University of Western Hungary
Doctorial School of Forestry and
Game Management Sciences

Doctorial (Ph.D.) thesis themes

Research of the spread strategies of the small balsam (*Impatiens parviflora* DC.) and the fireweed (*Erechtites hieracifolia* RAF. ex DC.)

Author:
Ágnes Csiszár

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Doctorial School: Gyula Roth Forestry and Game Management Sciences Doctorial School

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Director of studies: Dr. habil. Dénes Bartha

1. Preliminary and targets of researches

Biodiversity on the Earth is mostly endangered by ruination and fragmentation of habitats which factors are tightly followed by introduction and immigration of alien species. Species arriving to a new territory are usually not able to survive longer and only a few acclimatized ones will disperse invasively. However these species can be really harmful for native flora and fauna and may lead to global uniformness. So the effect on ecosystems as the invasive dispersiveness of each adventive plants are different also every habitat or conenoses can resist distinct way the alien species' invasions. Natural forest habitats in Central Europe have few persistent neophyte herbs and they are present mainly nearby the recent and ancient settlements. Nevertheless the small balsam (*Impatiens parviflora)* cca. 150 years after its introduction has become denizen and dispersed in Europe, occupied both open and semi-covered forestal habitats. Hungarian occurrence data of the fireweed (*Erechtites hieracifolia)* are principally connected to forestal habitats as well: it mostly appears in forest cuttings, along the forest-paths or forest-clearings. According to the actual Hungarian list of neophytes the two species I had chosen for doctorial thesis are both qualified as invasive neophytes. I have found both in huge numbers during my fieldtrips in the Sopron Hills; their dispersion is well observed phenomena recently. Analysing literature, data sheets of herbaria and flora maps I have drawn up the actual status of the two species in Hungary. As results the small balsam is exceedingly spread in West Transdanubia, Transdanubian and Northern Hills also along by the larger rivers. fireweeds' centre of occurrence is situated in the western region of Transdanubia, besides sporadically present in higher hills and some data are known from the Great Plain and Little Plain, too.

Whereas external (environmental) and internal (morphological, physiological) characters can also support acclimatization and propagation of the plants, so reasons of the two studied species' invasive success hereafter I approached by the environmental and plant views. First in my research I carried out instrumental measures of soil factors and analysed ecological indicators of the species that were presented in focused habitats. Both studied herbs are annual so their introduction and dispersal depend on generative reproductive success eminently that can be ensured by the bountiful seed production, prolonged germination spectrum and long seed viability. In the phase of introduction and spread allelopatic effects mean disadvantage for other plants' grow and development, therefore support effectively the adventive species.

Active regenerative capacity ensures species' successful adaptation to disturbance, so investigation of that may help us in repulsing this species. It is known that adventives are able to conquer new grounds because they have left their consumers and parasites behind at home. By the research of interactions between plants and animals we can get information not only the adventives plant's effects on the fauna, but also about the actual parasites that cause serious damages and may applicable for biological defence. In laboratory and field works I was aimed to draw scientific pictures of biotic and abiotic factors which play a role in the two species adaptation and propagation, consequently may usable against further expansion. Location of studies was Sopron Hills having both plants in large number in typical habitats. Working on my thesis about the small balsam (*Impatiens parviflora* DC.) and the fireweed *(Erechtites hieracifolia* RAF. ex DC.) I targeted the following questions:

- Where do the two species occur in Hungary based on literature, herbaria and flora-mapping data?
- How can we characterize their habitat in the Sopron Hills by Borhidi's Social Behaviour Types and Raunkiaer's life forms and Naturalness Valueses?
- Is there any observable other species that are de-emphasized by the two?
- How can we describe by soil parameters of the studied species' habitats in the Sopron Hills?
- If the differences in soil parameters can cause presence or absence of the two plants in the Sopron Hills?
- How much is the quantity of the two species seed and crop production?
- What kind of germination phenology is typical for the species in vitro (in laboratory) and in vivo (green house) conditions - germination of the soil seed bank?
- Which seed bank type do they belong as a result of the greenhouse seed bank germination?
- Have they got any allelopatic effect and (if they have) how does it appear in the inhibition of *Sinapis alba* (white mustard) and *Quercus petraea* (sessile oak) as test species germination and growth?
- How do the studied species regenerate in different phenophasis after variant sized cut back?
- Which consumers, pollinaters and pathogen organizations connect directly or indirectly to the researched species, also what is their function in distribution of the species?

