ACTA AGROBOTANICA
Vol. 64 (2): 25–32
2011

THE BIOLOGY OF FLOWERING OF WINTER ACONITE (*Eranthis hyemalis* (L.) SALISB.)

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Received: 07.01.2011

Abstract

Eranthis hyemalis belongs to the Ranunculaceae family whose representatives enrich early spring pollen flow and nectar for pollinating insects. Flowering biology and morphological characteristics flowers of winter aconite were studied. The forage value was estimated as the rate of nectar production.

Observations were carried out between 2008 and 2011 in the Botanical Garden of the Maria Curie-Skłodowska University located in the Lublin area.

In the conditions of Lublin, flowering of winter aconite plants started at the beginning of February and lasted until the end of March. The seasonal bloom dynamics was strongly affected by maximum temperatures, which intensified flower blooming, and snowfalls which hampered this process. During the day, flowers opened between 8.00 am and 3.00 pm, but the highest intensity was between 10.00 am and 12.00 am. The process of pollen release, with the average number of 29 stamens shedding pollen in the flowers, lasted from 2 to 3 days. During the day the largest number of anthers opened at noon hours, between 11.00 am and 1.00 pm, though a certain rise in this number was also observed in the morning hours between 8.00 and 9.00 am. *Eranthis hyemalis* flowers develop funnel-shaped nectaries, on average 3-6 per flower. The determined amount of nectar per flower was 1.23 mg, while the concentration of sugars in it averaged 72.11%. The weight of nectar sugar per flower was 0.88 mg.

Key words: winter aconite, *Eranthis hyemalis*, dynamics of flowering, nectar, pollen release.

INTRODUCTION

The genus *Eranthis* Salisb. of the Ranunculaceae family occurs in the wild in Europe and Asia (Walters et al. 1989; Szweykowscy, 2003). The above-mentioned genus comprises seven (Walters et al. 1989; Szweykowscy, 2003) or even ten species (Tutin et al. 1964).

Winter aconite (*Eranthis hyemalis)* occurs in the wild in Europe from the south-eastern part of France to Bulgaria (Szweykowscy, 2002). It comes from the fertile forests of France, Italy, Slovenia, Serbia, Bosnia, and Croatia (Polunin, 1969; Erhardt et al. 2002). It has been cultivated since 1570 (Marcinkowski, 2002) and has become widespread all over Europe (Tutin et al. 1964; Walters et al. 1989). In Poland winter aconite occurs sporadically in the western part of the country as a feral plant (Szweykowscy, 2003). It is also mentioned among ephemerophytes (Mirek et al. 2002). This plant grows mainly among light thicket and shady groves (Amann, 1997). It is an ornament of old parks (Szweykowscy, 2003). Winter aconite propagates profusely if the soil is sufficiently moist during the spring (Amann, 1997). It perfectly reproduces vegetatively by tubers and is not difficult in cultivation (Marcinkowski, 2002).

Winter aconite is a small perennial plant with a tuberous rhizome (Amann, 1997; Szweykowscy, 2003) or small spherical tubers (Walters et al. 1989; Marcinkowski, 2002). A characteristic feature of its plants is a whorl consisting of 5 deeply dissected leaves (Strasburger et al. 1967). But Szweykowscy (2003) report that there are three stem leaves, sessile, palmately lobed, arranged in an involucral whorl. The basal leaves, long-petiolate, palmately lobed, with 5-7 linear sections, appear after flowering cessation (Szweykowscy, 2003). The flowers of winter aconite are yellow- or golden-coloured and cup-shaped. They consist of 6 petals, 10-15 mm in length. The diameter of flowers reaches 20-30 mm

(Tutin et al. 1964; Polunin, 1967; Amann, 1997; Marcinkowski, 2002). The flowers close at 7 pm (Szweykowscy, 2003). There are nectaries in them (Szweykowscy, 2003).

The flowering period is at the turn of February and March in western and central Europe (Core, 1955; Amann, 1997; Erhardt, 2002; Szweykowscy, 2003). Marcinkowski (2002) reports that in the Polish conditions blooming may extend even into April.

