THE PHENOLOGICAL SYNCHRONY BETWEEN ALIEN APHID *IMPATIENTINUM ASIATICUM* NEVSKY AND ITS HOST - ALIEN PLANT *IMPATIENS PARVIFLORA* DC.

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Abstract. Small balsam, *Impatiens parviflora*, is one of the most dangerous alien plants in Slovakia invading forest and adjacent stands. The alien aphid, *Impatientinum asiaticum*, is monoecious on small balsam infesting the inflorescence of the plant and its yearly occurrence is interesting it term of potential of biological regulation of small balsam local prevalence. The aim of the paper was to compare the phenological synchrony between the aphid *I. asiaticum* and its host small balsam. Peak of aphid population abundance was recorded by the end of August, or beginning September (in 2009 or 2007 respectively); however in 2008 peak of abundance occurred untypically beginning July. The period of maximal population growth rate of the aphid coincided with the period of maximal mature fruit and seed production of small balsam. The closest tracking was recorded in the case of plants growing at clear cut stand where the peak of aphid abundance occurred a week before the maximum of mature fruits and seeds production of small balsam were recorded. At this time, the strong positive correlation (r=0.79414) between aphid number on plants and number of mature fruits was also recorded. The potential influence of climate change on *I. asiaticum* population dynamics in relation to biological regulation small balsam is discussed.

Introduction

Biotic invasions are one of the three main threats of the global biodiversity (Mack et al., 2000). Many invasive species exert strong impacts on invaded communities and ecosystems (Vila et al., 2009) and transform ecosystem properties which inevitably lead to changes in biological communities (Richardson at al., 2000). Small balsam, *Impatiens parviflora*, is one of the most dangerous alien plants in Slovakia growing mainly at forest and adjacent stands (Eliáš, 1992). The plant is wide-spread throughout Europe and established in most of European countries (http://www.europe-aliens.org). It was introduced from Central Asia to Europe in 19th century, the motivation being botanical curiosity (Trepl, 1984). A few years after was recorded from many eastern and central European towns as an escape from botanic gardens (Holman, 1971). Schmitz (1998b) found 13 insect taxa feeding on small balsam in Europe and subsequently pointed the positive influence on native fauna. Especially the Asian aphid *Impatientinum asiaticum* hosted reach aphidophagous fauna. *Impatientinum asiaticum* Nevski is an alien aphid being holocyclic and monoecious on small balsam. The aphid did not arrive to Europe at the same time as its host, because small balsam as an annual plant was introduced as seeds. The aphid arrived more than 100 years later (Heie, 1994). Holman (1971) discussed the aphid distribution shortly after it has been discovered in Europe and gave the arguments for the hypothesis that its rapid spreading from Asia took place by means of aeroplanes. *I. asiaticum* frequently form dense colonies mainly on flowers and flower stalks (Heie, 1994). Classical biological control is a powerful tool for suppression of invasive plants and insects in natural ecosystems. It provides a means to permanently suppress invaders and hence is sustainable (Van Driesche et al., 2010). *I. asiaticum* as a monophagous herbivore, regularly occurring and forming dense colonies in inflorescence of small balsam, could play the role in long term suppression of local population of this alien plant.

Material and methods

The study was carried out at the locality National Natural Reserve Báb, approximately 15km from Nitra city (south western Slovakia). The locality is representing the fragment of natural pannonian oak - hornbeam forest situated in intensively used agricultural landscape. There, the population dynamics of the aphid *Impatientinum asiaticum* on small balsam (*Impatiens parviflora*) was observed during summer in 2007, 2008 and 2009.

In 2007, only two variables were recorded on twenty randomly selected small balsam plants – number of aphids on the main stem and number of aphids on one lateral branch. In 2008 and 2009, we were recording more details to state: 1. population dynamics (number of aphids on the main stem); 2. aphid distribution on the main stem (number of aphids on pedicles, flowers and fruits); and 3. dynamics of fruits production (number of total and mature fruits produced on the main stem, number of seeds produced by mature fruits of the main stem). These variables were observed on the plants growing at three different stands – clear cut, forest edge and forest stand. At every stand twenty (in 2008) or thirty (in 2009) plants were permanently numbered.

We used the following dates to compare the phenological synchrony between *I. asiaticum* population dynamics and dynamics of generative development of small balsam: the dates when the maximum of total fruits, mature fruits and seed production was recorded; the date of aphid peak of abundance, and the date of maximal occurrence of aphids on fruits.

Results and discussion

Population dynamics of *Impatientinum asiaticum* on clear cut stand.