2. Materials & methods of the research

2.1. Habitat characterization of the small balsam and the fireweed in the Sopron Hills

In the Sopron Hills area 10 parcels with 5 x 5 metres sides were marked out in both plants case. Six of ten quadrates in the sampled area of the studied species had contained the species with several coverance value, the rest four parcels acted as control ones. I made coenological measurements in each quadrate included control as well, and then tested by counting Borhidi's Social Behaviour Types and Raunkiaer's life forms group mass and group portion also the Naturalness Valueses (P).

2.2. Soil characteristics of the habitats of the small balsam and the fireweed in the Sopron Hills

2.2.1. Analysing the ecological indication among Borhidi's relative ecological indicator values using the relative groundwater and ground humidity indicator numbers (WB), soil reaction relative value numbers (RB) and nitrogen demand relative value numbers (NB) were counted the group portions of the plants in sample and control areas. In between difference of the measured parameters were tested by InStat statistical program and t-test.

2.2.2. Soil characters technical measurements were carried out as follows: I took soil samples from every quadrate, three different places and two depths (0-10 cm and 10-20 cm) per each, after then pH value, total nitrogen and humus content were determined.

2.3. Study of the generative reproduction (seed production, germination spectrum, seed bank)

2.3.1. For determination of seed production and crop production in case of the two species I have counted the number of achenes and seeds in 30-30 individual plants.

2.3.2. Annual germination spectrum of the species were measured at room-temperature and in dark using PETRI-dish between two wet (by 5ml tap water) filter-paper with 3 x 50 seeds per species starting germination measurements in every month.

2.3.3. Study of the seed bank was carried out with 1200 cm^3 soil sample per parcel, from three places and two depths (0-5 cm, 5-10 cm) in each parcel. Seed banks were investigated by germination in greenhouse from March till October next year.

2.4. Study of allelopatic effects

2.4.1. Effects of extraction made from the shoots of *Impatiens parviflora* and *Erechtites hieracifolia* were tested on seeds germination of *Sinapis alba* first. Germinations of mustard seeds were carried out at room-temperature and in dark using PETRI-dish between two wet (by 5ml tap water) filter-paper. I made watery extractions of each examined plants with following concentrations: 1 g/100 ml, 3 g/100 ml and 5 g/100 ml. I recorded the germinated mustard seeds number on the third day. For evaluation of the results I applied InStat statistical softwer package and χ^2-test.

2.4.2. During the previous experiments the extraction of small balsam had only a mild effect while the extraction of fireweed significantly declined the rate of *Sinapis alba* seeds' germination therefore I tested allelopatic effect of fireweed on *Quercus petraea* acorns later. In the experiment 100 acorns were germinated on filter-paper covered cotton-wool at room-temperature in penumbra. Fifty of them were warred by tap water as control and fifty by fireweed extraction of 5 g/100 ml concentration. The number of the germinated acorns had been recorded during two months and the length of growing radicles during six weeks. Results were analysed by Instat statistical software and t-test.

2.4.3. In addition to study of Erechtites *hieracifolia* allelopatic and competitive effects versus *Quercus petraea* I sowed 3 x 50 acorns of *Quercus petrae* into perlite in unheated greenhouse. Fifty acorns acts as control which were watered by tap water, fifty were covered by dried fireweed shoots and beside other fifty acorns I sowed 70 achenes of fireweed. I made notes about the numbers of seedlings, height of oak upgrowths and the number of leaves. Analysis of the results was carried out by InStat statistical program package. In case of height measurement of oak upgrowths I applied t-test and in case of leaves' number measurements I used Mann-Whitney-test.

