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Blooming Biology and Pollen Exposure of Horse Chestnut Trees (*Aesculus* L.)

Biologia kwitnienia i pylenie drzew kasztanowca (*Aesculus* L.)

Abstract. In the years 1994-1998 the daily and seasonal dynamic of flowers starting to bloom as well as the pollen efficiency of *Aesculus hippocastanum* L. and *A. x carnea* Hayne were studied in Lublin. It was found out that *Aesculus* flowers opened only during the day-time, most abundantly between 5 a.m. and 8(9) a.m. As the day progressed the process slowed down until the end at 5(6) p.m. The number of flowers opened on consecutive days of blooming depended on the phase of the flowering period. It was also influenced by air temperature and insolation. The amount of pollen produced by the seven-stamen flower of horse-chestnut was conditioned by the genetic features of trees. The pollen efficiency per a unit of a tree-crown area depended on the number of developed flowers and on the amount of pollen produced by flowers. The last two features correlated well with the meteorological and soil conditions. The pollen efficiency per *A. hippocastanum* and *A. x carnea* tree was 22 g and 50 g, respectively. The daily pollen portions supplied to insects on consecutive days of blooming period strongly depended on the number of flowers developed on the tree. During 5-6 days of full blooming the individuals of *A. hippocastanum* supplied approx. 3 g of pollen each while the tree of *A. x carnea* produced 6 g of pollen, on average. These pollen quantities are small but in spring

they may be a valuable supplement of food flow for honeybees and wild pollinators.

INTRODUCTION

The common opinion that pollen of horse-chestnut trees is sometimes harmful for honeybee has not found scientific confirmation. Flowers of *Aesculus hippocastanum* L. and *A. x carnea* Hayne are readily visited by *Apis mellifera* L. workers and bumblebees (*Bombus* sp.) with the purpose of collecting both nectar and pollen, from which insects form quite big, brick-red pollen loads. Botanical analyses showed the presence of these pollen loads in a spring flow from different areas in Poland and France (Warakomska 1964, 1972, 1999). The horse-chestnut pollen grains were found in the microscope view of a bee bread and in the sediments of honey samples, taken from apiaries located near flowering horse-chestnut trees. This pollen was also accumulated in the brood cells of *Osmia rufa* L. (Wilkaniec and Warakomska 1992). It was interesting to study the blooming biology of ornamental trees from genus *Aesculus* L. as well as the quantity and the quality of the pollen provided by their flowers to pollinating insects.

MATERIAL AND METHODS

In the years 1994-1998, observations were carried out and pollen samples were collected in the Saski Park in Lublin. In this park 15-20 m high, dense-crowned, many-years old horse-chestnut trees grow. Every year they developed abundant inflorescences. During a blooming period, every day at 8 p.m. flower buds opened during a day were counted in marked inflorescences to find out the seasonal dynamic of flowering. The daily dynamic of flower opening, as well as the pollen exposure and pollinating insects visits were observed during 3-5 fine days in a peak-bloom of horse-chestnut trees. Then, in one-hour intervals, from early morning till late evening, the recently opened flowers in ten randomly chosen inflorescences were counted. That procedure was repeated on four individuals of species or hybrid, grown in some distance from each other. The estimation of the flower number per tree was made simultaneously by a few persons. At first, the precise number of inflorescences developed on the most representative, big branch of the tree was counted, then the number of such branches in a tree-crown was estimated. The mean number of flowers per one inflorescence was stated, using the data achieved from 30 racemes, randomly taken from different parts of crown. Pollen amounts per 1 flower, per 1 inflorescence and per 1 tree were obtained with the known methods (Szklanowska 1984, 1995, and 1999). The

biological value of pollen was evaluated by its viability, germination ability and potential energy. The length of a polar axis and an equatorial axis was measured in glycerine jelly slides.

