RENATA PISKORZ

THE EFFECT OF OAK-HORNBEAM DIVERSITY ON FLOWERING AND FRUITING OF *IMPATIENS PARVIFLORA* DC.

From Department of Botany
The August Cieszkowski Agricultural University of Poznań

ABSTRACT. Annual plants exhibit high phenotypic plasticity of those features, which are connected with generative reproduction. The plasticity in reproductive response to different habitats is clear in varying ephemeral habitats where therophytes often appear. This paper concerns the effect of different growth conditions in the same deciduous community on flower and fruit setting and ripening. The study was carried out on *Impatiens parviflora* in oak-hornbeam forest.

Key words: annual plant, flowering and fruiting, phenotypic plasticity, *Impatiens parviflora*, Central European oak-hornbeam forest

Introduction

Ontogenesis is connected with two basic life processes, i.e. the growth of the organism and reproduction. Each species developed in the course of evolution a certain model of growth and reproduction, called life history. This pattern is determined by the genetic program of a given individual; however, it is subjected to certain modifications if it is realized under different environmental conditions (**Falińska** 1996). Annual plants are distinguished from others by very strong phenotypic plasticity in terms of characters connected with generative reproduction (**Palmblad** 1968, **Falińska** 1979, **Symonides** 1987 a). This plasticity results first of all from the fact that therophytes have adapted to inhabiting very diverse, unstable habitats; secondly, fast and effective production of seeds capable of germination is decisive for the existence of therophytes, since frequently it is the only method of recruiting a new generation.

The aim of the presented studies was to determine to what extent diverse living conditions within one forest phytocenosis promote changes in the setting and maturing of flowers and fruits of an invasive species – small-flowered balsam *Impatiens parviflora*.

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Material and methods

Investigations were conducted in the Wielkopolski National Park. In forest division 136 plots were established which reflected internal diversification of the oak-hornbeam forest *Galio silvatici-Carpinetum*:

A – the best preserved patch of a typical oak-hornbeam forest with a compact tree canopy (cover of layer a – 90%);

B, C, D – patches of oak-hornbeam forests with accelerated symptoms of neophytization manifested by the abundance in the ground flora of *Impatiens parviflora* and nitrophilous plants from class *Artemisietea*. Plot B was marked under the canopy of a sparse stand (a_1 – 35%, a_2 – 20%), plots C and D – in tree stand gaps. Plot D was found in a depression of the ground. Analyses of the chemical composition of soils showed a higher current soil moisture content level in that site;

E – form of oak-hornbeam forest with mass invasion of *Carpinus betulus*;

F – contact zone of oak-hornbeam forest in the ecotone with communities similar to *Calamagrostio-Quercetum*.

On each plot a total of 30 balsam plants were selected. Measured plants were labelled. The first specimens were selected at random. These which died during the study were replaced by new ones, selected in a non-random manner. The criterion applied at their selection was a similar height to that of the dead specimens. The replacement was marked using the same number as the original specimen. In the period from May to August the percentage of replacements in relation to the entire sample did not exceed 20%. In the next month, as a result of high mortality of the specimens, the share of new plants increased to 60%. Replacement rate of the specimens was so high that the reliability of this study could have proved doubtful. The reason for its continuation was the fact that in the month, in which such a numerous replacement of specimens included in the sample occurred (September), balsam was still flowering and growing intensively. However, observations were limited to characters connected with generative development.

The following morphological features of plants were included in biometric measurements: stem length, the number of developed leaves, flower buds, the number of cleisto- and chasmogamous flowers, the number of unripe fruits, the number of ripe fruits, the number of petioles remaining after fruit drop, the length of ripe fruits, and the number of seeds in the fruit.

Cleistogamous flowers were distinguished on the basis of a detailed description given by **Franklin** (1919) and a drawing by **Symonides** (1987 b).

Results

In small-flowered balsam vegetative and generative development phases coincide. In other words, setting of the first flower buds, flowers and fruits does not result in the inhibition of stem development or cease of leaf production. Irrespective of the conditions under which specimens of the discussed species develop, the highest values for such characters as stem length and the number of leaves were observed after the initiation of generative development. Moreover, usually the dates, on which maximum values were found for both above mentioned characteristics, coincided with the date of the maximum value for generative organs (Fig. 1).

