ROSALIA Handbooks

Practical Experiences in Invasive Alien Plant Control




Duna-Ipoly National Park Directorate

Financial support for this manual has been provided by “Unified protection against invasive alien plants in sand and floodplain habitats” project. The aim of this project was to control invasive alien species (IAS) in sand and floodplain areas of Hungary and Slovakia, between 2012 and 2014. Duna-Ipoly National Park Directorate (DINPD) and its partner, Regional Association for Nature Conservation and Sustainable Development (BROZ) carried out the following actions:

- Know-how of former projects and management activities were compiled, area managers were trained.
- Species specific treatment was applied to control the most problematic species for conservation in 3 sites in Slovakia and 5 sites in Hungary, in floodplain and sand habitats. Total managed area in the project was 645 ha.
- The most important farming and managing stakeholders of IAS control were involved to change attitude and behaviour as well as to exchange professional information.

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PRACTICAL EXPERIENCES IN INVASIVE ALIEN PLANT CONTROL

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PRACTICAL EXPERIENCES IN INVASIVE ALIEN PLANT CONTROL

Edited by
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Preface

When the national park directorates were deprived of the power of authority ten years ago, it is safe to say that it marked the beginning of a new era in nature conservation in Hungary.

This new era has inevitably brought new challenges but at the same time new opportunities, to which the Duna–Ipoly National Park Directorate have tried to respond in a timely manner. We have placed a stronger emphasis on research to aid our professional activities, and on conservation management and treatment experiments. In addition, we have strived to consolidate and summarise the continuously accumulating new information with scientific precision. This motivation gave rise to the Rosalia Volume of Studies series, as well as the Rosalia Handbooks – the third issue of which you are holding in your hands – which aim to share professional experiences of treatments.

After editions on the management of the grasslands under protection, and on the improvement and maintenance of the natural conditions of protected forests, we now focus in this third edition on an equally urgent problem. Here we discuss the theory and domestic practices of controlling the spread of invasive alien plant species, primarily based on projects that were implemented by the directorates of national parks and researchers of higher education institutions. This issue does not aim to provide the reader with methods, technologies and treatment tips that are universally applicable under all circumstances. Given the topic at hand, that would be impossible. However, besides describing our successful results, we also try to give an account of failed attempts. Our foremost objective is to provide those who are interested in this field with a point of view, a direction, advice about potential further steps as well as possible solutions – and we have tried to accomplish all this in an accessible manner.

The handbook contains thirty manuscripts that provide an insight into treatment methods applied in Hungary by the researchers of national parks and institutions of higher education. Compiling the experiences gathered on areas with different characteristics, we have created a concluding chapter that presents the possibilities for conservation management for each species. I hope to have been able to spark your interest with these opening thoughts.

I wholeheartedly recommend the third issue of the Rosalia Handbooks to those who deal with the control of invasive species on a daily bases, to conservation professionals, farmers, NGOs and all citizens committed to, and actively involved in, the conservation of our natural heritage.

Budapest, January, 2015

András Füri
director

Introduction
Ágnes Csiszár

Invasive alien species (IAS) cause serious problems in Hungary, as they do worldwide, in areas of conservation, forestry and agriculture, and even public health and the economy. To control IAS, early detection and rapid response are of upmost importance in order to prevent their further spread. If the invasion affects larger areas, the control of IAS requires considerably higher resources and budget input; the success of the eradication can also be influenced by numerous other factors. To develop elimination and control technologies which can be widely and effectively used against IAS, first we must carry out several practice-based research projects and assessments, and these may often yield unfavourable results. To reach our aim, not only comprehensive research but active exchange of information and experiences between IAS specialists is needed.

At the conference titled *"Agresszív adventív növényfajok és a természetvédelem"* (*Aggressive Adventive Plant Species and Conservation)*, organised in Jósvafő, Hungary in 1998, the list of the most dangerous alien species (at least from a conservation perspective) in this country was compiled (Sz. Tóth and Szmorad 1998). Since then, a number of publications have been issued on this topic. In Hungary, more publications have been edited that focus on invasive alien plant species. "*Özönnövények I. és II"* (*Invasive Alien Plant Species, Volume I and II)* of the Nature Conservation Office of the Ministry for Environment and Water (Mihály and Botta-Dukát 2004, Botta-Dukát and Mihály 2006) – issued within a series of special review volumes – discuss the most significant IAS of Hungary in detail, and present the taxonomy, morphology, origin, distribution, life cycle, habitat preference and biotic interactions, as well as their economic and conservation significance, together with information on their management. The first volume includes chapters titled *Theoretic Background of the Defence Against the Invasive Alien Plant Species and Activities to Control the Invasive Alien Plant Species in National Park Directorates* (Szidonya *et al.* 2004, Virók *et al.* 2004). Additionally, the chapters on each species include information on the conservation management of IAS. The publication *"Inváziós növényfajok Magyarországon"* (*Invasive Alien Plant Species in Hungary)*, issued in 2012, characterized a further 74 invasive or potentially invasive species. However, their control methods were not discussed in detail due to limitations in the scope of the book (Csiszár 2012).