RESULTS

Blooming biology. The conical inflorescences of horse chestnut, depending on the species, developed the protogynous, perfect flowers as well as the flowers with a rudimentary pistil and the typical staminate flowers on the same axis. The presence of big, remarkable signal guides on petals is an adaptation to entomophily. These guides, changing colour or intensifying the scent inside corolla, facilitate finding and recognizing the kind and presence or absence of food by pollinators. With flower opening, nectar secretion starts and the guides on petals are high yellow. After pollination is completed, the colour of spots turned into orange, then into red and nectar secretion is finished. The secretion accumulates in the base of calyx, between claws of two upper petals and the highest localized stamen. There are 7 stamens in a horse-chestnut flower, with anthers dehiscing subsequently. Depending on weather conditions as well as on the daytime when a flower bud is getting open, the pollen exposure continues 1 to 2 days. When anthers dehiscence starts early in the morning, the pollen exposure of all anthers is finished the next day, between 9 and 10 a.m. In flowers opened in the afternoon, the first anther dehisces only in the morning of the following day. The pollen exposure in the last stamens ends on the third day of flower life. The androecium is well developed in all kinds of horse-chestnut flowers but it is the most productive in the staminate flowers. In *Aesculus* L. inflorescence, the typical staminate flowers and the male flowers with a rudimentary pistil are more numerous and they are developed mostly in an upper part of inflorescence. The number of perfect protogynous flowers is lower, only about 1/5 of all flowers in the inflorescence. The total number of flowers per one inflorescence ranges from 57 to 172, depending on the species. When all pollen is removed from the anthers, petals fall very quickly, even though they are still in full turgor. The pericarp grew only from the well-developed ovaries with fertilized ovules, so from the set, echinate, one- or two-seeded capsules only the one, localized at the bottom of the inflorescence ripened.

Daily dynamic of flower opening. The flower buds of both horse-chestnut trees were opening during all day, with the highest intensification in the

morning hours (Fig. 1). Under good weather conditions that process started between 5 and 6 a.m. East European Time. The highest number of opened flowers was noted between 6 a.m. and 8 a.m., over 50% of all flower buds opened during the day. As the day progressed the process significantly slowed down and in one-hour intervals, from 8 a.m. till 5 p.m. (6 p.m.); the increase was only 5-7 % of the total number of opened flowers.

Pollen efficiency. In 1994-1998, the mean amount of pollen per 100 flowers ranged significantly from 4.5 to 12.6 mg for *A. hippocastanum* L. and from 6.7 to 14.4 mg for *A. x carnea* Hayne. The average values from 5 years of studies (Tab. 1) showed that every year the pollen efficiency per 100 flowers of white-flowered species (7.44 mg) was lower than that of red-flowered hybrid (10.26 mg). The pollen efficiency was influenced by weather conditions during a blooming period as well as by the genetic features of individuals. Yearly observed lower pollen efficiency of *A. hippocastanum*, when compared with *A. x carnea*, was connected with the pollen amount produced in the anthers. Depending on the year of studies, the amount of pollen obtained from 100 stamens of *A. hippocastanum* ranged from 6 to 18 mg (mean 10.62 mg), while in the case of *A. x carnea* the values were 9-20 mg and 14.56 mg on average. In 1995-1997, no matter which taxon was considered, the mean amounts of pollen produced by 100 anthers were lower than the mean values obtained in the years 1994 and 1998. That was an influence of poorer weather conditions during microsporogenesis. In 1996, despite the sunny spring, a long-lasting dry weather and high temperatures, and in 1997 a rainy, cold weather in the month preceding the flowering period of horse-chestnut trees, probably disturbed the normal process of pollen maturation.

The dimensions of pollen grains and their viability. The pollen grains of the studied *Aesculus* L. species are 3-colporate, pleurotreme and prolate.

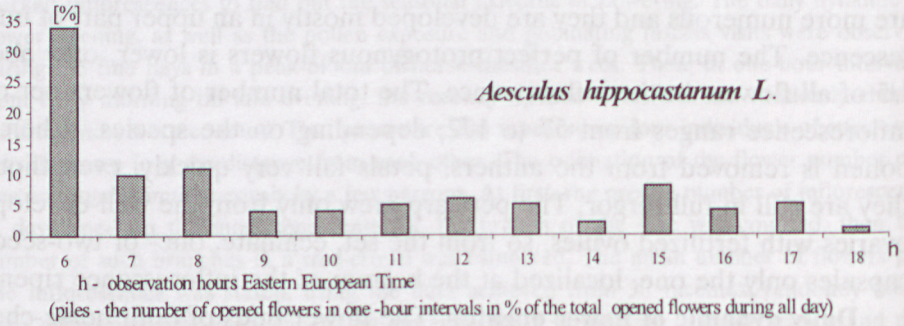

Fig. 1. The daily dynamic of horse-chestnut flowers starting to bloom

Tab. 1. Pollen efficiency calculated for horse-chestnut flowers and trees for five year-long research