The yellow-coloured flowers of plant species of the buttercup family lure many pollinators (Amann, 1997; Lipiński, 2010) and can be a valuable source of pollen (Szklanowska, 1995; Denisow and Żuraw, 2003). In the period when there is no pollen, bees can not produce royal jelly or even beeswax, the mother bee stops laying eggs and larvae die in the cells (Howes, 1979; Lipiński, 2010). In most of the area of Poland, currently there is a shortage of important early spring bee forage (Jabłoński, 1994). This is why flower gardens that provide to insects an abundant and easy food source in the form of nectar and pollen are of great importance (Jabłoński, 1994; Kołtowski, 2006).

The aim of the present study was to determine the rate of flowering and pollen release of winter aconite cultivated in gardens, which can be an excellent supplement to the food resource for bees waking up in the spring. The nectar production rate was also was determined.

MATERIALS AND METHODS

The investigations were conducted in 2008-2011 in the Botanical Garden of the Maria Curie-Skłodowska University located in the Lublin area. Specimens of winter aconite (*Eranthis hyemalis* (L.) Salisb.) growing in a dense patch on a slope, under the canopy of a branchy maple, were selected for the observations. This site had a south-eastern exposure. Every year the flowering time was determined; the start of flowering was determined to be when 10% of the plants in a designated area opened the perianth leaves. In 2009 the seasonal flowering rate was investigated and it was analysed against the background of the atmospheric conditions during the flowering period of the plants. To this end, newly opened buds were counted every day at 10 am in the designated area of 1 m^2 and marked with a coloured thread.

The daily rate of flower opening was analyzed in 2009 every hour during a period of three days of full bloom, by counting newly opened flowers on the designated experimental area of 1 m^2.

The duration of pollen release was examined in 2009. For this purpose, 5 new flowers that had started shedding pollen were marked every 2 hours during 2 days of the full flowering period. Then, the number of stamens that shed pollen was determined every 2 hours until all the stamens in the flower were empty of pollen. In total, 50 flowers were observed.

The daily rate of pollen shed in the winter aconite flowers was observed in 2010. To this end, the number of stamens that had started shedding pollen was counted in 10 flowers every hour during 3 days of the full flowering period.

In 2011 the rate of nectar production in the flowers was examined by Jabłoński's method (2003). In order to determine the weight of nectar, 12 samples with 5 flowers in each were collected. Nectar sugar concentration was measured with an Abbe refractometer. The nectaries in the flowers were examined under a stereoscopic microscope.

RESULTS AND DISCUSSION

Plant morphology. The tuberous rhizome is an underground organ of winter aconite (Fig. 1b,c). It can easily be divided into fragments that are single tubers, which are described by Walter et al. (1989) and Marcinkowski (2002). Winter aconite self-propagates through seeds, which readily germinate shortly after they are shed from the follicles (Fig. 2a), provided that there is adequate moisture in the soil. Many young seedlings were observed in the observational plot which had suitable growth conditions. In the first and second year after sowing, only long-petiolate palmate leaves grow out of the ground, characterized by a deeply lobed leaf blade (Fig. 1a,b). In the third year, flower stalks also grow out of the rhizomes (Fig. 1c). One whorl, composed of three sessile, deeply lobed leaves, occurs just below the flower on the stem (Fig. 2), in accordance with a description by Szweykowscy (2003). The leaves create a kind of ruff situated under the terminal flower (Figs 3-5). The flowers of winter aconite reached a diameter between 2.5 cm and 3.0 cm (Fig. 6). According with Szafer`s and Wojtusiakowa`s (1969) classification, winter aconite flowers are included in bowl-shaped flowers with completely hidden nectaries (Fig. 6c). Many insects from different groups have access to these flowers, except insects with a short proboscis. These authors say that this kind of nectaries are attractive for insects because of their shape and colour (Fig. 7). Stamens in the flowers are arranged spirally on an elongated floral axis (Fig. 6d). Apocarpic gynoecium consisted from 3-5 free pistils with an elongated one-chambered ovary and a stigma on a short style (Fig. 6e). After flowering, elongated follicles appeared at the tip of the flower.