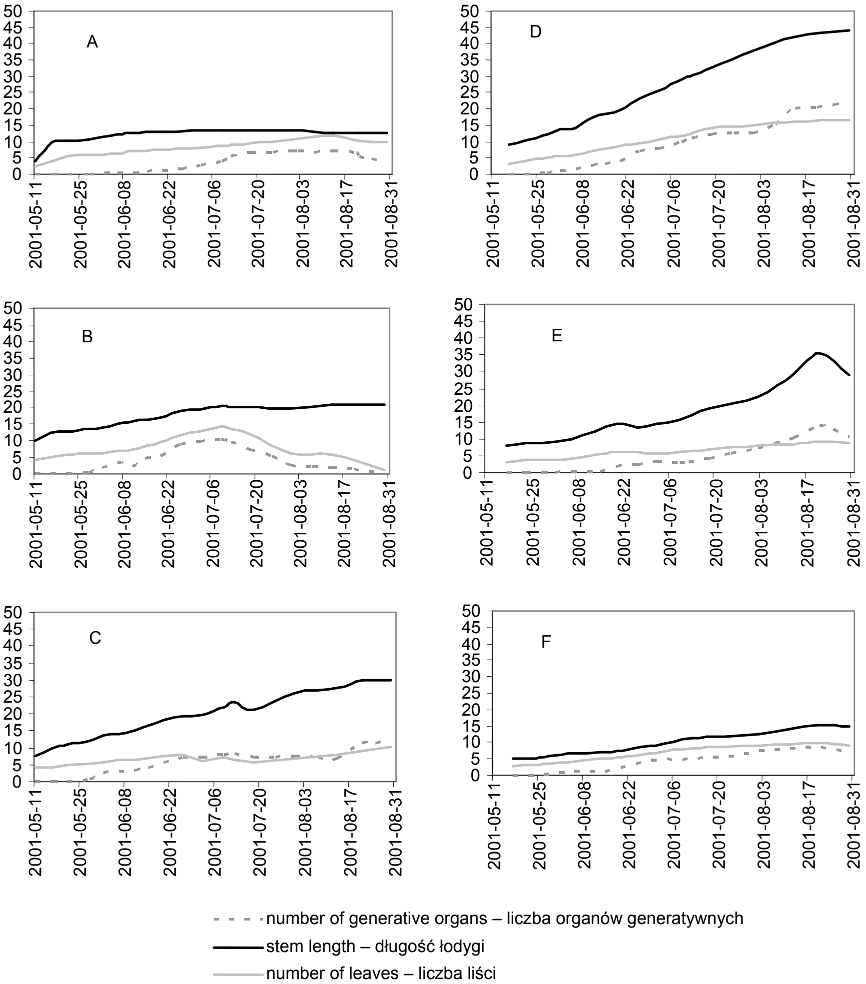

Fig. 1. Vegetative and reproductive growth of *Impatiens parviflora* DC.
in oak-hornbeam forest (A-E) and ecotone area (F)
Ryc. 1. Rozwój wegetatywny i generatywny *Impatiens parviflora* DC.
w lesie dębowo-grabowym (A-E) i ekotonie (F)

The phase of generative development in *Impatiens parviflora* under different environmental conditions was initiated with a slight time shift – on the labelled specimens the first, still unformed flower buds appeared between 21 and 28 May (Fig. 2 a).

Under different environmental conditions the length of generative development varied. Under moderate shade conditions balsam distinctly shortens the time of flowering and fruiting. In these plants first flowers appeared the earliest i.e. in the beginning of June (Fig. 2 b, c), while fruit dispersal was completed as early as the end of July (Fig. 3 b, c).