Since *Invasive Alien Plant Species, Volume I* was published a decade has passed, which is a long time in invasive biology research. During this time, new adventive species have turned to be invasive or potentially invasive, and species considered invasive even before have appeared in many more new habitats. Consequently, a new handbook is needed which compiles practice-oriented experience in invasion control. (When the above mentioned publications were issued, these practices were in the experimental phase or we, as practitioners, could rely on only foreign literature.) National parks, foresters, farmers and NGOs tackle invasive alien species in several locations in Hungary. For this reason, the exchange of information and the summarisation of experiences have become essential. This handbook aims to collect the control methods and management information of the invasive non-native plant species so as to enable their eradication in different sites and habitats. However, treatments used former were sometimes unsuccessful or resulted in negative experiences: we can help to avoid these in future with the aid of this publication. In the planning phase for the preparation of this edition, we faced up to the fact that we cannot describe the eradication techniques of all the important IAS in Hungary (we either do not have adequate information or our colleagues responsible for these projects have not had the opportunity to publish the control techniques). In this handbook we intended to collate control methods for non-native invasive plant species as comprehensively as possible. Due to the size of the handbook, we do not discuss the control of the aggressively-spreading native species, which can cause conservation problems, and the technologies used in agriculture to overcome these.

In the first chapters of this handbook we provide basic information which supports and prepares IAS control (e.g. different survey methods on the invasive plant populations prior to management planning, detailed description of the eradication methods and the equipment used). These chapters are followed by case studies that describe IAS elimination and control techniques in certain areas. Each chapter begins with the presentation of the natural characteristics of the given area, as these factors can highly influence the technologies to be applied, as well as their proper execution and their success. The authors aim to describe the IAS control methods in as much detail as possible to ensure that these can be adapted by others. However, we have to note (and we often address this in the chapters that follow) that certain eradication methods can be strongly influenced by the period, method and circumstances of the management: chiefly the site characteristics and the weather conditions. These factors are presented in detail when our experiences are described. As our main goal was to compile a practice-oriented handbook, only those literature references that are the most important, topic- and practice-oriented are listed at the end of the chapters. The series of case studies is followed by summarizing chapters in which are discussed the most important conservation and economic problems caused by each IAS and the biological characteristics influencing the spread and control of the species (morphological, anatomical, physiological, reproduction biological, etc.). The chemical and non-chemical management methods are also summarized here in tables. We hope that we have managed to compile and edit a handbook that helps to prevent the further spread of the invasive alien plant species and successfully supports the conservation of our natural values.

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On the possibilities and international experience of invasive plant control

Botond Mihály

Introduction

The appearance of non-native species in new territories was previously exclusively discussed in scientific publications aimed at researchers active in that field. However, this situation seems to be changing in Hungary, as in other countries, as more and more articles are published that try to raise awareness in the general public to problems that had only previously concerned researchers. The most recent case illustrating this phenomenon is of several accounts being published in 2014 about the health risks and the appearance of giant hogweed (*Heracleum mantegazzianum*) in Hungary. It is interesting to note that the issue entitled *Biological Invasions in Hungary – Invasive alien plants*, published in the series of conservational studies of the Ministry of Environment and Water, placed particular emphasis on this plant alongside numerous other invasive species.

The ecological, environmental and economic problems caused by invasive plants are getting more and more attention worldwide. Apart from their impact on biodiversity, the scale of economic harm they cause is significant and manifold. According to estimates by the European Environmental Agency, the economic damage caused by invasive alien species on public health, agriculture, forestry and fishing is at least 12 billion euros annually in Europe alone. The United Kingdom, for example, spends annually 175 million euros on the control knotweed species (*Fallopia* spp.).

The severity of the issue is well illustrated by the fact that numerous international institutions (e.g. the IUCN (International Union for Conservation of Nature), the EPPO (European and Mediterranean Plant Protection Organization)) and various agreements (e.g. the CBD (Convention on Biological Diversity), the CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora), the IPPC (International Plant Protection Convention, Bern Convention on the Conservation of European Wildlife and Natural Habitats) have included the problem of invasive species among their objectives. However, the approach to the issue, its regulations and the funding necessary for intervention varies significantly from region to region.

The most comprehensive document dealing with invasive species in Europe is the *European Strategy against Invasive Species*, published in 2007, and also translated to Hungarian within the framework of the Bern Convention. The European regulation of the control of invasive species, to be finalised shortly, is also based on the key concepts laid down in this strategy.

The wide-ranging international activity against invasive species is mostly concentrated on familiarising interested parties with the ecology of such species, their early detection and the development of monitoring programmes. However, several island states (e.g. New Zealand, Japan and Australia) have introduced serious preventive measures, which also impact citizens, in order to control the intentional and accidental introduction of non-native species. There are examples for plant protection quarantines as well as coordinated and synergistic measures against invasive species (e.g. Biosecurity New Zealand).

Once a non-native species has appeared on a new territory, it is advisable to start control when the population is still sporadic, since there is a high probability that total control can be achieved quickly. Control in this phase requires the least investment and treatment is the most effective. Notwithstanding, we often encounter established invasive species that are already causing significant economic, environmental and health problems, which means that their control requires a short-term solution. This is exponentially true in the case of protected natural areas, where invasive species, especially invasive plants with their conversion ability, fundamentally endanger the sustenance and conservation of native habitats. When managing such territories, management must be primarily directed at preventing the spread and controlling the invasive species. Consequently, protection against invasive species is an integral part of the management plans of certain protected natural areas.

We have reached a point when the potential solutions available to land managers must be discussed so that they can meet the requirements of preserving the ecological condition of the area, while complying with the principle of "think globally, act locally". With this in mind, in the following I shall try to summarise the theoretical possibilities described in international publications. It is important to stress that there is no general method that is equally effective against all species. The methods discussed in international accounts require local, area-based adaptation, paying special attention to the complete compliance with current regulations.