The flowering pattern. The development of flowers took place in very early spring, and even in

winter. Buds of winter aconite, covered by the ruff the lobed leaves, grew out of the litter created from the fallen leaves and fruit of the maple tree shading them already at the end of January. The opening of the first flowers started on February 5th (Table 1). The estimated number of flowers per 1 m^2 area ranged from 224 in the first year to 350 in the last year of the study (Table 1). Periodic decreases in temperature and snowfall in the initial period of flowering of the plants inhibited the blooming of new flowers (Fig. 8, 9), but did not damage the flowers. In the period of deterioration in weather conditions and every day around 7.00 pm, the perianth closed, probably to protect the generative organs against low temperatures. During the day, new flowers opened around 9.00 am (Fig. 10). Depending on weather conditions, the daily peak of flowering was between 10.00 and 12.00 am. The process of new buds opening was already finished at 3.00 pm.

Pollen release. From 17 to 38 (on average 29) stamens were estimated in one flower of winter aconite. The process of pollen release took place from the lowest located stamens on the axis of the flower. Temperature and precipitation had the biggest influence on the pattern of pollen release (Fig. 8, Table 2). Pollen shed in the flower lasted from 2 to 3 days. The time of the day in which pollen shed started had no effect on the intensity of this process. Positive minimum temperature as well as the absence of snowfall at the beginning of pollen release clearly accelerated the maturation of the anthers in a flower. During the day, from 6 to 12 stamens shed pollen. Analyzing the daily dynamics of pollen shed, some increase was noted in the morning as well as a distinct peak in the afternoon (Fig. 11). After the stamens shed pollen from their pollen sacs, they fell off.

The structure of the nectary and the process of nectar secretion in flowers. Typically, 6 or 5 funnel-shaped nectaries occurred in the flowers of winter aconite (Figs 6c, 7). A similar number of nectaries, with the same structure, is described by Żuraw and Denisow (2002) in the flowers of *Helleborus foetidus*. Occasionally, there were 3 or 4 nectaries in the flower. Nectar appeared already in the initial phase of pollen shed. The average weight of the nectar secreted from one flower was 1.23 mg and it was lower by 0.23 mg than the values reported by Maurizio and Grafl (1969). Nectar sugar concentration measured with the refractometer ranged from 61.2% to 78% (on average 72.11%) and it was more than 46% higher than that reported by the above-mentioned authors. The calculated weight of sugars in the nectar from one flower ranged from 0.64 mg to 1.14 mg (on average 0.88 mg) and it was more than twice the amount specified by Maurizio and Grafl (1969) at the level of 0.38 mg. The nectaries in the flowers of winter aconite fell off at the same time as the latest dehiscent anthers. The sepals became detached from the receptacle as the last ones.

Visitation by pollinating insects. The flowers of winter aconite attract insects by their smell as well as the shape and colour of the yellow perianth. The tissue of the perianth of winter aconite has the ability to reflect UV rays in the same way as hellebore flowers (Maurizio and Grafl, 1969). It is one of the adaptations to honey bee visitation. The construction of the eyes of the bee allows it to see the ultraviolet colour range that is invisible to the human eye (Szafer and Wojtusiakowa, 1969). During the study period, on sunny windless days honeybee foragers were occasionally observed on the flowers.