Investigated trees	Year	mg / 100 anthers	mg / 10 flowers	mg / one inflores.	g / one tree	kg / 100* run. m.
Aesculus hippocastanum L.	1994	18.0	12.6	185.2	40.7	0.81
	1995	9.8	6.9	109.7	20.3	0.41
	1996	6.5	4.5	53.4	10.4	0.21
	1997	6.6	4.6	69.0	11.5	0.23
	1998	12.2	8.5	146.2	27.2	0.54
	Average	10.62	7.44	112.70	22.02	0.44
Aesculus x carnea Hayne	1994	20.5	14.4	87.8	75.2	1.50
	1995	16.4	11.5	69.0	55.1	1.10
	1996	12.6	8.8	69.5	34.7	0.69
	1997	9.5	6.7	45.6	30.3	0.61
	1998	14.3	10.0	67.0	57.2	1.15
	Average	14.66	10.26	67.78	50.5	1.01

* — Received from the number of 20 trees growing along a 100 running meter avenue

Tab. 2. Biological value of pollen grains of horse-chestnut

Investigated trees	Year	Studied feature in %		
		Pollen* viability	Pollen germination	Potential** energy
Aesculus hippocastanum L	1994	99.7	68.0	68.2
	1995	98.0	63.9	65.2
	1996	78.5	40.0	51.0
	1997	92.6	47.2	51.0
	1998	98.0	64.8	66.0
	Average	93.36	56.78	60.5
Aesculus x carnea Hayne	1994	99.7	58.2	58.4
	1995	92.5	47.0	50.8
	1996	86.5	25.0	28.9
	1997	93.2	35.3	37.9
	1998	94.7	48.3	51.6
	Average	93.32	42.88	45.52

* — Pollen viability investigated after 24 h (in % of vivid grains)
** — Pollen germination in relation to viability in %

Tab. 3. The daily portions of pollen supplied by horse-chestnut tree flowers on successive days of blooming period in May of 1998

Days of May	Temperature in ° C		Rain-fall in	Humi-dity in	Number of bloomed flowers per tree		Quantity of pollen delivered per tree in			
							I		II	
	min.	max.	mm	%	I *	II **	g	%	g	%
5	8	15	9.8	94	550	-	0.5	1.8	-	-
6	6	17	-	72	1472	-	1.3	4.8	-	-
7	8	19	-	63	1394	-	1.2	4.4	-	-
8	6	22	-	76	2057	580	1.8	6.4	0.6	1.0
9	9	27	-	59	4416	4398	3.8	13.8	4.4	7.6
10	8	29	-	60	4180	7989	3.5	13.0	8.0	14.0
11	7	27	-	66	3331	7576	2.2	10.4	7.6	13.2
12	6	28	-	58	2572	6958	2.8	8.0	7.0	12.2
13	10	20	-	74	1648	5225	1.4	5.1	5.2	9.1
14	5	20	-	64	1405	2910	1.2	4.4	2.9	5.1
15	7	18	4.6	85	808	869	0.7	2.5	0.9	1.5
16	4	16	-	84	1136	1996	0.9	3.5	2.0	3.5
17	7	22	-	69	1301	3876	1.1	4.0	3.9	6.8
18	6	23	-	73	1282	1692	1.1	4.0	1.7	3.0
19	12	24	0.6	69	1179	1205	1.0	3.7	1.2	2.1
20	9	27	-	70	1223	3580	1.0	3.8	3.6	6.3
21	5	22	9.2	74	971	1215	0.8	3.1	1.2	2.1
22	6	14	4.9	88	480	1198	0.4	1.5	1.2	2.1
23	1	11	1.8	78	314	725	0.3	0.9	0.7	1.3
24	-0.5	12	1.8	72	230	950	0.2	0.7	1.0	1.7
25	8	18	-	80	-	1518	-	-	1.5	2.6
26	4	25	-	74	-	1297	-	-	1.3	2.3
27	4	26	-	74	-	820	-	-	0.8	1.4
28	6	29	-	75	-	498	-	-	0.5	0.9
Sums	-	-	32.7	-	31949	57486	27.20	100	57.20	100
Average	5.4	18.3	-	62.5	-	-	-	-	-	-