Fig. 1. The beautiful Hottentot-fig. (Photo: B. Mihály)

Mechanical control

Mechanical methods (cutting, mowing, uprooting) can be applied for the control of most populations of invasive species. However, its execution is difficult in highly infested larger areas and is highly labour-intensive. It is important that mowing should be conducted when plants react in the most sensitive way and when subsequent pollen and seed dispersion can be prevented.

Let us take a look at several examples where this treatment method was found the most effective.

The Hottentot-fig (*Carpobrotus edulis*), which causes a lot of problems along the coasts of the Mediterranean Sea, was originally introduced as a pioneer groundcover plant from South Africa (Fig. 1). It has established cohesive populations in numerous areas that can only be controlled by manual uprooting (Fig. 2). The protection programme conducted by 130 volunteers on an area of 10,000 m^2 on the island of Menorca was subsidised by EU LIFE Nature. Animals do not target the plant for grazing due to its salty leaves, while biological control possibilities and natural pests are not known. It is imperative that the root structure of the plant be also extracted while minimizing disturbance of the soil.

Fig. 2. Hottentot-fig population on the Azores. (Photo: B. Mihály)

Common rhododendron (*Rhododendron ponticum*), previously introduced to England and Ireland as an ornamental plant, now endangers grazed pastures with its aggressive spread. Most of the control treatments against it are mechanical in nature, such as cutting, including the removal and incineration of the root structure. As the plant contains toxic substances, herbivore animals do not graze on it, while other natural pests are not known. Chemical treatment is rendered difficult by its thick, leathery leaves. However, injecting herbicides into the stump after cutting helps prevent subsequent resprouting.

Due to the high regenerative capacity of the tree of heaven (*Ailanthus altissima*), only combined treatment proves effective (continuous manual removal of young rootshoots, cutting and girdling). The deterioration of the vitality of the trees can be observed from the first year after the treatment. On the other hand, definitive results require several years of continued treatment.

Significant international experience has by now become available in the control of giant hogweed, introduced in Europe in the 19th century as an ornamental plant, for it only to spread from gardens. The most important point to note is that contact with any part of the plant requires enhanced precaution (protective gear). Mechanical intervention (cutting and grazing) must be conducted prior to florescence and seed production. The most effective, yet at the same time the most labour-intensive, procedure is 10-cm-deep uprooting. In spite of extensive research, natural pests of the plant for biological control have not been discovered to this day.

Grazing can be an effective solution for numerous herbaceous species and shrubs. This is mostly conducted with goats and sheep. Danish researchers, for example, have reported successful control programmes over lands infested by the Japanese rose (*Rosa rugosa*). An advantage of grazing is that it is minimally labour-intensive, the area and time commitment is easily determinable, and it can be repeated if necessary. A further benefit is that this method can be applied under relief conditions that are not, or at most only partially, accessible by machines. A hindrance to the method is that some plants might contain chemicals that rule out or influence utilisation for food (e.g. toxins or alkaloids). Other morphological characteristics of plants (e.g. thorns) do not normally pose a restriction for the above-mentioned animals.

Chemical control

In the light of international and domestic research findings, it can be concluded that chemical treatments can be an effective complementary procedure against numerous invasive plants. When developing and conducting chemical treatments, two fundamental principles must be adhered to fully: treatment must be both safe and effective. Safety in this case includes the safety of the people applying the chemicals as well as living (e.g. non-target plants, pollinating insects, vertebrates) and non-living environmental elements (underground and surface waters, soil, air) (Fig. 3). Although a given product might be effective in a specific dosage, its application might do more harm than good if the conditions for safe use are not met.

Chemical control means the special application of products used in agriculture and licenced as pesticides. However, it is important to note that such application of these products is only marginally governed by international regulations of pesticides (e.g. Regulation (EC) No 1107/2009), since these are primarily aimed at regulating the agricultural use of those chemicals. Consequently, marketing authorisations and permits for use in non-agricultural areas that often provide a habitat for invasive plants (e.g. ruderal lands) are very rarely accessible. Another restrictive factor is that the majority of invasive plants that pose the most severe problems can be found around aquatic habitats, where the application of herbicides is not advisable.

Herbicides and their chemical agents can be classified into several groups based on their mode of action. We must differentiate between selective and total herbicides. While the former can be an effective targeted method against a taxon or a given species, the latter damages all plants affected by the spray. The application possibilities of contact and absorbing (systematic) agents are completely different, as well as those of leave-penetrating and ground-penetrating substances. Based on the application method, we can distinguish between total area and targeted treatments (e.g. injection into trunks, cut stump treatment). In the latter case the environmental exposure and thus environmental risk of the chemicals are the lowest. Experiments are being conducted with special plant protection chemical formulas (foams and gels) that rule out the potential drifting of the chemicals. Total area treatments include land and aerial distribution methods. However, it must be noted that regulations governing the aerial application of herbicides have been tightened by the European Union.

In the case of knotweed (*Fallopia* spp.) in England, glyphosate-containing chemicals were used for treating the stumps of cut sprouts. This treatment, however, cannot be used on areas in close proximity to bodies of water. Controlling the plant was effective with six annual mowing and treatment with herbicides.

New Zealand has conducted experiments with the aerial distribution of herbicides over the past 30 years. Triclopyr-, glyphosate- and metsulfuron-containing diluted solutions in the amount of 150 l/ha were dispersed to control twisted pine (*Pinus contorta*), black pine (*Pinus nigra*) and Douglas fir (*Pseudotsuga menziesii*). According to a local study, the cost of the treatments against unwanted pine species in the Southern Island increases tenfold in every six years. While control of seedlings costs approximately $ 3 per hectare, it takes 1500 $ to control the same area of 25-year-old trees.