2.5. Examination of the regenerative capacity

For the examination of regenerative capacity I cut back topshoots of 200 individuals of each species, half of them I cut back until 15 cm from the ground, and left 5 cm stem for the rests. I made it two times: first in the vegetative secondly in the generative phase of plants. According to cut-size I recorded the numbers of sideshoots and length of the longest sideshoot in case of 50-50 plants.

2.6. Study of interactions between plants and animals

Studiing plant and animal interactions I examined 100-100 individuals of both plant species to count the insects that were found on them. After recording data I divided insects into following groups: phytophages, mycetophages, phloem suckers, afidophages, predators, parasites and flower visitors. Insects were identified by Mr. György Traser.

2.7. Study of phytopatogenic mycetes

In case of plant and animal interactions of the small balsam I noted the numbers of leaves and individuals that were attacked by mycetes, however I had not found this signs on fireweeds individuals. Spores on the collected leaves were identified by Ms Ilona Szabó.

3. Results of researches

3.1. Habitat characterization of the small balsam and the fireweed in the Sopron Hills

Group portions of Social Behavior Types of the species found in the sampling and control sites of small balsam have shown large similarity and there haven't been any significant difference in Naturalness Valueses either. In case of fireweed difference in group portions had found between sample-sites and control-sites, in the latter one rate of natural competitors and specialists was higher, while the rate of aggressive, alien competitors, weeds and ruderal competitors showed lower degree. Naturalness Valueses of the two sites slightly differ from each other. Measurements of group mass had leaded to similar results in both species: sample-sites were characterized by significant group mass of aliens and aggressive competitors due to the presence of the two invasive plants. In control-sites mainly disturbance tolerant plants of natural habitats have occupied the empty niches of these plants, furthermore in case of the small balsam the natural competitors while in case of the fireweed the native flora ruderal competitors and specialists were presented with larger group mass. Distribution of Raunkiaer's life forms were resemblant in sample and control sites with significant dominance of the perennial herbs in each studied unit, group portion of annual herbs have reached only about half of that though as regards the number of individuals annual plants formed the dominant group. Consequently at the time of recording in the focused area if not in case the number of species but native species had been decreased in the number of individuals and crowd, however durability of this state is different at the two studied species. Number of fireweeds gradually decline from the fourth and fifth year after forest cutting in the area, then the species disappear from surface vegetation as succession goes ahead. Presence of small balsam is permanent though at the beginning settle on empty soil surfaces which are not covered by other plants. Where it occurs in high quantity may cause recession of other forestal herbs of undergrowth.

3.2. Soil characteristics of the habitats of the small balsam and the fireweed in the Sopron Hills

As regards humidity of ground, chemical reaction, content of nitrogen and humus as studied parameters showed excessive similarity among the sampling and control sites in both species, so their presence in the sampling sites and absence in the control sites were not interpretable by any difference of soil characters. Results of the measurements presume that the presence of the small balsam and the fireweed may depend on disturbance and succession state differences. Results of field and laboratory works indicate neutral, mesotrophic, nitrogen- and nutrient-rich humic soil in the habitat of small balsam in the Sopron Hills. In case of the habitat of fireweed detectors and species' indicator values also show nitrogen and nutrient-rich humic soil, but in point of chemical reactions the two methods have leaded to divergent results. Laboratorial examinations indicate acid soil reactions while the coenological records' highest group portion appeared at plants of neutral habitats and high-tolerant indifferent species. Differences are likely come from the early phase of succession when the less specialised, neutral soil-liker and disturbance-resistant and weed form species are dominant, nevertheless several strong acidophil, acid chemical reaction indicators, moderate and less acidophil plants occurred in the records as well. Study of soil characteristics from the point of the two species' habitat demands view increase our knowledge and characterize the habitat of neophytes in the Sopron Hills.