Explanations: I * — *Aesculus hippocastanum* L.; II ** — *Aesculus x carnea* Hayne (The trees had crown diameter of about 4 m and crown height of 5-6 m)

The length of polar axis (P) ranged from 8.4 to 11.0 µm while the length of equatorial axis (E) ranged from 6.8 to 9.0 µm. Pollen grains of *A. x carnea* were dark yellow. The mean lengths of E and P axes were 11 µm and 9 µm, respectively. Pollen grains of *A. hippocastanum* were similar in shape but they were orange-yellow. Mean E length was 8.4 µm, P length was 6.8 µm.

The pollen of *Aesculus* L. was characterized by high viability, 90% on average. Only in 1996 the percentage of sterile grains increased to 20. The data confirmed high food value of the horse-chestnut pollen (Tab. 2). The germination capacity tested in agar medium, ranged from 25% to 68%, depending on the year of studies. The average germination capacities of pollen grains of *Aesculus hippocastanum* and of *A. x carnea* were 56.8% and 42.9%, respectively. The potential energy of pollen, calculated as the germination capacity: pollen viability ratio, showed that the biological value of horse-chestnut pollen ranges from 45% to 60%.

Daily portions of pollen supplied by one tree. On consecutive days of the blooming period the rate of flower opening in inflorescences was strongly influenced by weather conditions. Even in 1998, when the weather was quite stable, with rainfalls and slight changes of air humidity only in the third decade of May, that tendency was also observed (Tab. 3). The difference in the time of the beginning of blooming between the white-and the red-flowered trees was only 3 days. Between 7th and 13th May, the weather was sunny and warm, with temperatures above 20°C, and air humidity about 60%, and the peak-bloom started just on the second day after first flowers had opened. However, the period of the termination of flowering was extended as the result of temperature and humidity fluctuations, especially between 21st and 24th May. The first significant set-back of flowering took place on May 15th. The night ground-frosts occurring on 23rd and 24th May definitely ended the blooming of *Aesculus hippocastanum*. Since 24th May, when temperatures increased to 30°C, the last flower buds in *A. x carnea* inflorescences speeded their opening but the flowers wilted earlier. The blooming of this hybrid finished on May 29th. Against the background of weather conditions, the significant positive correlations between the daily portions of pollen supplied by horse-chestnut trees and the number of opened flowers as well as the pollen efficiency per 1 flower were stated (Tab. 3). Under dry, sunny and warm weather, the daily pollen portions obtained from *A. hippocastanum* tree, during 5-6 days of the peak-bloom when 2000-4000 flowers opened were 2-4 g. In the same phenological phase more abundantly blooming tree of *A. x carnea*, opening daily 5000-7000 flowers, supplied 4 to 8 g of pollen, the amount twice bigger, in comparison to the previous species. At the end of full blooming on 15th May, when rain fell and air temperature significantly decreased, the rate of flower buds development slowed down. The daily portion of pollen per one tree also decreased to less than 1 g. Since 16th May to the end of the blooming period, the daily pollen portions supplied by one

tree of *A. hippocastanum* still decreased. In the same time the daily pollen portions produced by *A. x carnea* tree were above 3 g, especially during the days of precipitate opening and cessation of the last flowers.