In 2007 we firstly encountered the aphid infesting small balsam at the locality and the aphid population was already in its maximum rate development – 41.2 and 17.3 aphids was recorded on average on the main stem or lateral branch respectively.

In 2008 the aphid infestation started during second half of June; we recorded already 11.0 aphids on average in inflorescences of the main shoot at 19th June. Peak of abundance was recorded 3rd July and 38.15 individuals were recorded. After, the population of *I. asiaticum* on small balsam decreased gradually during August (fig. 1). We ended the regular counting on 3rd September when 16.0 of individuals were recorded on average.

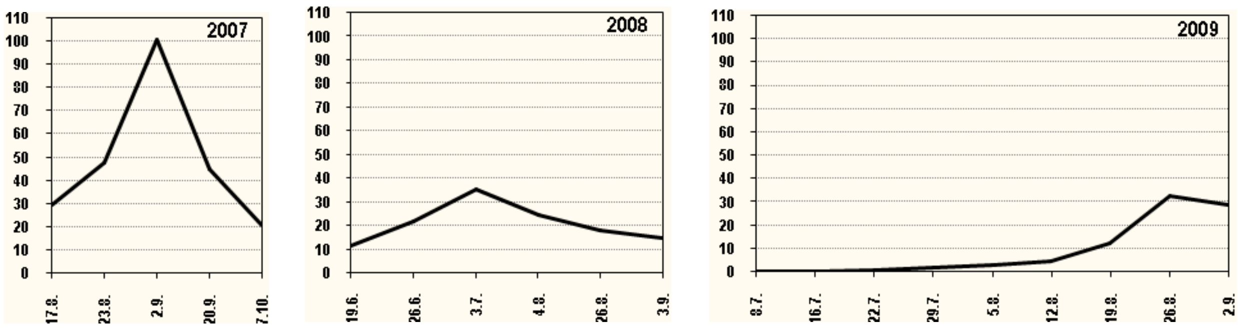

Figure1. Population dynamics of *Impatientinum asiaticum* on small balsam (*Impatiens parviflora*) growing at clear cut stand during the vegetation season of 2007, 2008 and 2009 at the locality Báb (SW Slovakia). In 2007 the method of randomly selected host plant was used and the values represent average number of aphids infesting main stem and one lateral branch. In 2008 and 2009, the method of permanently marked host plant was used ant the values represent average number of aphids on the main stem.

In 2009, we firstly recorded the aphids on 8th July and 0.1 individuals were recorded on average. Aphid population was than growing in the course of July and first half of August and reached peak of abundance on 26th August; 32,52 individuals were recorded on average.

Distribution of *I. asiaticum* on small balsam growing on clear cut stand.

The aphid infested only inflorescence of the small balsam during the three years of study. But, in 2007 we observed that a part of colony at the plant infest not only flower stalks, but also the fruits, especially the basal part of the fruit and adjacent part of stalk. In that case the aphids were concentrated manly around the part of fruit fixation. For this reason we studied the distribution of aphids in inflorescence in detail during the two following years. We discovered that it is not at all neglected number. The part of aphid population colonizing fruits can reach 40% (in 2008) and even 61% (in 2009). During the peak of aphid population abundance the portion reached was similar in both years 37% and 36% in 2008 or 2009 respectively.

Dynamics of fruits production of small balsam.

In 2008, maximal fruit production was recorded on 3rd July and 35.5 fruits were recorded per one plant on average. In 2009, 33.43 fruits were recorded on average at the maximum of fruit production in 2009. These numbers were recorded from the plants growing on clear cut stand. As concerning fruit production at the two other stands, plants growing at forest edge produced about half to two thirds less fruits, depending on date. The fruit production was the lowest in case of plants growing in forest, the fruit production.

Phenological synchrony between *I. asiaticum* population dynamics and small balsam fruit production.

The comparison between timing of selected "key events" of phenological phases between aphid and its host in 2009 is graphically shown in table 1.We can see, the coincidence between time of maximal fruit and seeds production peak of aphid population abundance, and peak of aphid occurrence on fruits, in the case of the three stands.

The strong positive correlation between aphid numbers on plant and number of total and mature fruits was not recorded for all terms. But, as we can see in table 2, there were some terms when strong positive correlation was recorded. For these dates, large variability in aphid number on individual plants was recorded. For example, on 2nd September, the minimal number of aphid was 2 individuals so the maximal was 132 aphids.

Table 1 The comparison between timing of maximum of generative production of *Impatiens parviflora* (maximum of total fruits, mature fruits and seeds production) and peak of *Impatientinum asiaticum* abundance on small balsam (peak of aphid occurrence on the main stem and fruits on main stem) during growing season 2009 at the locality Báb (SW Slovakia).