An Irish publication gives a detailed account of the application possibilities of 2.4-D, triclopyr and picloram agents against knotweed (*Fallopia* spp.), giant hogweed (*Heracleum mantegazzianum*) and Himalayan balsam (*Impatiens glandulifera*). However, it calls attention to the fact that their application might be hindered by the protection of pollinating insects and waters.

In conclusion, we can establish that although chemical treatments can be applied in most cases, this control method does not provide a singular, long-term, sustainable solution.

Biological control

The principal of biological control of non-native species is to try and introduce a biological agent (plant pathogenic fungi, pest insects) that is present in the original environment of the invasive species and is harmful for the target organism, is specific to the host, and at the same time is able to control it due to significant gradation (Fig. 4). Effective control can be maintained long-term since there is an equilibrium between the host plant and the pest population.

One of the difficulties of biological control is that the natural enemies of the invasive species are not or very rarely introduced to the new area together with the invasive species. Arbitrary introduction to the new environment and long-term survival in the desired amount cannot be achieved in most cases. Another obstacle is that the ecological resilience of potent natural enemies capable of mass reproduction is often high; moreover, they are often polyphagous. This can have negative consequences that can damage certain cultivated plants or other non-targeted species. It is interesting to note that more than 300 types of phytophagous insects were found on the goldenrod species (*Solidago* spp.) of North American origin in their original habitats, while only 55 such species were observed in the Swiss population and at a significantly lower density.

CABI, as the leading non-profit research organisation dealing with biological control, have introduced 75 natural pests (arthropods and fungi) against 30 weed species in 35 countries over the past 50 years. The most significant result of their activity in Europe is that the open-air application of *Aphalara itadori* (Hemiptera, Psyllidae) against knotweed was authorised in the UK after 10 years of survey. The event was even reported by the BBC on 9 March 2010. Depending on the results of the 5-year post-treatment monitoring process, this could be the first exotic natural pest used against invasive species that might be used for control purposes in other EU member states.

Fig. 4. Natural pests on the common milkweed. (Photo: B. Mihály)

Fig. 3. Special attention must be paid to non-target organisms during chemical treatment. (Photo: B. Mihály)

Two major problems were encountered during the development of a control strategy against an aquatic plant, the water hyacinth (*Eichhornia crassipes*). On the one hand, the plant is a significant source of biomass (200 tonnes from 1 acre of land), which is collectable, though its subsequent management is complicated. On the other hand, chemical control is especially difficult due to the aquatic environment. The most effective solution in the regions affected by this problem has proved to be the introduction of two South American weevils and a hyacinth moth.

The problem of aquatic plants in not unknown in Hungary either, as the water lettuce (*Pistia stratiotes*) appears from time to time in mat-like formations. Numerous natural pests have been recognised in the US against this species (*Neohydronomus affinis* (Coleoptera: Curculionidae), *Samea multiplicali*s and *Synclita obliteralis* (Lepidoptera: Pyralidae), *Spodoptera pectinicornis* (Lepidoptera: Noctuidae)), but none of them have been able to significantly control the plant during the surveys. Fortunately, in Hungary the species population is significantly reduced throughout the winter season. However, the excess decompensating organic materials have a negative impact on the ecological conditions of waters.

There have been numerous international experiments with biological control methods and living organisms (e.g. *Puccinia xanthii*, *Zygogramma suturalis*) against common ragweed (*Ambrosia artemisiifolia*), which is also common in Hungary, but no practical method has been devised that is acceptable and can be efficient long-term over a large area. Fortunately, this plant can be effectively controlled with diligently conducted mechanical and chemical treatments.

Summary

It can be seen clearly from the above that the range of methods available internationally for the protection against invasive species is rather broad. However, there is no general method for controlling these species; the desired result can be achieved through different methods region by region due to the diverse relief and agro-ecological conditions, as well as the restrictive factors determining the treatments available (e.g. proximity of water). The scale of the desired result (control or total eradication) can also vary according to the area.

It is important to emphasise that eradication of invasive species over a specific area can only be effective long-term if the conservation management is also aimed at the factors triggering the invasion (e.g. disruption of soil or changing of cultivation method). It is also imperative that the intervention should not have unfavourable effects (e.g. the use of soil-penetrating chemicals with long-term effect or a complete change of light conditions) which in any way might hinder the resettlement of the natural ecosystem.

The simultaneous and interdependent cooperation of several professional fields is needed for the planning and successful execution of protective plans, as only those experts of a given field can answer specific questions like 'what, why, how and with what?' when moved outside of the comfort zone of their everyday thinking processes and are open to familiarising themselves with the arguments of other fields in order to develop and execute new approaches.

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Invasive species mapping in the development and high-precision implementation of conservation actions

Gábor Bakó

Introduction

Relevant spatial information, which is essential for planning, technical and economic decision-making, as well as for management, is best obtained by using remote sensing methods. This is because the accuracy of maps created by time-consuming field surveys, with its inherent difficulties related to the inaccessibility of certain areas and limited line of sight, is significantly lower than those obtained from the photo-optical methods involved in aerial mapping (Licskó 2005). As opposed to point-by-point data collection, remote sensing allows for uniform mapping with an almost homogeneous level of accuracy and spatial detail. In most cases, however, it cannot wholly replace field surveying since analyses created based on ortho-image maps can only be validated on-site; study areas for remote sensing are also designated with the help of field surveys.