3.3. Study of the generative reproduction (seed production, germination spectrum, seed bank)

For my experienced results the two studied species the productions of seed and crop were different in order: seed production of the small balsam was 369 per individual contrary to the fireweed had 32390 seed per individual. The reasons of discrepancy are likely come partly from the different morphology, taxonomy and partly from seed production that reciprocally proportional of seedmass in case of the two species. Seed productions defined by the measurements overpass the literature data of both species, so ensure the settle and distribution of the plants built upon this bountiful seed production. Study of germination phenology has conducted to significantly different result at the two species. In case of germination at room-temperature the fireweed achenes were germinating all year except two months which feature ensures the continuous spread at favourable temperature conditions. However none of the seeds of the small balsam had started germination during the experiment.

Seed bank of the soil was studied by germination in greenhouse. In case of the fireweed seedlings appeared in crowds in the first week of the experiment period and were germinating from the beginning of April till the end of July. The species have germinated from the seed bank of sampling and control sites as well thus its presence in the sampling sites and absence in the control sites are not interpretable by the presence or absence in the seed bank. Proportion of germinated achenes of upper and lower soil strata qualified the seed bank type of the fireweed to short-term persistent namely the survivor of its seed can reach 2 up to 5 years. The small balsam hadn't germinated in the first year and only one seedling appeared in the second year of the greenhouse experiment. Low vigour of germination of the species had experienced during the studies may explicable that ceasing of seeds dormancy is a result of many factors complex effect. Probably there hadn't given the requisite conditions for releasing of dormancy: this could be deficiency of humidity under storing or length of storage-time before stratification also might be the contamination of seeds.

3.4. Study of allelopatic effect

Watery extractions of the small balsam (concentration: 5 g/100 ml) and the fireweed (concentrations: 3 g/100 ml, 5 g/100 ml) inhibited significantly the germination of the white mustard seeds. Allelopatic effect of fireweed compared with small balsam was stronger, henceforth the allelopatic effect of fireweed (concentration: 5 g/100 ml) was studied on acorns of sessile oak which is an autochthonous stand species and forest-economically important tree. Treatment of fireweed extraction had depressed the ratio of the acorns germination and the average length of radicles. Results of the greenhouse experiments have certified that fireweed retards not only the germination of acorns but also the seedlings' growth and development: in case we sowed acorns and fireweed together height and number of leaves of the sessile oak seedlings fall behind the control. This shows competitive activity beside allelopatic effect. Finally, the experiments have certified the small balsam mild, and the fireweed more expressed allelopatic potecial. Treatments were all carried out by watery extractions which may happen in natural conditions by rainwater wash-out, however allelopatic effects of the extractions should be tested in the plants' habitat.

3.5. Examination of the regenerative capacity

Both plant species have regenerated considerably fast and effectively in generative state following 15 cm cutback: burgeons appeared on the new side-shoots at the fireweeds during the second but at the small balsams' individuals during the first week then turned to flowers and fruits. After cutted-back in vegetative phase the fireweed regeneration was similar in tempo and degree to generative state. In contrast individuals of the small balsam have died in few weeks after cutback in vegetative state. Effects of 5cm and 15 cm long cutback were remarkably different in the two plant species. After 15 cm long cutback one part of the individuals have regenerated successfully but following 5 cm cutback, even if the generation of side-shoots had started, individuals have died shortly or long time after and none of them have reached to generative phase. Damaging affections of cutback were exaggerated by aridity and intraspecific competition. Different regenerative capacity of the two studied plants may explicable with diverse morphology, the inferior part of the stems have different number of nodes which predestines the possible sideshoot numbers.

3.6. Study of interactions between plants and animals

This research have revealed through direct or indirect feed connections 212 individuals of 45 arthropod species in case of the fireweeds and 1528 individuals of 17 species in the small balsam. On the fireweeds leaf miners were the most important phytophages, their tunnels occurred in 29 percentages of the plants. Parasitoid wasps which are parasiting leaf miners have been observed five times. Phloem-suckers occurred in 28 percentages of plants: 17% chinches, 5% cicadas, 6% had aphides and wax insects. Aphidophages that feed on aphides were presented by 4 species and appeared on 17 plants. Fireweed have characterized by very rich flower visitor fauna, altogether 42 specimens of 16 insects family have visited the plant species: for feeding there were usually dipteras and hymenopteras. Also 16 specimens of 6 species of predators were presented on fireweeds which hunt for afidophages, phytophages, floem-suckers and visitors of flowers. Phytophages of the small balsam were leaf miners in the largest number; their tunnels have been found on 34 leaves of 20 plants. Phloem-suckers were the most remarkable group of the small balsam's insect fauna with 1442 aphides and 74% of presence on plants. Rich colonies of aphides serves as feed-source of hoverflies larvae also frequently visited by ants collecting honey-dew, afidophages occurred in 22% of the plants.