Table 1.
Flowering of the plants
during the study period (2008-2011)

Study year	Time of flowering	The number of days in the flowering period	Flowers x m^{-2}
2008	5.02. – 10.03.	33	224
2009	25.02. – 20.03.	25	315
2010	3.03. – 19.03.	17	274
2011	7.02. - 22.03.	44	350
average		30	290.75

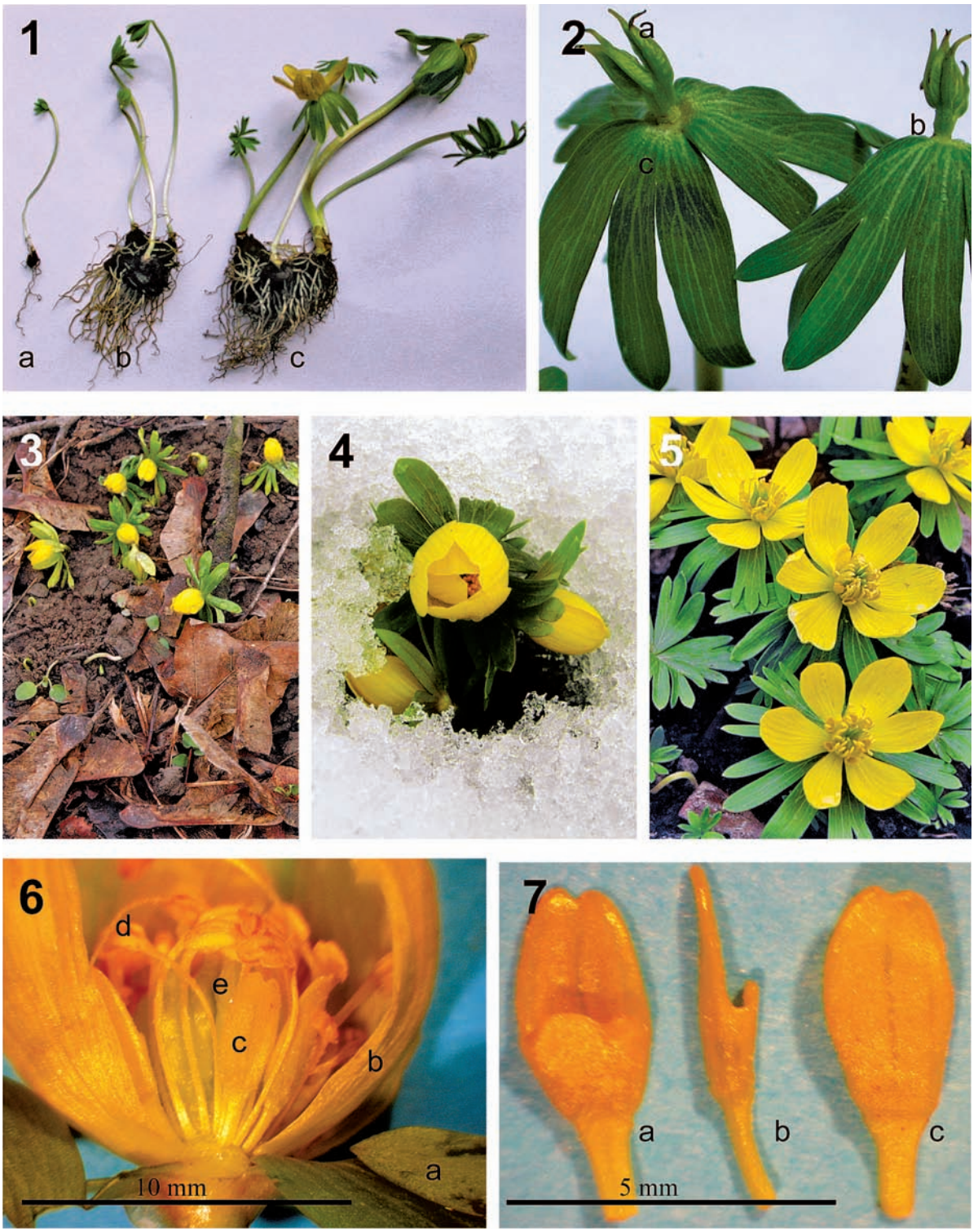

Fig. 1. Consecutive stages of plant growth and development: a –seedling; b – young rhizome (vegetative phase), c – mature rhizome (generative phase), x 0.3
Fig. 2. Fruit setting stage: a –fruits (follicles); b –elongated axis of the flower (hypanthium); c – deep lobed bracts arranged in a whorl, x 2
Fig. 3. Buds of *Eranthis hyemalis* growing out from between fallen maple leaves and fruits, x 0.2
Fig. 4. Flowers of *Eranthis hyemalis* surrounded by fresh snow, x 1
Fig. 5. Winter aconite at full bloom, x 1
Fig. 6. Flower cross section: a – floral bract; b – sepal; c – nectary; d – stamen; e – pistil
Fig. 7. Nectary: a –centripetal side; b – lateral view; c – centrifugal side