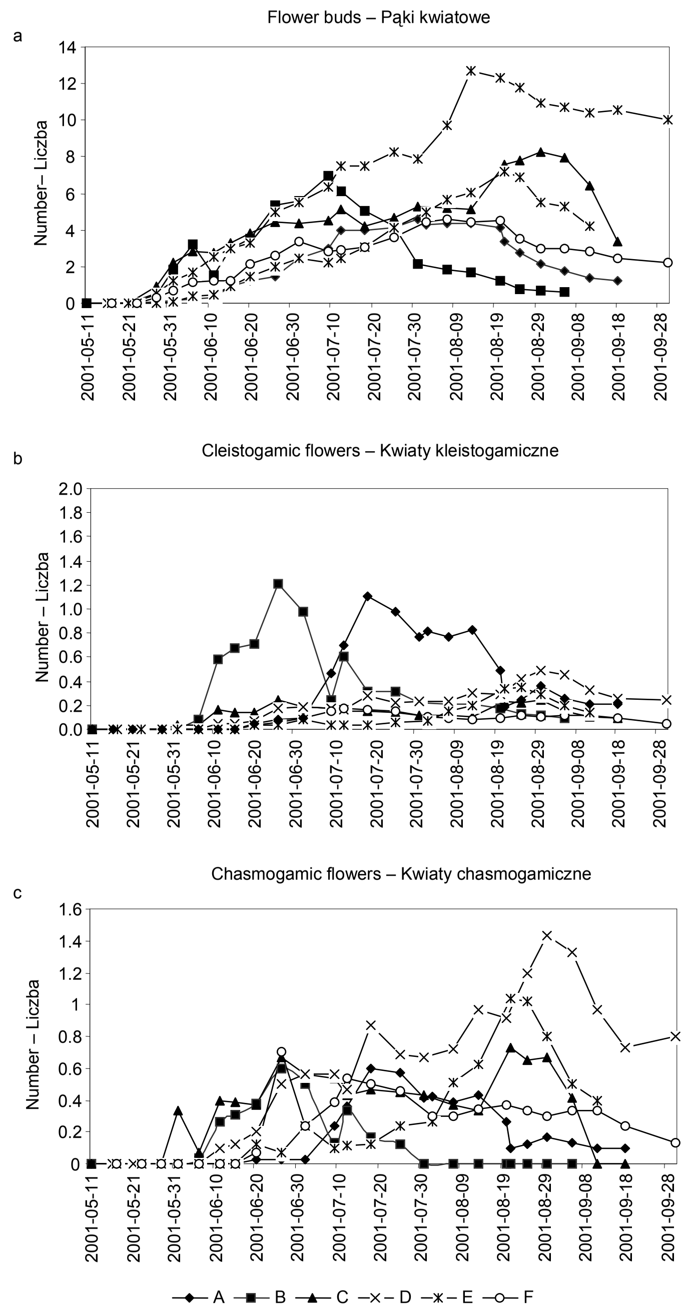

Fig. 2. Seasonal changes in bud and flower numbers on *Impatiens parviflora* DC. in oak-hornbeam forest (A-E) and ecotone area (F)
Ryc. 2. Sezonowe zmiany liczby pąków kwiatowych i kwiatów na *Impatiens parviflora* DC. w lesie dębowo-grabowym (A-E) i ekotonie (F)

