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DIVERSITY OF DIPTERA FLOWER VISITORS OF *PULSATILLA GRANDIS* IN THE BAKONY MTS (HUNGARY)

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Abstract: Plant-insect relations are very diverse and affected by many different factors. When the temperature is low, the number of pollinators is mostly limited. In our study we document Diptera taxa collected on the early flowering, legally protected *Pulsatilla grandis* Wender. Diptera were collected on the Csatár Hill (near Veszprém) and Vörös Hill (at Balatonalmádi) in the spring of 2019. The average number of Diptera individuals collected per hour were 1.7 and 2.4, respectively. At both sites the frequency of visitations was the highest around midday, then became lower in the afternoon. The majority of the collected insects belonged to hoverflies, and the most abundant species proved to be *Brachypalpus valgus*. However, the proportion of collected males and females was different at the two sites. The understanding of relations between rare plant species and their pollinators is important from the aspect of ecology and nature conservation as well.

Key words: *Brachypalpus valgus*, fly, hoverflies, pollinator, protected plant species

INTRODUCTION

Plant-insect relations are very diverse and affected by many different factors. There is a mutual dependence between them: flowers provide shelter and forage for insects, while insects can carry pollen to pistils and thus can help pollination directly or indirectly.

The interdependence of plants and insects is especially increased in early spring, when the forage resources to insects are scarce. On the other hand, at low temperature the number of insects is limited, and thus the plants' need for pollinators is great (Kratochwil 1988).

The order Diptera is one of the most species rich group of insects, and they play an important role in natural ecosystems. In general, their body is less hairy than that of bees, but pollen can stick to them, so they are potential pollinators of plants (Soltész 2017).

Diptera taxa have significant role in the formation and maintenance of ecological balance on Earth. For example, there are predator species feeding on pests

(e.g. hoverflies) and parasites (e.g. tachinids). Of the order Diptera the hoverflies take part primarily in pollen transfer. Their adults are flower visitors feeding on pollen, nectar and plant liquid. They prefer visiting *Ranunculus repens* L., *Crataegus laevigiata* (Poir.) DC. and the species of the genus *Fragaria* L. They rarely visit the members of Caryophyllaceae, Brassicaceae (except for rapeseed) and Lamiaceae, because they produce little pollen and/or nectar, which are, moreover, hardly accessible for hoverflies (especially in Lamiaceae). The size of pollen also influences insects' flower preference, since adults can eat only pollen grains that are smaller than 100 μm in diameter (Földesi 2011).

The protogynous flowers of the studied *Pulsatilla grandis* Wender. are mainly cross-pollinated so insects have significant role in the lifetime of the species. In the absence of cross-pollination, self-pollination is possible as well (Lindell 1998, Walker and Pinches 2011, Zimmermann 1935).

Pulsatilla flowers produce significant amount of pollen, and attract insects with nectar too. The nectar is secreted by small staminodes which are located at the base of the androecium. The segregation of nectar starts at the same time as pistil receptivity (Weryszko-Chmielewska and Sulborska 2011).

According to our previous studies (Mészáros and Józan 2018) *Pulsatilla grandis* is mainly pollinated by Aculeata species (Hymenoptera), but Diptera individuals were collected as well. In a former study carried out in the Bakony Mts (Tóth 2001) *Platycheirus fulviventris* (Macquart, 1829) and *Rhingia campestris* Meigen, 1822 were observed on *Pulsatilla nigricans* Störck. (which is a close relative of *P. grandis*).

The aim of our study was to compare the Diptera species collected from the flowers of two *Pulsatilla grandis* populations.