Maximum of	Clear cut stand					Forest edge stand					Forest stand				
	fruits production	mature fruits	seeds production	aphids on fruits	aphid population	fruits production	mature fruits	seeds production	aphids on fruits	aphid population	fruits production	mature fruits	seeds production	aphids on fruits	aphid population
8.7.											■				
16.7.															
22.7.													■	■	
29.7.															
5.8.	■			■		■						■			
12.8.									■						
19.8.								■							■
26.8.					■										
2.9.		■	■				■			■					

Table 2. Correlation coefficients between *Impatientinum asiaticum* number and number of fruits (total and mature) on small balsam recorded at the locality Báb (SW Slovakia) in 2009.

	total number of fruits on plant			**number of mature fruits**		
type of stand date	clear cut	forest edge	forest	clear cut	forest edge	forest
8.7.	-0.12136	0.09205	0.26676	-0.18211	0.14017	-0.06217
22.7.	0.043547	0.153961	0.629419	-0.17492	0.060233	**0.595195**
5.8.	0.24741	0.0646	**0.79402**	0.00841	-0.09388	-0.05528
19.8.	0.358022	**0.681381**	0.6198	0.388801	**0.411025**	-0.39643
2.9.	**0.79414**	0.41579	-0.15749	**0.67946**	0.30374	*no mature fruits*

The detailed comparison of population dynamics of *I. asiaticum* on small balsam of the three years of survey is not possible because the method and frequency of records were not the same. Considering the potential of *I. asiaticum* as natural suppressor of local prevalence of small balsam we can only concentrate on “key events” of the problem. Small balsam as an annual herb is reproducing only by seeds. So, the presence of any herbivore in inflorescence is thus at least promising. According our results, *I. asiaticum* is present on plant during whole period of flowering. In Europe, flowering of small balsam usually begins in May or June and lasts until September or October, with the oldest recorded plants being 7 months old (Coombe, 1956). On 7th October 2007 we recorded more than 20 aphids on average on small balsam. However our regular counting was ended beginning September in 2008 and 2009, there were still heavy infested plants on the locality. The only limit for aphid occurrence seems to the presence of its host in physiologically convenient status. As concerning phenological synchrony; it is important for herbivorous insects to synchronise their development with that of their host plants. For tree dwelling aphids, Dixon (2003) considers bud burst for trees and egg hatching for aphids as the two important points. In our case we concentrated to the maximum of fruit production for small balsam, and for *I.asiaticum* the date of beginning of infestation and the record of peak of population. The best situation was recorded in the case of plants growing on clear cut stand - table 1 show that these key terms of host and herbivore dynamics are or overlapping or the aphid population maximum is a bit in advance. The phenological synchrony is not clear in care of forest growing plants. But, there needs to be added the fact, that the production of fruits and seeds of forest growing small balsam plants was incomparable weaker than in case of clear-cut growing plants.

We could responsibly answer the question if *I. asiaticum* is able long term suppressing the small balsam local prevalence after set of several years of detailed study. Particularly, small balsam is capable to produce enormous amount of seeds. Of course, the number of seeds produced per plant varies considerably depending on soil conditions and crowding, estimated at a maximum of up to 10,000 seeds per plant (Coombe, 1956) although 1000-2000 is more common (Trepl, 1984). *I. asiaticum* is not the only natural “enemy” of small balsam. The rust fungus *Puccinia komarowii* is also monoecious and could cause 100% mortality of small balsam seedlings in some cases (Eliáš, 1995). The pathogen is also present on our study locality and we observed the symptoms of infection every year.

In 2008, the population dynamics of *I. asiaticum* was different from this observed in 2009. We consider more important population decrease in August. We suppose that this was caused by extremely dry weather in August 2008. The plants were also suffering but the fruit production was not as influenced as the population dynamics of the aphid. Mody et al. (2009) studied in experimental conditions the influence of short term drought. They stated important negative influence on apple aphid population if the drought lasted more than two weeks. As concerning climate change, some authors already used models based on long term records of several aphid species to predict the potential changes. For example, Hughes and Bazzaz (2001) did not expect negative effect of higher CO_2 concentration on sucking incest. They explain it by the ability of aphids adapt to quality change of host plant and the ability to synthesize amino acids (Hughes, Bazzaz, 2001). Based on his mathematical model, Newman (2003) also does not predict change of aphid population dynamics, when he combined elevated CO_2 concentration with higher temperature in his model. All authors mentioned above consistently referred that the quality of host plant plays the key role. From our experience heavy rain had also negative influence on aphid population dynamics because it can cause partial or even total exclusion of aphid individuals from the plant.

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