 1979, Masierowska 2003).

Pollen presentation in the investigated species commenced with anthers dehiscing in the long-filamented stamens of the inner whorl. A similar sequence of anther dehiscence was described for *Brassica juncea* (Masierowska 2003). The dehiscence of anthers starting with those almost at level with the stigma may secure self-pollination when, for lack of

entomofauna, cross-pollination is difficult. Among the species of the Brassicaceae family, autogamous, partly autogamous and allogamous taxa are known. However, all of them benefit from cross-pollination and insect participation in the process (Faegri and van der Pijl 1979, Proctor et al. 1996). It cannot be excluded that species represent different pollination strategies to achieve the most efficient reproductive success.

Water content of anther tissues of the investigated species and cultivars was found to be 60-70%. This value is lower than that reported by Warakomska (1972) for *Brassica napus* var. *napus*. However, Warakomska (1972) published only one-year data. According to the measurements made by the author of this study the trait is subject to variation. It not only varies from species to species, but it also varies with the general water balance of the plants.

The general pollen efficiency of the investigated species (2.72 – 8.86 g per 10 m^2) is close to that of the ornamentals of the genera *Pulsatilla* and *Trollius*. *Pulsatilla* and *Trollius* are recognized as very good pollen-yielding taxa (Szklanowska et al. 2003, Denisow and Żuraw 2003). The general pollen efficiency of the studied species is slightly lower than that found in the ornamental salves (Bożek 2002). In order to provide a full description of the investigated groundcover species it is advisable to observe nectar secretion and to assess nectar output.

CONCLUSIONS

— In south-eastern Poland the blooming of ground cover perennial ornamentals of the Brassicaceae family (*Arabis* spp., *Aubrieta x hybrida*, *Iberis sempervirens*, *Alyssum saxatile*) occurs from mid-April to the first days of June.

— The flowers of the ornamental Brassicaceae expand mainly in early morning hours.

— Considerable drops in winter and early spring temperatures result in reduced blooming abundance in *Arabis* spp., *Aubrieta* x *hybrida,* and in *Alyssum saxatile* and *Iberis sempervirens*.

— Blooming abundance was the main influence on the amount of pollen flow. The investigated taxa may yield 2.72 - 8.86 g of pollen per 10 m^2 of compact ground cover.

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KWITNIENIE I WYDAJNOŚĆ PYŁKOWA KILKU OZDOBNYCH BYLIN Z RODZINY BRASSICACEAE

Denisow B.

Streszczenie

Obserwacje biologii kwitnienia oraz ocenę procesu pylenia prowadzono w latach 2002-2004 na terenie Ogrodu Botanicznego UMCS w Lublinie. Do badań wytypowano kobiercowe gatunki z rodziny Brassicaceae: *Arabis caucasica* Wild. ex Schltdl., *Arabis procurrens* Waldst. et Kit, *Aubrieta* x *hybrida* Bergm ('Gloriosa' i 'Blue Emperor'), *Iberis sempervirens* L., *Alyssum saxatile* L. (syn. *Aurine saxatilis* (L.) Desf.). Posługiwano się powszechnie stosowanymi w botanice pszczelarskiej metodami Jabłońskiego i Szklanowskiej (1997) oraz Warakomskiej (1972) w modyfikacji Szklanowskiej (1995). Kwitnienie badanych gatunków i odmian ozdobnych bylin przypadało w okresie od drugiej dekady kwietnia do pierwszych dni czerwca. Ich kwiaty otwierały się głównie we wczesnych godzinach porannych, przeciętnie około 50% kwiatów *Arabis* rozwijało się do 8.00 h czasu letniego (GMT + 2 h), a ponad 85% kwiatów odmian *Aubrieta x hybrida* rozkwitało przed 11.00 h. Do najobficiej kwitnących zakwalifikowano *Alyssum saxatile, Arabis procurrens* i *Iberis sempervirens,* które w lata obfitego kwitnienia wytwarzały średnio powyżej 60 tys. kwiatów na 10 m^2. Wszystkie badane gatunki i odmiany na znacznie niższe od przeciętnych temperatury powietrza w okresie zimowym i wczesnowiosennym reagowały istotnym spadkiem liczby wytworzonych kwiatów na jednostce powierzchni. Pręciki w kwiatach *Iberis sempervirens* dostarczały przeciętnie 1,16 mg pyłku ze 100 pylników, największe *Aubrieta x hybrida* 'Blue Emperor' 6,68 mg ze 100 pylników. Zbliżone wielkością główki pręcikowe w kwiatach *Arabis procurrens* i *A. caucasica,* ze względu na wyraźnie różny procentowy udział pyłku, dostarczały przeciętnie odpowiednio 1,16 mg i 2,97 mg pyłku ze 100 pręcików. Przeciętna wydajność pyłkowa wynosi od 2,72 g (*Arabis procurrens*) do 8,86 g (*Aubrieta* x *hybrida* 'Blue Emperor') z 10 m^2.

Słowa kluczowe: kwitnienie, wydajność pyłkowa, Brassicaceae.