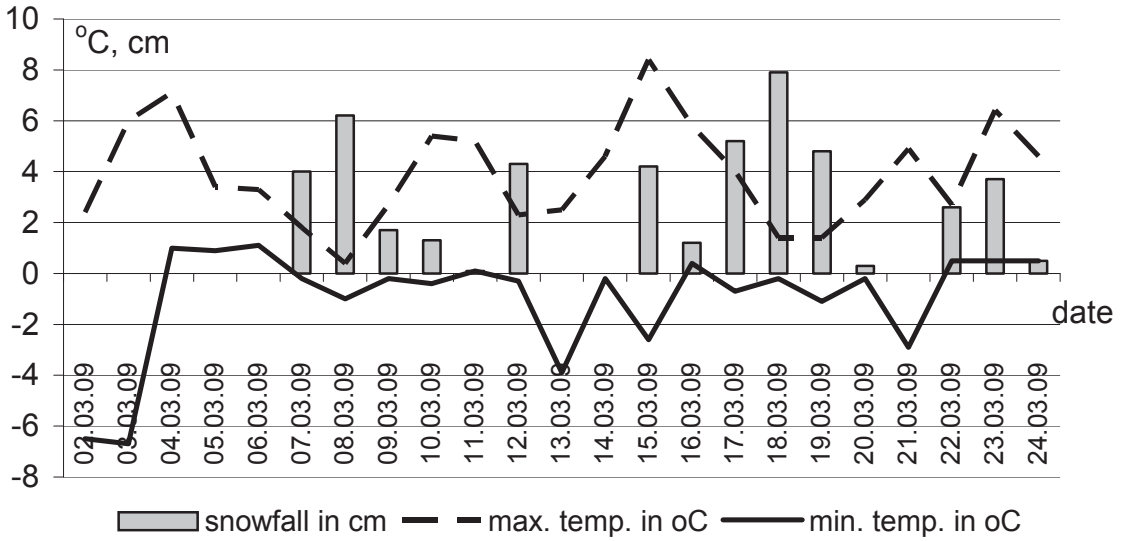

Fig. 8. The distribution of selected weather parameters during flowering of winter aconite in 2009.