Remote sensing is a method of assessment which provides spatial data about surfaces without any disturbance to nature. Conserving the natural condition of indigenous plant cover and avoiding its disturbance are of critical importance in avoiding further infestation by introduced species. It is also recommended to review which the methods are to support botanical research.

Invasive species mapping with remote sensing

Multispectral remote sensing

Multi-spectral and hyper-spectral remote sensing methods are mainly used to create a type of functional vegetation map (Ustin and Gamon 2010); however, this only allows for the detection of a given species providing its spectrally- detectable eco-physiological characteristics significantly differ from that of the surrounding plants and admixed plant species. In a site covered with herbaceous plants, if the target species is just as healthy and photosynthetically active as surrounding plants with similar leaf structure, multi-spectral separation might fail. The occurrence of a given species in nature is much more complex. Clearly-definable patches with a certain level of exposure may feature several species, and there can be significant physiological differences even within one specimen. Thus, only in exceptional cases can 30–cm or lower resolution remote sensing prove suitable for the kind of mapping suitable as the basis for well-planned preventive and operative measures. Exceptional cases include when an evergreen invasive species appearing in the upper canopy layer needs to be separated from the surrounding deciduous cover, or when certain special factors/effects (such as specific pests) make the plant species distinctly visible and stand out of its environment. Besides spectral information, the most accurate mapping methods are also supported by the texture analysis of high-resolution imagery (Pearlstin *et al.* 2013).

The importance of the spatial scale of the measurement

The most intuitive and practical remote-sensing approach for the assessment of alien invasive species is to analyse high spatial resolution imagery and visually monitor the spatial distribution of non-indigenous species (Huang and Asner 2009), in doing so combining visual analysis or supervised computer analysis with field surveying.

Satellite imagery and aerial imagery, which are both available in increasingly high resolution (raster datasets created by remote sensing), have been used in a number of land cover and biodiversity monitoring processes. However, besides multi-spectral evaluation techniques and classification procedures - which have became traditional in the last few decades - the evaluation opportunities offered by high-resolution imagery have remained largely ignored (Fuan and Ming-Jhong 2006). This is the case even when species cannot be clearly detected from images at traditional resolution, and the reliability of conclusions made from these images is extremely low (Turner *et al.* 2003). Small- and medium- resolution imagery offers significantly more information through methods based on the spectral separation of terrestrial objects (multi-spectral processes) than from data acquired by the splitting of spectral channels. The effects of atmospheric distortions aside, this method provides highly accurate surface information about the vitality, carbon sequestration, water availability and other, primarily eco-physiological, parameters of the vegetation. Nonetheless, if our objective is the detection of certain species or the creation of a complex vegetation map, multi-spectral imaging cannot provide satisfactory assistance for interpreting data that is less detailed than required for the scale of the survey. The quickest, most cost-efficient and reliable data collection method for species- and community-level maps is high-resolution remote sensing, coloured or multispectral earth monitoring at 3–25 cm spatial resolution (Bakó and Gulyás 2013).

Selecting the correct spatial resolution does not only depend on the size of the smallest patches on the field which need to be mapped; the minimum resolution of the survey is determined by the signals necessary for identifying the patch types. The pixel size should be at least one quarter of the width of the smallest field patches that we would like to indicate on the map. This is because the pixel borders do not necessarily overlap with the contours of the smallest object to be mapped, and thus they can be mixed into the surrounding colours (Hunt *et al.* 2012).

In essence, weed patches of a given width can only be separated from their surroundings if it can be assured that the necessary number of pixels are recorded (Fig. 1).

Notwithstanding, the identification of weed patches depends on such spectral and textural differences that cannot be detected at a resolution which barely shows the smallest field patches that need to be mapped. Consequently, the scale of the survey needs to adapt to a resolution which ensures clear identification and precise localization (Bakó 2012). Imagery must display not only the patches themselves but the visual signals characteristic of those patches on several pixels (Fig. 2).

The importance of the pace of the surveying essential

Most species can be cost-efficiently detected in one or two discrete periods. During these periods specimens of the species markedly stand out from their surroundings. Such periods may include bud burst or blossoming in the spring, or the period when leaves change colour and fall in the autumn. These processes occur at a different pace and time for each plant species, and this provides a good basis for mapping. As the detection of plant species can only be carried out effectively during these short periods of a few weeks or even days, in surveys covering larger areas (surveys at a regional, provincial, district or national level) it is extremely important that data collection is condicted quickly and in a unified way. If the plant cover under

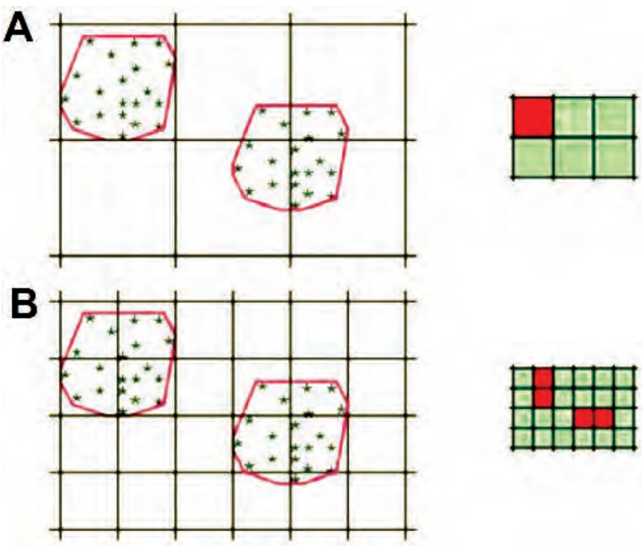

Fig. 1. A = If pixel size equals the size of patches to be mapped, then most patches are not detected. B = If pixel size is significantly smaller than patch size, then most patches will be shown on at least one pixel