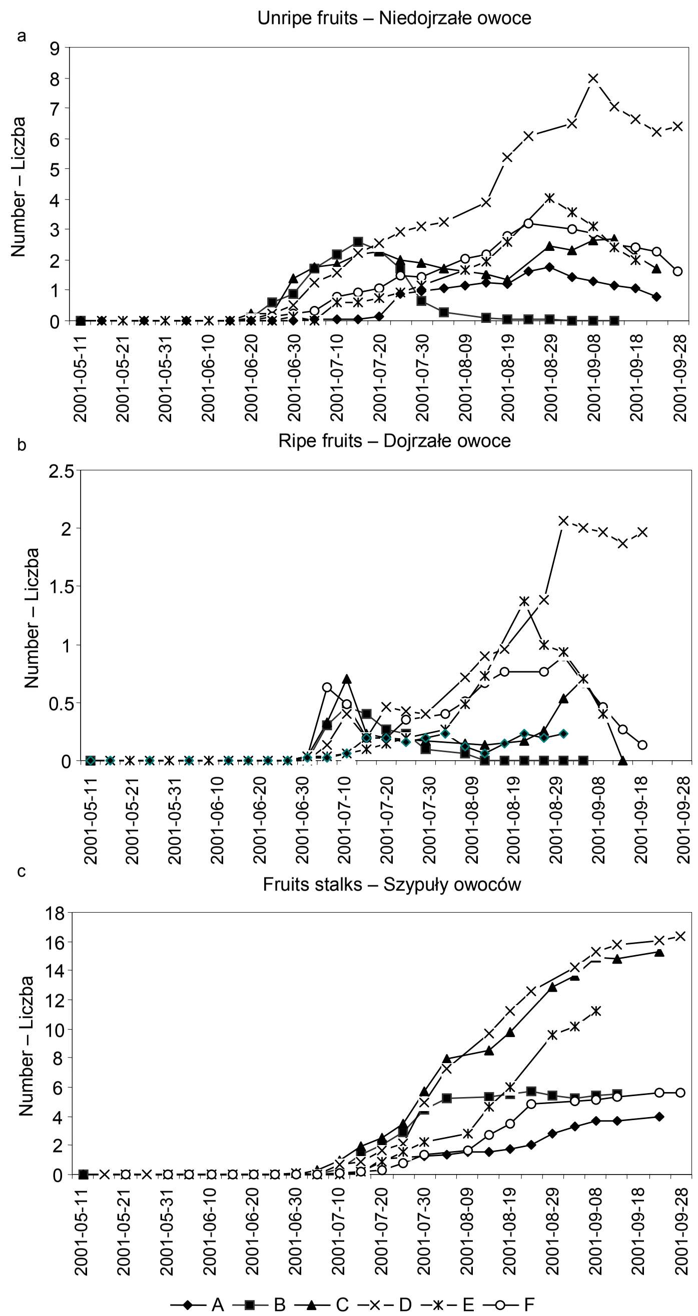

Fig. 3. Seasonal changes in the number of fruits and stalks after fruiting on *Impatiens parviflora* DC. in oak-hornbeam forest (A-E) and ecotone area (F)
Ryc. 3. Sezonowe zmiany liczby owoców i wolnych szypuł po owocach na *Impatiens parviflora* DC. w lesie dębowo-grabowym (A-E) i ekotonie (F)

In August no fruits were observed on plants, and no increase was found in the number of petioles left on the plants after fruits were dropped. In the other oak-hornbeam forest patches, as well as the ecotone zone plants flowered and fruited as late as September.

Conditions under which balsam develops affect significantly the intensity with which reproduction organs are produced. The biggest numbers of flower buds, flowers and fruits are observed on these specimens, which develop in tree stand gaps, i.e. in experimental plots C and D. The lowest numbers of flower buds, flowers and fruits are set by balsam plants growing under strong shade conditions, i.e. in the best preserved oak-hornbeam forest patch (A).

A detailed analysis of sequences of numbers for individual generative organs indicates as well that:

– Flower buds remained on plants until the end of their life cycle (Fig. 2 a). During the last measurement the biggest numbers were observed in specimens from tree stand gaps, while the lowest in samples from plots A and B;

– The percentage of cleistogamous and chasmogamous flowers showed spatial diversification. Along with increasing shading the pool of self-pollinating flowers increased to 65-70%. In plots C, D, E and F approx. 75% flowers were chasmogamous flowers. The intensity of production of both flower types occurred under identical environmental conditions at approximately the same time;

– In spite of rather large discrepancies in the time of fruit setting their ripening occurred almost simultaneously on all the analyzed plots. The course of curves of dynamics in case of production of ripe and unripe fruits is very similar; moreover, large similarities are found with the course of curves for flower production. The biggest consistency was observed in the patch of hornbeam invasion (E) and in the tree stand gap (D).

The change in the number of petioles remaining after fruits were dropped was used as a measure of seed dispersal dynamics. Detailed observations of the fruiting process in *Impatiens parviflora* showed that some fruits drop before seeds are completely formed. In such a case fruit drop is not preceded by their opening and seeds originating from these fruits do not participate in the recruitment of a new generation. Thus, this index is a certain oversimplification and need not be connected with the fertility of these specimens.

In some cases (B, C, D) the presence of the first “free” petioles was observed on the day when the first ripe fruits appeared. The rate of seed dispersal was initially slight and it increased afterwards. The highest increase was observed in tree stand gaps. Values reported here on the last day of observations were 16.4 for plot D and 15.3 for plot B, respectively. The lowest increase was found in the best preserved patch of oak-hornbeam forest (the final value of 3.97). Due to the replacement of specimens in plot B a decrease in the curve slope was observed.