Aphidophages were prey of spiders primarily among predators, spider species involved four families. During the research I found quite poor fauna of flower-visitors that included cockroaches (*Ectobiidae*), blossom beetles and tumbling flower beetles (*Mordellidae*). Following literature data I could only observe hoverflies one year after the study period, however as regards of the small balsam the mechanism of self-pollution also support the success of the generative reproduction. Though in case of both species I have observed several consumer organizations, I haven't recorded any serious damage or dead of plant individuals of any species.

3.7. Study of phytopatogenic mycetes

21 of the examined 100 specimens of the small balsam had uredospores and teleutospores of *Puccinia komarovii*, one of the phytopatogenic mycetes, they occurred altogether on 173 leave-backs. At the beginning of August I haven't experienced decline of vitality but it is possible that strongly infected plants died before examination.

4. Conclusions and proposals

Results of the research of the distribution strategy of the small balsam and the fireweed have remarkable outcomes that help us to better understanding the background of plant invasions by the presentation of supporter and retarder factors of the two species distribution, meanwhile used for prevention of the species' invasion or limitation of their spread. The small balsam can form extent, continuous aggregations reducing the diversity of upgrowth in our semi-humid deciduous our in park forests of river-flats. Based on my studies in the Sopron Hills survive and distribution of individuals can repulsed by aridity or propagation of aphides and a phytopatogenic rust fungus, *Puccinia komarovii.* According to literature data the number of seedlings was reduced by frost in early spring. Natural vegetation compositions with dense upgrowth can stop the further spread of the plant, meanwhile distribution and formation of open ground-surfaces give offer favourable conditions for penetration and settle of the species. So conservation of our forests' naturality is deeply considerable. If the species has already multiplied it may necessary to pull back its further distribution. Based on experience of the regenerative potential experiments in mechanical treatment of the plant in vegetative state is a successful counterwork against the species' distribution. In generative state following cutback the plant regenerate quickly by dichotomy of the upper sideshoots and have flowers and crops soon. In this phase only cotyledons and cutback under the shoots formed in the cotyledons' axillae inhibit successful regeneration of plants because leafy shoots don't grow from the hypocotyls. Mechanical treatments realized in vegetative phase are more favourable from the point of maturation delimitation therefore only one treatment could lead us to the demanded result. For biological control of the species' number of individuals it is necessary to consider the apply of the tightly connected consumers and pathogens: in case of the small balsam the *Phytoliriomyza melampyga* leaf miner species, the *Impatientinum asiaticum* aphis species and a phytopatogenic mycete, *Puccinia komarovii* occurs quite often on the plant individuals. The *Phytoliriomyza melampyga* appears on the native *Impatiens noli-tangere*, but the *Impatientinum asiaticum* have settled successfully on the *Impatiens glandulifera* and it is not impossible that the distribution will continue. The *Puccinia komarovii* can infect other species of *Impatiens* genus as well, though literature data haven't mentioned any harm of the *Impatiens noli-tangere*. The abovementioned enumeration shows that without complex knowledge about the hostspecifity of pathogenic and harmful organizations the biological applications would mean non-incurable risks.