MATERIAL AND METHODS

Study species

Pulsatilla grandis Wender. is a perennial species, flowering in early spring, starting blooming in March. It is a rare and endangered species in Central Europe (Kaligarič *et al.* 2006), legally protected in Hungary. The species is sporadic in the Transdanubian Mts, North Hungarian Mts and southern Transdanubia, and rare in western Transdanubia, Hungarian Great Plain and Little Hungarian Plain (Bartha 2012). The number of individuals occurring in Hungary was estimated at 4–5.5 million in 2009 (Dostalova and Király 2013), but shows a decreasing tendency. The species is a representative of steppe flora, flowering mainly on sunny, rocky, dry grasslands, especially on alkali soils (Randic *et al.* 2013).

It is a perennial forming thick subterranean rhizome. The leaves start to grow at the beginning of flowering, and the young leaves are densely haired. Its widely opened flower is bell shaped, solitary, erect with a blue or violet perianth. At first the flowers look sessile, but soon afterwards their peduncles elongate. The yellow stamens (which reach the half length of the perianth) contrast sharply with the violet coloured perianth and pistils. Later the pistil elongates and develops into a feather-like organ, which helps the spread of seeds. When the fruit is ripening the perianth becomes brown and falls. Older individuals can produce even 12 flowers (Farkas 1999, 2014, Soó 1966).

Study sites

The 340 m high Csatár Hill can be found near Veszprém city (Hungary). The hill is built up of dolomite (Jakus 1980). The study site lies at 328–335 m a.s.l., and its vegetation can be classified as *Chrysopogono-Caricetum humilis* Zólyomi (1950) 1958 association. During our previous studies we have recorded 9 legally protected plant species on the area: *Anacamptis pyramidalis* (L.) Rich., *Erysimum odoratum* Ehrh., *Jurinea mollis* (L.) Rchb., *Linum tenuifolium* L., *Orchis morio* L., *Plantago argentea* Chaix in Vill., *Polygala major* Jacq., *Pulsatilla grandis* Wender., *Stipa pennata* L. (Mészáros *et al.* 2018). About 1,000 individuals of *Pulsatilla grandis* live on the northeastern slope of the hill. The extent of its population is *ca* 0.6 ha.

The 258 m high Vörös Hill can be found near Balatonalmádi and Vörösberény (Hungary), built up of limestone. The study site lies at 258 m a.s.l., and its vegetation can also be classified as *Chrysopogono-Caricetum humilis* Zólyomi (1950) 1958 association. During our previous studies we have recorded the occurrence of 10 legally protected plant species: *Dictamnus albus* L., *Erysimum odoratum* Ehrh., *Jurinea mollis* (L.) Rchb., *Linum flavum* L., *Linum tenuifolium* L., *Orchis purpurea* Huds., *Polygala major* Jacq., *Pulsatilla grandis* Wender., *Serratula radiata* (Waldst. et Kit.) M. Bieb., *Stipa eriocaulis* Borbás (Mészáros *et al.* 2018). A large population of *Pulsatilla grandis* (*ca* 800 individuals) thrives on the northeastern slope of the hill. The extent of its population is *ca* 0.66 ha.

Collecting Diptera

Diptera individuals were collected in the spring of 2019 at both study sites, which belong to the Bakonyvidék Mesoregion in Hungary (Dövényi 2010). On the Csatár Hill site the insects were collected in a 25 hours long period, on 16, 19, 23 and 24 March, while on the Vörös Hill site in a 9 hours long period, on 9, 10, 14, 15, 17, 21, 22 and 23 March. The collecting procedure took place well before daylight saving time, so it was not needed to convert standard time to summer time.

Only insects found on *P. grandis* flowers were collected. The sites were scanned by 1–2 researchers continuously. Insects were collected with a butterfly net 30 cm in diameter, but the original net had been replaced by a dense and transparent tulle net, which is suitable for Diptera collecting.

Insects were collected individually and put into glasses in every hour. Consequently, repeated visitations of flowers were not possible, and every individual was counted once. For the sake of efficiency, the insects were not sorted according to their behaviour (e.g. breeding, sleeping in the flower).