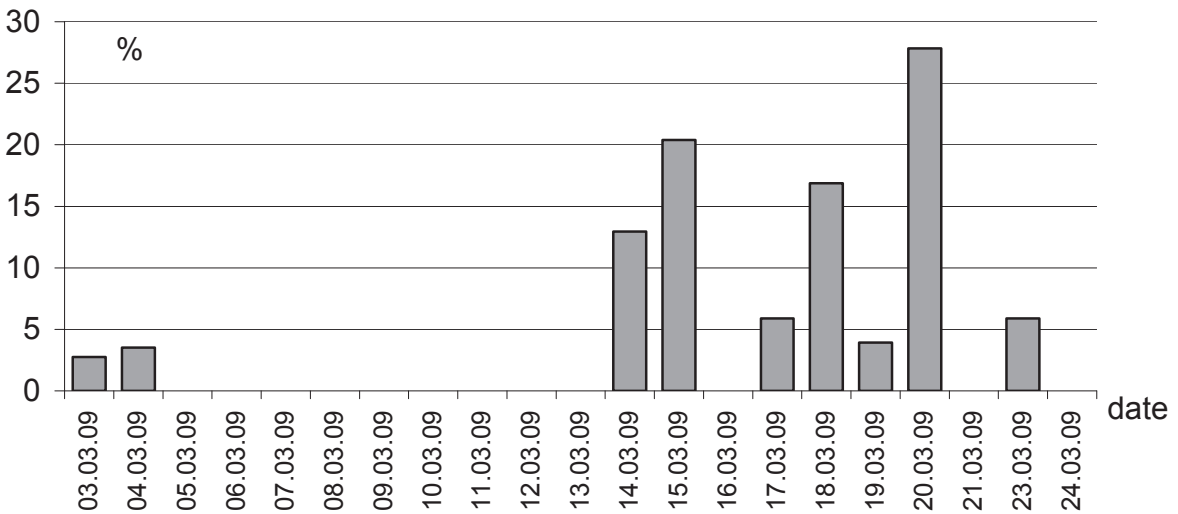

Fig. 9. The seasonal flowering pattern of *Eranthis hyemalis* flowers in 2009.

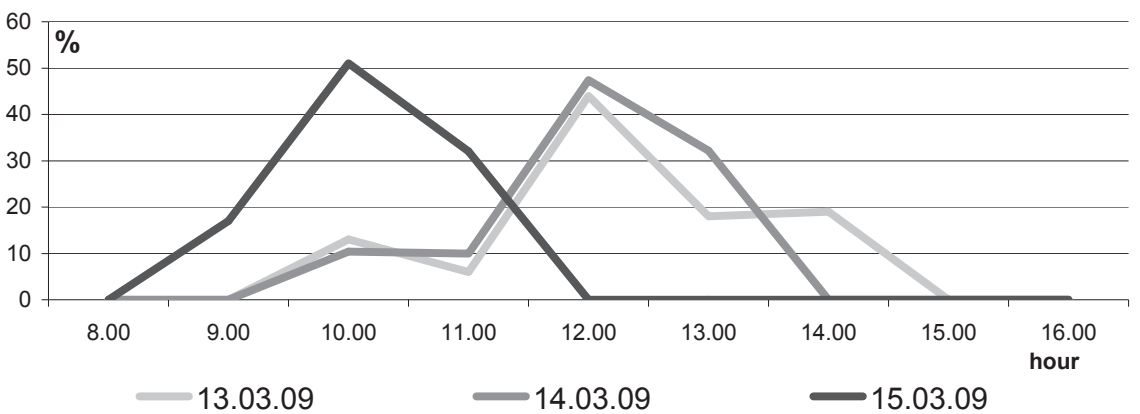

Fig. 10. The daily flowering rate on 13-15 March 2009.

Table 2.
Pollen release in *Eranthis hyemalis* flowers

Time of flower marking		The average number of stamens releasing pollen in one flower, in the consecutive days of observation															The average number of stamens in a flower
		5.03.09					6.03.09					7.03.09					
		Reading time															
		08.00	10.00	12.00	14.00	16.00	08.00	10.00	12.00	14.00	16.00	08.00	10.00	12.00	14.00	16:00	
5.03.09	08.00	2.6	4.0	1.2	2.6	0.2	0.6	0.6	0.4	0.6	0.6	3.8	4.4	0.4	1.2		22.6
	10.00		2.2	1.4	1.2	0.2	0.8	2.8	1.6	1.4	1.4	2.4	7.4	2.0			24.8
	12.00			2.2	1.6	0.4	0.8	3.4	3.2	2.6	2.6	5.8	4.0				26.6
	14.00				3.0	1.0	5.8	3.2	1.6	1.2	2.0	3.5	4.0	1.6			26.9
	16.00					3.0	6.8	2.2	1.6	1.4	4.8	7.0	1.4	0.0	0.4		28.6
6.03.09	08.00						2.4	3.4	0.8	2.8	2.8	12.0	3.6				27.8
	10.00							2.4	1.4	3.4	4.4	13.0	1.6				26.2
	12.00								2.8	4.4	5.6	11.0	1.0				24.8
	14.00									3.2	4.4	13.0	6.6	1.0			28.2
	16.00										4.4	8.0	13.0	1.8			27.2