The fireweed could be multitudinous on forest cutting in the third or the fourth year after tree cut; the nearly two-metre high specimen can have the advantage over other species fighting for light, water and nutrients. Beside interspecific competition their allelopatic effect can be also expressed thereby retarding development and growth of saplings. Disturbation and fire help the germination of achenes: the plant often becomes dominant after burning an area. Where it occurs in aggregations beat back of the species may be necessary from forestal-economicaly or conservational interest. Results of the regenerative potential experiments show that given population of fireweed can be weaken indeed by two-times mechanical treatment per year. In addition arid weather of the summer can enhance the number of perished individuals. Chemicals washed-out by the rain from the bagged individuals, that can cause allelopatic effect so it's better to remove them after the treatment. Study of interactions between plant and animals have revealed aphides and leaf miners connected to the plants in the largest number of individuals. Nevertheless presence of consumers haven't eventuated the reduction of individuals vitality, thus apply them in biological treatment against fireweed is unjustified so far. However identification of the insect species and mapping of their hostplant spectrum is necessary as well.

Publications connected to the thesis

Books chapters:

- BARTHA, D. − CSISZÁR, Á. 2004: Green ash. In: MIHÁLY, B. − BOTTA-DUKÁT, Z. (ed. by): Biological invasions in Hungary. Invasive plants. − Volumes of the Nature Conservation Office, Ministry of Environment and Water. Vol.: 9. TermészetBÚVÁR Foundation Press, Budapest, pp.: 131-142.
- BARTHA, D. − BOTTA-DUKÁT, Z. − CSISZÁR, Á. − DANCZA, I. 2004: Function of ecological and green corridors in distribution of the invasive plants. In: MIHÁLY, B. − BOTTA-DUKÁT, Z. (ed. by.): Biological invasions in Hungary. Invasive plants. − Volumes of the Nature Conservation Office, Ministry of Environment and Water. Vol.: 9. TermészetBÚVÁR Foundation Press, Budapest, pp.: 111-122

Scientific publications:

- BARTHA, D. – CSISZÁR, Á. 2004: Adventive Taxa in der ungarischen Dendroflora. − Mitteilungen der Deutschen Dendrologischen Gesellschaft **89**: 149-162.
- CSISZÁR, Á. 2004: New seed bank records for species of the Hungarian flora − Tájökológiai Lapok **2** (2): 219-229.

Other publications:

- CSISZÁR, Á. 2001: Strategy of weeds. Why introduced plants expand? − Élet és Tudomány **56** (50): 1580-1582.

Oral presentations:

- CSISZÁR, Á.: Study of the communities-relation of the small balsam (*Impatiens parviflora* DC.) and the fireweed (*Erechtites hieracifolia* RAF. ex DC.) in the Sopron Hills. − Session of the Hungarian Biological Association Department of Ecology. Title of the session: „Plant invasion". METESZ Conference-center of Buda, Budapest. 12 April 2001.
- CSISZÁR, Á.: Survey of seed banks weed and cutting associations in the Sopron Hills. − II. Carpathian Basin Biological Symposium, Botanical section. Hungarian Natural History Museum. 22 November 2001.

Poster presentations:

- CSISZÁR, Á.: Adventive plants in the Sopron Hills. − Actual flora a vegetation research in Hungary. III. National Conference, Szombathely, 1999.
- CSISZÁR, Á.: Study of ecological factor that affect distribution of adventive plants in the Sopron Hills. − V. Ecologist Congress in Debrecen, 2000.
- CSISZÁR, Á.: Research of seed bank of forest-habitats in the Sopron Hills. − Actual flora and vegetation research in the Carpathian Basin V., Pécs, 2002, pp.: 94-95.
- CSISZÁR, Á.: Investigation of insect fauna on the fireweed and the small balsam. − Gödöllő, VI. Hungarian Ecologist Congress. Abstracts of presentations and posters. 2003, p.: 66.
- BARTHA, D. – CSISZÁR, Á.: Adventive tree and shrub species in Hungary. − 7th International Conference on the Ecology and Management of Alien Plant Invasions. Wyndham Bonaventure Resort, Ft. Lauderdale, Florida, November 2003.

Reports of researches:

- "Research of few aggressively spread plant species" OTKA project grant (Number: T 033114), 1999-2003.
- "Investigation of pesticides in afforestations of the TAEG Inc. Hill-country Forestry" project
- „Working-out of a technology for reduction of the alien trees. First part: the black locust."
- „Distribution of invasive plants and their conservational control strategy in Hungary, chapters: I.-II."