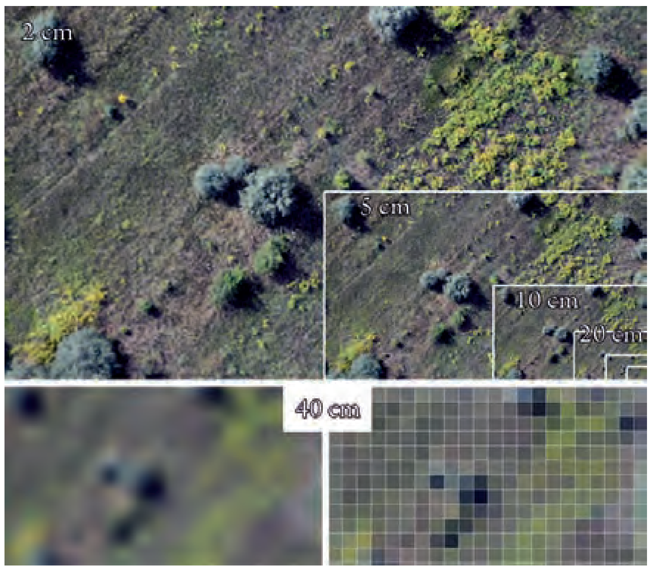

Fig. 2. Patches of *Solidago* and *Elaeagnus angustifolia* as shown on ortho images of different spatial resolution, and as shown using two types of interpolation on the scale of the country-level survey with standard resolution. It is clearly discernible that low resolution does not allow for either the identification of patch type (land cover category) or the accurate mapping/isolation of infested patches

examination has changed to another phenological state in some parts of the survey area – and this includes not only the species to be detected but all the species it needs to be separated from - Invasive species mapping used for the development and high-precision implementation of conservation actions then the analysis of images becomes much more complex and difficult; moreover, the extent to which processing can be automated decreases as does the reliability of data acquired from the imagery.

The evaluation of remotely sensed raster data

During the evaluation of imagery we derive target maps and thematic maps from the raster data sets. The vector graphic geospatial dataset thus created is generalised, as it only contains information that complies with the criteria of the analysis. For instance, the final product of a survey aiming to provide a spatial evaluation of *Solidago* species could be a vector graphic map which only shows patches infested with *Solidago*; a complex vegetation map showing several land cover units and featuring patch types formed by other species could also be obtained as well. The geometric units of the database created as a result of the analysis are usually polygons: sets of these polygons make up the thematic map. Polygons may come with background information that is included in the attribute table. Such information may include:

- areas linked to the given patches (which is essential information for planning measures);
- perimeter (an important indicator of the resolution of the survey);
- centre coordinate (information mainly facilitating field work, which can be automatically generated with the help of centroids);
- cover (as a percentage);
- data related to admixed species (which is information pertinent to diversity and conservation);
- soil scientific information (data available on soil chemistry and soil physics);
- date of the first detection of infestation (which helps determine the dynamics and spatial characteristics of the spread);
- height of stands, etc.

These pieces of information are available in the GIS (geographic information system) by clicking on the given polygon, or with the help of search functions which, for instance, can be used to filter relevant patches based on a given question. This aids the creation of complex vegetation management and control measure map sketches, which in turn supports professional decision-making (Bakó *et al.* 2014). The system can also provide answers to other complex questions; spatial interpretation is essential from the point of view of future actions.

Supplementary field surveys and eliminating the possibility of error

The detection of infested patches by aerial or satellite remote sensing in sample areas typical of the given habitat can be validated by field surveys. During field surveys it should be kept in mind that the average error of navigation GPS is around 15 m. This average is sufficient for urban maps where the navigation system adjusts our current position to the closest paved road; however, it is not suitable for determining the accuracy of maps. For this purpose we can use geodetic GPS equipment, which offers a parallel accuracy of 2 cm and vertical accuracy of 5 cm, using high-quality correction data (RTK). It should also be noted that as it is impossible to designate the boundaries of a vegetation patch when on the ground, as checks and GCP (ground control point) measurements are point-based. Patch boundaries are transitional so isolines are always determined based on some criteria or decision. In those cases where criteria are exact and fixed, patch boundaries can be analysed relative to one another; however, if the parameters of the procedure are changed during the operative assessment phase, the final result will not be reliable, statistically speaking.

Polygons on a map created by a remote sensing method which represent infested patches indicate areas where the invasive plant species has firmly established. It should also be remembered that sprouts and seedlings of the invasive species could easily be found hidden in the surrounding vegetation, further away from identified patches (Fig. 3). These sporadically occurring specimen or stands hidden by vegetation cannot be detected by aerial or spaceborne remote sensing due to the limited resolution of sensors and possible obstructions. For root suckers a certain buffer zone may be designated in the light of botanical knowledge and site characteristics; for wind-dispersed seeds, however, the situation is much more difficult to assess in the three-dimensional space, relying instead purely on statistical methods.