DISCUSSION

The data concerning the dynamics of horse-chestnut flowering, the daily portions of pollen supplied to insects as well as the biological value have no references in the scientific sources. The mean amount of pollen produced by 10 flowers of *Aesculus hippocastanum* L. (7.44 mg) was similar to the value reported earlier for this species by Warakomska (1972). However, the obtained average pollen amounts per 10 flowers of *Aesculus hippocastanum* and *A. x carnea* ranged widely from 4.5 to 12.6 mg and from 6.7 to 14.4 mg, respectively. It was probably a response of *Aesculus* individuals to changes in weather conditions. A similar effect was found for many different plants (Jabłoński and Szklanowska 1997). Analyses of horse-chestnut pollen grains viability and their germination capability confirmed the influence of weather conditions on the biological value of *Aesculus* pollen, too. The pollen grains of investigated taxons differed from each other in size. The dimensions of *Aesculus hippocastanum* pollen grains were similar to the values reported by Stachurska et al. (1970). Besides weather conditions the pollen efficiency of the studied trees was affected by their genetic features. That was why *A. x carnea* individuals developed 2-3 times more flowers and also produced more pollen than those of *Aesculus hippocastanum*. The daily portions of pollen supplied by *A. x carnea* flowers to pollinating insects, during a peak-bloom period, were also higher. However, the pollen efficiency of the horse-chestnut tree was not high in comparison to twelve taxons of linden-trees (Szklanowska and Teper 1999); one twenty-five-year old tree of *Tilia platyphyllos* Scop. may supply insects with the same amount of pollen as twenty horse-chestnut trees do. However, the studied *Aesculus* taxons are valuable as a food source mostly because of their springtime blooming period, when pollinating insects highly need pollen food. Warakomska (1999) found pollen grains of horse-chestnut present in pollen loads as well as in pollen bread and spring honey. This pollen is also readily collected by bumblebees and wild solitary bees, among others *Osmia rufa* (Wilkaniec and Warakomska 1992).

CONCLUSIONS

1. The daily dynamic of flowers starting to bloom shows a constant pattern. The horse-chestnut flower buds opened only during the day-time. The peak occurs between 5(6) a.m. and 8(9) a.m. E.E.T., when over 50% of all flowers are opening. The number of flowers opened on consecutive days of the blooming period was influenced mainly by weather conditions.

2. The mean amounts of pollen produced per seven-stamened flower of *Aesculus hippocastanum* L. and *A. x carnea* Hayne were 0.74 and 1.03 mg, respectively. The pollen efficiency of one inflorescence depended on the number of developed flowers and ranged from 53 to 185 mg for *A. hippocastanum* and from 45 to 88 mg for *A. x carnea*. The pollen efficiencies per *A. x carnea* and *A. hippocastanum* tree were 50 and 22 g, respectively.

3. The pollen of the studied taxons has high food value for honeybees. Its viability is high: 80-100 %, but not all vivid grains germinated in a medium, as was observed in 1996 and 1997, when the anthers also produced less pollen.

4. The daily portions of pollen supplied to insects depended on the number and rate of flowers opening. It was stated that during 5-6 days of a peak-bloom, the tree of *A. hippocastanum* produced approx. 3 g of pollen while the tree of *A. x carnea* — 6 g of pollen. They were not big amounts, but during springtime all sources of pollen food are valuable for honeybees, as well as for wild pollinating insects.

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STRESZCZENIE

W latach 1994-1998 badano dzienną i sezonową dynamikę rozkwitania kwiatów oraz wydajność pyłkową drzew 2 taksonów kasztanowca: *Aesculus hippocastanum* L. i *A. x carnea* Hayne na terenie parku w centrum Lublina. Stwierdzono, że kwiaty na drzewach z rodzaju *Aesculus* L. rozkwitają tylko w dzień i najintensywniej od 5(6) do 8(9) rano. Liczba kwiatów rozkwitających w kolejnych dniach zależy przede wszystkim od fazy okresu kwitnienia oraz od temperatury i usłonecznienia. O wydajności pyłkowej z jednostki powierzchni koron decyduje liczba wytworzonych kwiatów i ich obfitość pylenia, a z kolei obie te cechy korelują z warunkami klimatyczno-glebowymi. Wydajność pyłkowa z jednego drzewa (22 g *A. hippocastanum* i 50 g *A. x carnea*) oraz wielkość dziennych porcji dostarczanego owadom pyłku w kolejnych dniach okresu kwitnienia zależały jednak najbardziej od liczby kwiatów na drzewie. W fazie pełni kwitnienia przez 5-6 dni badane drzewa *A. hippocastanum* dostarczały po około 3 g pyłku, a *A. x carnea* przeciętnie po 6 g. Są to małe ilości pyłku, ale wiosną dla owadów pszczołowatych stanowią także cenne uzupełnienie taśmy pokarmowej.