The collected individuals were identified by Sándor Tóth according to Majer (1977), Mihályi (1975, 1979), Tóth (1977) and Wéber (1975).

RESULTS

On the Vörös Hill 60 individuals of 17 species (representing 6 families) were collected. 53.3% of them were male (32 individuals) and 46.7% female (28 individuals) (Tables 1–2). The number of flower visitations was the lowest between 9–10 a.m. (5 individuals per hour), and the highest between 11–12 a.m. (18 individuals per hour) (Fig. 1). On the Csatár Hill 15 individuals of 6 species (representing 3 families) were collected. 40% of them was male (6 individuals) and 60% female (9 individuals) (Tables 3–4). The number of flower visitations was the lowest between 11–12 a.m. (0 individuals per hour), and the highest between 12–1 p.m. (8 individuals per hour) (Fig. 2).

The rank abundance curves (Fig. 3) demonstrate that both sites had one dominant species (*Brachypalpus valgus*), while the abundance of the other species was significantly lower. The curve constructed at the Vörös Hill site decreases sharply at the beginning, because the second most frequent species (*Eristalis tenax*) was far less abundant (10%) than the dominant one (46.7%). On the other hand, the curve constructed at the Csatár Hill site decreases less sharply, because the second most frequent species (*Pollenia rudis*) was fairly abundant (26.7%). The last section of the graphs reached a plateau at a low level, because the rarest 9 visitor species were represented by only 1–1 individuals, respectively.

DISCUSSION

Although both sites have a northeastern exposure, the mean number of collected Diptera individuals per hour was different (Vörös Hill: 2.4, Csatár Hill: 1.7). At both sites the frequency of visitations was the highest around midday, then became lower in the afternoon. At the Csatár Hill site no Diptera was found between 11–12 a.m. Our observations partly contradict the results of Földesi (2011), who found that adult hoverflies are most active in the hours before mid-

Table 1. *Pulsatilla grandis* visiting Diptera species in decreasing frequency (Vörös Hill, 2019).

Species	Family	Nr of individuals	Male	Female	Time of visitation
Brachypalpus valgus (Panzer, 1798)	Syrphidae	28	22	6	9 a.m.–3 p.m.
Eristalis tenax (Linnaeus, 1758)	Syrphidae	6	2	4	11 a.m.–1 p.m.
Pollenia rudis (Fabricius, 1786)	Calliphoridae	4	1	3	9–10 a.m., 11 a.m.–2 p.m.
Brachypalpus laphriformis (Fallén, 1816)	Syrphidae	4	2	2	10–11 a.m., 12–1 p.m.
Sphaerophoria scripta (Linnaeus, 1758)	Syrphidae	3	3		10–11 a.m.
Pollenia amentaria (Scopoli, 1763)	Calliphoridae	3	1	2	1–2 p.m.
Nemotelus pantherinus (Linnaeus, 1758)	Stratiomyidae	2	1	1	12–1 p.m.
Tachinidae sp. indet.	Tachinidae	2		2	12–1 p.m.
Chrysotoxum elegans Loew, 1841	Syrphidae	1		1	12–1 p.m.
Eupeodes luniger (Meigen, 1822)	Syrphidae	1		1	10–11 a.m.
Scaeva selenitica (Meigen, 1822)	Syrphidae	1		1	2–3 p.m.
Scaeva pyrastri (Linnaeus, 1758)	Syrphidae	1		1	12–1 p.m.
Blondelia nigripes (Fallén, 1810)	Tachinidae	1		1	12–1 p.m.
Germaria ruficeps (Fallén, 1820)	Tachinidae	1		1	12–1 p.m.
Empis sp. indet.	Empididae	1		1	9–10 a.m.
Muscidae sp. indet.	Muscidae	1		1	10–11 a.m.
Criorhina asilica (Fallén, 1816)	Syrphidae	1		1	1–2 p.m.
Total		60 (17 species)	32	28	9 a.m.–3 p.m.