Time series analysis for monitoring changes and effects

Remote sensing also allows for investigating to what extent a given biological invasion effects the eco-

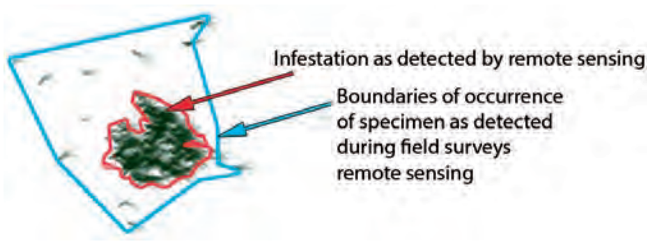

Fig. 3. In some special cases seedlings may be found at greater distances away from the infested patches

system (Huang and Asner 2009), and for examining which habitat features, environmental conditions or control measures can decelerate the spread. Time series analysis can be used to monitor changes in plant communities, thus the negative impacts an invasive species has on its surroundings may also be analysed in order to justify control measures. Time-series data collection provides assistance in supervising the effectiveness of control measures and treatments, as well.

Modelling based on spatial data

With the help of high-resolution mapping we are able not only to obtain information about texture (visual information), but it also becomes possible to generate a digital elevation model. A database which is derived from data sets created during aerial surveys supported by on-ground GCP collection (geodetic survey) can serve as a data source for early warning systems (Andrew and Ustin 2009). In the light of knowledge obtained about environmental variables (distance from water courses, altitude, steepness, exposure, irradiation, convexity, precipitation and soil conditions, etc.) and the current rate of infestation and characteristics of the species, we can predict the spread of invasive plant species. Environmental variables and the rate of infestation can be derived from remotely-sensed data.

Mapping the spread of specific plant species

Tree of heaven (*Ailanthus altissima*)

Herbicide treatment is best carried out in the optimal phenological phase, usually in the autumn for woody stands: the intensive nutrient flow toward the roots is capable of delivering the chemical to every tissue. *Ailanthus* sprouts should be cut down mechanically in the middle of the summer so that sprout spraying or sprout wiping in the autumn does not have to be carried out on tall (a few meter-high) trees. For this reason it is recommended to survey infested areas in the early summer period. However, in dryer years biological activity may decrease several months sooner, so the timing of treatments should be adapted accordingly. When selecting the treatment period, the life-cycle of sensitive, protected plant species must also be taken into consideration. Consequently, when planning survey parameters it is recommended to create a vegetation map of the area surrounding the infestation to attempt to assess the occurrence of such species. The task of mapping the surrounding vegetation is naturally more complex than detecting a given weed species which occurs in massive numbers. If the intervention is not followed by habitat restoration, it may trigger further plant infestation. Preliminary surveys can also prove useful when assessing whether habitat reconstruction following the treatments has been successful. As the seeds of alien invasive plants may still be present in the seed bank of the treated area, environmental restoration cannot be considered completed until a long period of time after intervention, and vegetation should be surveyed from time to time.

Leaf unfolding for *Ailanthus* usually starts in the beginning/middle of April, with sprouts of reddish brown colour which can prove useful in the case of aerial remote sensing of high geometric resolution. Its foliage soon turns into homogeneous green, and its spectral reflectance properties become similar to that of many indigenous species. The thick growth of *Ailanthus* sprouts can be located on high spatial resolution ortho images taken in the winter or early spring when the foliage is still thin. The root bark and leaves of *Ailanthus* contain substances which inhibit the germination and growth of other plants, and this leads to the thinning of understorey in infested areas; in the case of long-standing infestations, this means that the ground provides strong background contrast for aerial optical detection in the wintertime as long as there is no snow cover.

Ailanthus does not have any serious pests or diseases known in Hungary, so aerial imagery taken at the end of summer or beginning of autumn can clearly distinguish its lush foliage from that of a Sapnidacae (e.g. horse chestnut) or Fagaceae (e.g. pedunculate oak) species, which are severely damaged by plant diseases and pests in this period. This, however, depends on the conditions of the site as well, more specifically on soil thickness and water availability: *Ailanthus* specimen growing in dolomitic rocky grasslands with shallow soil layers tend to wither by the end of summer. In the light of information about site conditions gained through mapping, the possibility of analysis errors caused by the inaccurate assessment of phenological stages can be decreased. In the case of aerial surveys conducted at the end of the growing period in flatland forests and infested oak forests, obstruction by the upper canopy level poses an insurmountable problem, so surveys are recommended to be carried out in the winter. Flights specifically targeted at detecting *Ailanthus* are best conducted over flat and hilly areas with dry sand and forest soils where the mean annual temperature is over 8 °C.

Surveying *Ailanthus* in inhabited areas using aerial and spaceborne remote sensing is not always recommended. Representatives of the species often grow at the edge of buildings, or even from cracks in the wall. Its hairy seeds are dispersed by wind and easily set root if stuck in some kind of crack or at the wall of houses. After setting root, the growing plant cracks the paving of buildings, roads and monuments; cracks caused by specimen growing on roofs let in the rainwater and cause rapid deterioration to the buildings. This causes severe damage to the poorly-maintained buildings owned by the railway company, accelerating the degradation of abandoned complexes. It has occurred before that buildings have collapsed due to the spread of the species within a few decades. The methodology of remote sensing is not capable of detecting such local occurrences, except for some exceptions. Such exceptions include urban GIS with high-resolution time-series ortho images, or the decision support systems and real property cadastres of certain entities. Small sporadic patches of infestation in urban areas can be best monitored by creating a database in which local citizens can report occurrences.