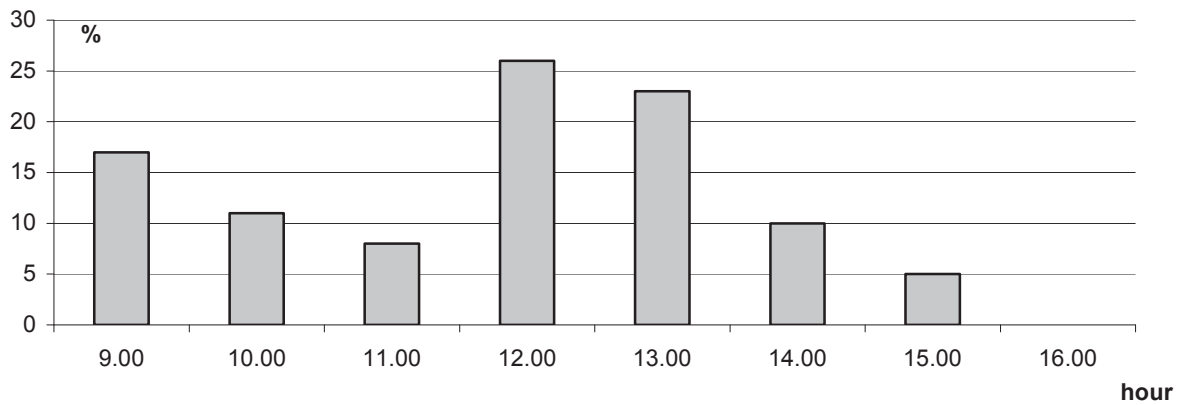

Fig. 11. The daily pollen release rate in *Eranthis hyemalis* flowers on 5 March 2010.

CONCLUSIONS

In the conditions of Lublin, the flowering of winter aconite lasts from 5th February to 22nd March.

Snowfall occurring during the flowering of winter aconite inhibits the opening of new buds, but it does no damage to blooming buds.

Depending on weather conditions, during the day new flowers open from 8.00 am to 3.00 pm.

The process of pollen release from the stamens, with their average number of 29, lasts from 2 to 3 days.

The funnel-shaped nectaries secrete nectar in the amount of 1.23 mg per flower and sugar concentration is about 72%.

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Biologia kwitnienia rannika zimowego [*Eranthis hyemalis* (l.) Salisb.]

Streszczenie

Eranthis hyemalis należy do rodziny Ranunculaceae, której przedstawiciele wzbogacają wczesnowiosenny pożytek pyłkowy i nektarowy dla owadów zapylających. Celem pracy było poznanie biologii kwitnienia i cech morfologicznych kwiatów rannika zimowego oraz wartości pożytkowej wyrażonej obfitością nektarowania.

Obserwacje prowadzono w latach 2008-2011 na terenie Ogrodu Botanicznego UMCS w Lublinie.

W warunkach Lublina kwitnienie roślin trwało od początku lutego do końca marca. Na sezonową dynamikę rozkwitania decydujący wpływ miały temperatury maksymalne, które intensyfikowały rozkwitanie kwiatów, ale również opady śniegu, które całkowicie hamowały ten proces. W ciągu dnia kwiaty rozkwitały od godziny 8.00 do 15.00 z największym nasileniem w godzinach 10.00-12.00. Proces pylenia pręcików w liczbie średnio 29 w kwiecie trwał od 2 do 3 dni. W ciągu dnia najwięcej pylników otwierało się w godzinach południowych 11.00-13.00, choć zauważono również pewną zwyżkę w godzinach porannych 8.00-9.00. Kwiaty rannika wykształcają lejkowatego kształtu listki miodnikowe w liczbie od 3 do 6. Oznaczona ilość nektaru z 1 kwiatu wynosiła 1,23 mg, a koncentracja cukrów w nim zawartych średnio 72,11%. Masa cukrów oznaczonych z 1 kwiatu wynosiła 0,88 mg.