Table 2. *Pulsatilla grandis* visiting Diptera families in decreasing frequency (Vörös Hill, 2019).

Family	Nr of individuals	Male	Female
Syrphidae	46	29	17
Calliphoridae	7	2	5
Tachinidae	4		4
Stratiomyidae	2	1	1
Empididae	1		1
Muscidae	1		1
Total	60	32	28

Table 3. *Pulsatilla grandis* flower visitor Diptera species in decreasing order/frequency (Csatár Hill, 2019).

Species	Family	Nr of individuals	Male	Female	Time of visitation
Brachypalpus valgus (Panzer, 1798)	Syrphidae	6	4	2	12–1 p.m.
Pollenia rudis (Fabricius, 1786)	Calliphoridae	4	1	3	12–2 p.m.
Muscidae sp. indet.	Muscidae	2	1	1	1–2 p.m.
Scaeva pyrastri (Linnaeus, 1758)	Syrphidae	1		1	10–11 a.m.
Calliphora vicina Robineau-Desvoidy, 1830	Calliphoridae	1		1	1–2 p.m.
Pollenia amentaria (Scopoli, 1763)	Calliphoridae	1		1	12–1 p.m.
Total		15 (6 species)	6	9	10 a.m.–2 p.m.

Table 4. *Pulsatilla grandis* visiting Diptera families in decreasing frequency (Csatár Hill, 2019).

Family	Nr of individuals	Male	Female
Syrphidae	7	4	3
Calliphoridae	6	1	5
Muscidae	2	1	1
Total	15	6	9

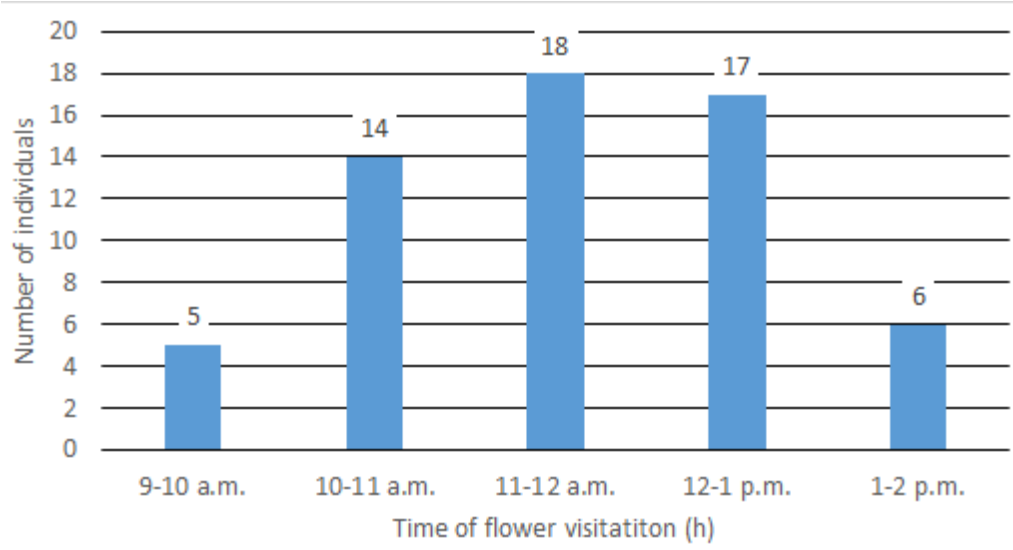

Fig. 1. Temporal distribution of *Pulsatilla grandis* flower visitor Diptera on the Vörös Hill (2019).