May thus lifetime seed production be determined for an individual specimen? Certain indications may be the number of petioles left after capsule drop and the size of fruits and the number of seeds, which had been found in them. Due to the above mentioned premature fruit drop the obtained results may only be treated as estimates. Mean lengths of mature capsules ranged from 1.09 cm to 1.79 cm. Plants developing in strongly shaded sites had the smallest fruits, whereas the largest were observed in plants, which were growing on plots D and E. The number of seeds in capsules ranged from one to four. Irrespective of site conditions, the percentage of capsules containing one seed was the highest. On the basis of the presented data it was found that in case of *Impatiens parviflora* plants their lifetime production of seeds ranged from four to 21 (Table 1).

Table 1

Estimated individual seed production of *Impatiens parviflora* DC. in oak-hornbeam forest (A-E) and ecotone area (F)

Szacunkowa osobnicza produkcja nasion *Impatiens parviflora* DC. w lesie dębowo-grabowym (A-E) i ekotonie (F)

Locality Powierzchnia	Fruits length Długość owoców (cm)	Participation of fruits which contain Udział owoców zawierających				Mean stalk number on specimen Średnia liczba szypuł na osobniku	Estimated number of seeds produced by plant during the vegetation period Szacunkowa liczba nasion wyproduko-wanych przez roślinę przez cały okres wegetacji
		one seed jedno nasiono	two seeds dwa nasiona	three seeds trzy nasiona	four seeds cztery nasiona		
		(%)					
A	1.23	100	–	–	–	4	4
B	1.37	94	6	–	–	5	5
C	1.48	94	6	–	–	15	16
D	1.79	72	21	6	1	16	21
E	1.71	87	10	3	–	11	12
F	1.49	92	8	–	–	6	6

Discussion

Models of therophyte resources distribution assume an abrupt transition from the vegetative to generative phase. Then all the energy inputs are used to produce reproduction organs. It is manifested in the rapid growth retardation of body size and biomass of shoots and leaves from the moment first flower buds are set (Kermit 1983 after **Symonides** 1988, **Symonides** 1987 a, **Kozłowski** 1992). These studies showed that after its transition into the generative phase *Impatiens parviflora* continues to grow and increase the number of leaves. **Symonides** (1988) confirmed that such a situation may occur when the plant begins to produce generative organs early.

The conducted observations show that in diverse patches of oak-hornbeam forest *Impatiens parviflora* enters the phase of generative development early and almost simultaneously. Early initiation of flowering occurs frequently, especially in these therophytes, which have adapted to living in a periodically disturbed environment (**Symonides** 1988).

The analyzed species is characterized by a very long period of generative development. This character of balsam was pointed out previously by other researchers (**Erkamo** 1952, **Coombe** 1956, **Trepl** 1984, **Rameau** et **al.** 1989).

Irrespective of the condition under which the plants develop, excessive production is observed of reproductive organs, which will not be used in reproduction, since ripe fruits will not develop from them. These observations were made by the author also during her studies on the phenology of balsam (**Piskorz** and **Klimko** 2002). It is difficult to determine why an annual plant would afford such energy loss.

In case of expansive plants belonging to the so-called weeds, situations were frequently observed (**Palmblad** 1968), when reproductive effort considerably exceeded the value, which would make it possible for the species to remain in the occupied area. Other studies indicate that a high reproductive effort is a characteristic of numerous annual species (**King** and **Roughgarden** 1982). In view of this information it seems likely that in such an expansive therophyte as *Impatiens parviflora* high overproduction of seeds and a very high reproductive effort (RE) will be observed. However, studies conducted in the Wielkopolski National Park did not show high values for any of these characters. It is estimated that specimens produced from four to 21 seeds during the entire vegetative period, while RE was approx. 1-2.5% including flowers and fruits. The listing below presents the results of other studies on the same, as well as other closely related species.

– **Eliáš** (1992) showed that the input of biomass into flowers and fruits in the tallest specimens of *Impatiens parviflora* (exceeding the height of 1.06 m), which were growing in the forest marginal zone, was 7.43%. The mean for the whole population was higher (9.2%). On this basis a ratio of generative organ weight to the total weight of the plant may be calculated, yielding an estimate of the RE value (actually overestimated), which in dominants is 10.9% while in all plants – 8.1%, respectively. Both results do not indicate the occurrence of overproduction of ripe fruits and seeds.

– **Coombe** (1956) estimated that a well-developed specimen of small-flowered balsam disperses a total of 10 seeds in the period of three months.

– **Abrahamson** and **Hershey** (1997) found that reproductive effort in *Impatiens capensis* is 7.1% in dry habitats and 7.4% in damp habitats.

– **Falencka-Jabłońska** (1991) stated that the mean number of fruits in *Impatiens noli-tangere* in *Tilio-Carpinetum* forests is 1.3 (specimens with cleistogamous flowers) and 4.2 (including cleisto- and chasmogamous flowers). In the *Circaeo-Alnetum* community the number of fruits was 3.0 and 16.3. Thus, the mean number of seeds ranged from 6.2 to 14.5. In tree stand gaps in the subcontinental oak-hornbeam forest plants produced most frequently from 7 to 11 seeds, while in gaps in the ash-elm riverside carr from 3 to 7 seeds, respectively.

The studies cited above indicate that species from genus *Impatiens* do not show a high biotic potential and justify the claim that reproductive potential may be considerably modified by environmental factors.

Conclusions

1. In contrast to numerous annual plants, in small-flowered balsam there is no time division of energy resources into vegetative and generative development.

2. In differing patches of oak-hornbeam forest *Impatiens parviflora* enters the phase of generative development early and almost at the same time, generative development is extended and finishes earlier in semi-shaded sites in comparison to the other patches.

3. Production of flowers and fruits is strongly modified by environmental factors. Plants growing in tree stand gaps flower and fruit most abundantly. The lowest numbers of generative organs are set by these specimens which develop under a compact canopy of the tree stand in the best preserved patch of oak-hornbeam forest.

4. Previous observations (**Piskorz** and **Klimko** 2002) confirmed that in the oak-hornbeam forest overproduction is observed of reproductive organs, which are not used in reproduction. This is a common phenomenon. Habitat conditions determine only the intensity of overproduction.

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WPŁYW ZRÓŻNICOWANIA GRĄDU NA KWITNIENIE I OWOCOWANIE *IMPATIENS PARVIFLORA* DC.

S t r e s z c z e n i e

Rośliny jednoroczne wyróżniają się spośród innych bardzo silną plastycznością fenotypową w zakresie cech związanych z reprodukcją generatywną. Celem badań było określenie wpływu mozaikowego zróżnicowania płatów *Galio sylvatici-Carpinetum* na zawiązywanie i dojrzewanie kwiatów i owoców niecierpka drobnokwiatowego *Impatiens parviflora*. Stwierdzono, że w przeciwieństwie do wielu roślin jednorocznych, u niecierpka drobnokwiatowego nie ma czasowego podziału zasobów energetycznych na rozwój wegetatywny i generatywny. W zróżnicowanych płatach lasu dębowo-grabowego *I. parviflora* wkracza w fazę rozwoju generatywnego wcześnie i prawie jednocześnie, rozwój generatywny jest wydłużony, lecz kończy się wyraźnie wcześniej w miejscach półcienistych w porównaniu z pozostałymi płatami. Produkcja kwiatów i owoców jest silnie modyfikowana przez czynniki środowiskowe: najobficiej kwitną i owocują rośliny rosnące w lukach drzewostanowych, najmniej organów generatywnych zawiązują te osobniki, które rozwijają się pod zwartym okapem drzewostanu w najlepiej zachowanym płacie lasu dębowo-grabowego. Potwierdzono wcześniejsze obserwacje (**Piskorz** i **Klimko** 2002), że u niecierpka występuje nadprodukcja organów rozmnażania, które nie są wykorzystane w rozmnażaniu. Obecne badania wskazują, że warunki występowania decydują o nasileniu nadprodukcji.

Author's address:
Renata Piskorz, Katedra Botaniki, Akademia Rolnicza im. Augusta Cieszkowskiego w Poznaniu, ul. Wojska Polskiego 71 C, 60-625 Poznań, e-mail: reniapis@au.poznan.pl