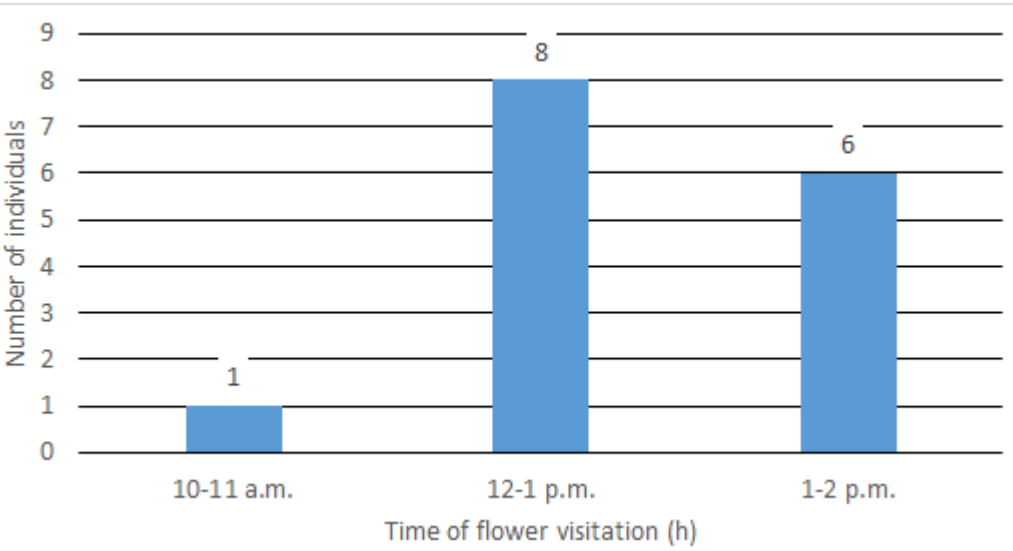

Fig. 2. Temporal distribution of *Pulsatilla grandis* flower visitor Diptera on the Csatár Hill (2019).

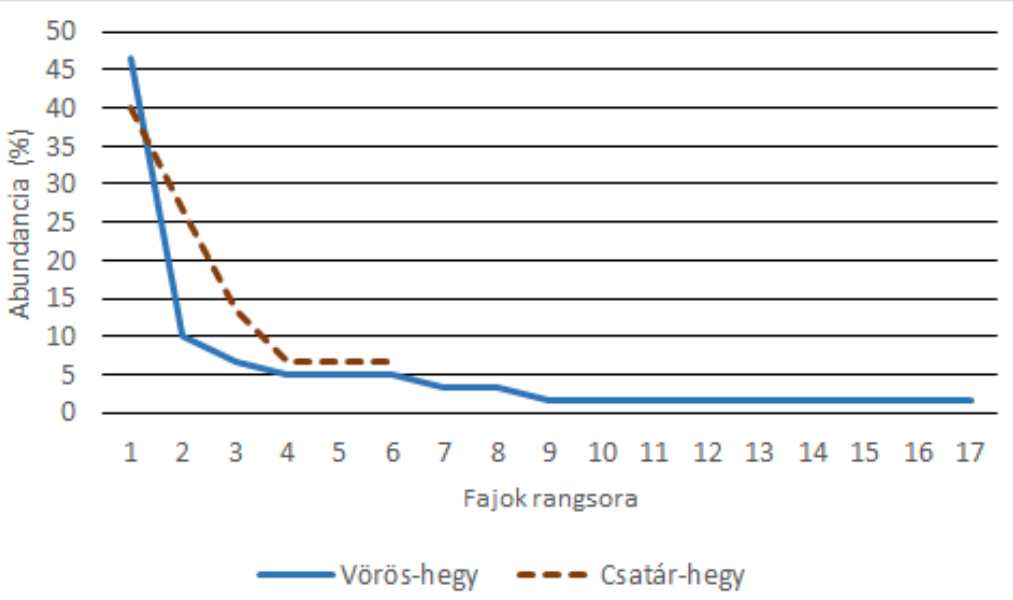

Fig. 3. Rank abundance of *Pulsatilla grandis* visitor Diptera species.

day. The proportion of collected males and females was different at the two sites (on the Vörös Hill site males prevailed, on the Csatár Hill site females dominated), showing random patterns of sex distribution.

Brachypalpus valgus was the most frequent species at both sites. This species is moderately common in Hungary and lives mainly in forested areas (Tóth 2001). Indeed, our study sites are bordered by forests.

Hoverflies formed the majority of collected individuals at both sites. Strzałkowska-Abramek *et al.* (2016) showed that the plant species *Pulsatilla vulgaris* (a close relative of *P. grandis*) had 185 anther per flower on average, its pollen grains were oblate-spheroid shaped, medium sized, with 33 and 35 μm axes. These data are in conformity with the statements of Földesi (2011) that hoverflies prefer visiting plants producing a lot of pollen, but can eat only pollen grains that are smaller than 100 μm in diameter.

Although we focused on the whole order Diptera, we noticed only members of the Brachycera suborder, and no species was observed from the Nematocera suborder.

According to Tóth (1975) adults of the family Stratiomyidae live mainly in humid, marshy habitats. Surprisingly, we have collected them in dry grasslands.

All hoverfly species collected in our study had already been reported from the Bakony Mts (Tóth 2001), but no hoverflies have been observed on *Pulsatilla grandis* flowers so far. Our study records 9 hoverfly visitors of that species. Of them *Platycheirus fulviventris* and *Rhingia campestris* had already been observed on *Pulsatilla nigricans* Störck in the Bakony Mts.

In *Pulsatilla grandis* the yellow stamens contrast sharply with the violet pistils and blue perianth. Colours play an important role in the orientation of insects. Tóth (2011) stresses the usefulness of yellow traps for collecting hoverflies, especially from late autumn to early spring. Czencz (1987) tested the effects of the colour of surroundings of yellow traps by thrips. His results showed that the surrounding colour can strengthen or weaken the collecting efficiency of traps. A blue background increased the efficiency of yellow trap (placed in flowering alfalfa field). The results of Moffitt (1964) were similar: African violets with blue flowers (and yellow stamens) were damaged more seriously by the western flower thrips (*Frankliniella occidentalis* (Pergande, 1895) than violets with yellow and pink flowers. Apparently, the morphology of *Pulsatilla* flowers favours flower visitors (Zimmermann 1935). Its large, bell-shaped, actinomorph, purple flowers with many yellow stamens attract insects (Essl 2005, Walker and Pinches 2011).

Our results are contributions to the knowledge of ecology of *Pulsatilla grandis*, and provide new information about the flower visiting behaviour of Diptera. The understanding of relations between rare plant species and their pollinators is important from the aspect of ecology and nature conservation as well.

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Összefoglaló: A növény-rovar kapcsolatok rendkívül szerteágazóak, és számos tényező által befolyásoltak. A kora tavaszi virágoknak nagy szükségük van a korai virághoz látogatókra, hiszen az alacsony hőmérséklet miatt még kevés megporzó áll rendelkezésre. Tanulmányunkban a kora tavaszi virágzású, védett *Pulsatilla grandis* Wender. virágokon gyűjtött kétszárnyúakat (Diptera) ismertetjük. A gyűjtéseket 2019 tavaszán végeztük a közigazgatásilag Veszprémhez tartozó Csatár-hegyen és a Balatonalmádiban található Vörös-hegyen. Az óránként gyűjtött átlagos Diptera-szám a Vörös-hegyen 2,4, a Csatár-hegyen pedig 1,7 egyed volt. Az egyedek óránkénti eloszlása mindkét területen a déli órákban volt a legintenzívebb, aztán csökkent a nap folyamán. Mindegyik populációban a zengőlegyek voltak többségben, és a *Brachypalpus valgus* fajból gyűjtöttük a legtöbbet. A hímek és a nőstények eloszlása mindkét területen más képet mutatott. A ritka növények és pollinátoraik közötti számos kapcsolat feltárása mind ökológiailag, mind természetvédelmileg fontos.

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