Goldenrod species (*Solidago* spp.)

Chemical control is not recommended for goldenrod species for conservation purposes, but eradication with mechanical tillage can offer an effective solution. This type of intervention, however, may facilitate the further spread and re-establishment of goldenrod by disturbing the indigenous plant cover when accessing infested areas, or by treating healthy areas which were classified by mistake as being infested. Control measures carried out in invaded grasslands, including the flail mowing of goldenrod in the fall or winter, followed by hoeing then regular mowing, need to be preceded by proper land management planning (Botta-Dukát and Dancza 2004). As goldenrod species have already infested vast areas of Hungary, and keep spreading at a very high rate, the size and number of affected lands call for mechanical control that is as automated as possible. Moreover, invasive species control can only prove effective if carried out in the whole area of the region at approximately the same time, thus avoiding re-infestation. In such cases of large-scale action it is impossible to ensure that all members of the operating staff (machine operators, and supervising and executive staff) have thorough botanical knowledge, nor can we expect that work be carried out in units of a few square meters, as the limited direct view obtained on the ground would require. The fast (that is, carried out over the course of the same growing period) and integrated treatment of sites which are composed of different patches has become possible with the help of precision interventions. The planning of precision interventions requires vector graphic target maps which are created based on remotely sensed data (from multispectral or multi-colour sensors of either spaceborne or airborne platforms), which are then transformed into ortho images with the help of photogrammetric image processing, and are evaluated (classified, interpreted or processed using a hybrid classification method) by professional analysts (Fig. 4). This same target map is then loaded into the on-board GPS and navigation equipment of machinery and vehicles. As a result, machinery can access target areas along either the shortest route, or a route that avoids natural values, thus causing the smallest possible disturbance and soil compaction on the way. The treatment of infested areas is actually restricted to infested patches and eradicates unwanted vegetation while complying with regulations related to the given species. The size of buffer zones can be set up in advance based on the conditions and site characteristics indicated on the map. The level, method and scale of the intervention can be changed locally.

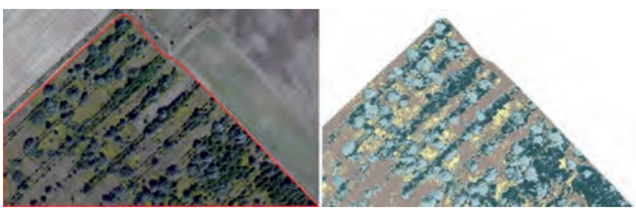

Fig. 4. Surveying method illustrated in a segment of a management area near Halásztelek. Patches infested with goldenrod and Russian olive shown on a zoomed out portion of a high-resolution ortho image and on the target map (Huber 2014)

Giant goldenrod (*Solidago gigantea*) and Canadian goldenrod (*Solidago canadensis*) blossom between June and October with characteristically yellow inflorescence, and this facilitates the aerial mapping of the species with electro-optical imaging from the months of June to August. Aerial imagery captured by the digital camera is converted into an orthophoto map through photogrammetric processing, which is practically a geoinformation data set ready for analysis. An ortho-image is a photo rich in detail with pixels whose geographic coordinates are all known. The costs of the control of giant goldenrod (*Solidago gigantea*) or common milkweed (*Asclepias syriaca*) are estimated to be of the order of billions of forints (Mihály and Botta-Dukát 2004), which means that if, with the help of precision techniques developed during the planning phase, the treatment is restricted to infested patches and their spread zones, a tremendous amount of money can be saved. The nature conservation benefits of precision interventions cannot be considered as negligible either, as they cause an inevitable degree of disturbance to the indigenous plant cover.

Russian olive (*Elaeagnus angustifolia*)

Due to the colour of its leaves, Russian olive can be reliably detected with photo-optical sensors. At a 10-cm spatial resolution the invasive cover of the species can be safely mapped, but in most cases its foliage

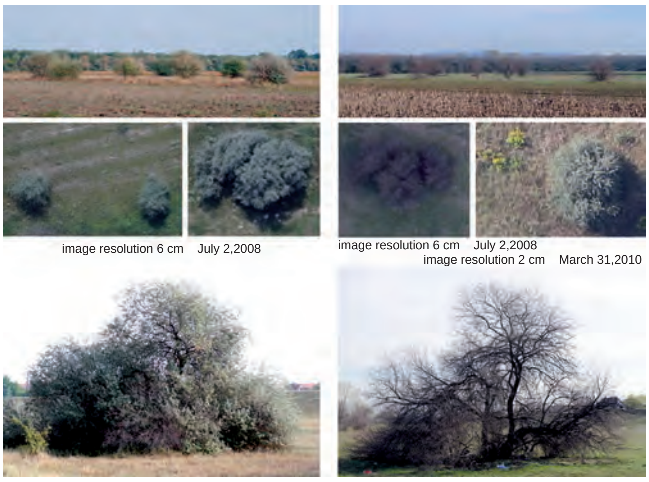

Fig. 5. Russian olive trees captured in orthophotos taken in the winter or early spring, and photographed on-site. (Bakó 2010)

can be easily discerned at a resolution of 20 cm, as well. Starting from around 14 cm spatial resolution, the surveying of Russian olive can be considered reliable, cost-efficient and effective as in the growing period even RGB sensors are capable of detecting its specimen. The species can also be easily detected by aerial imagery taken in the wintertime, due to the characteristic structure and colour of its branches; however, mapping in this period requires ortho images of a spatial resolution of 6 cm or higher (Fig. 5).

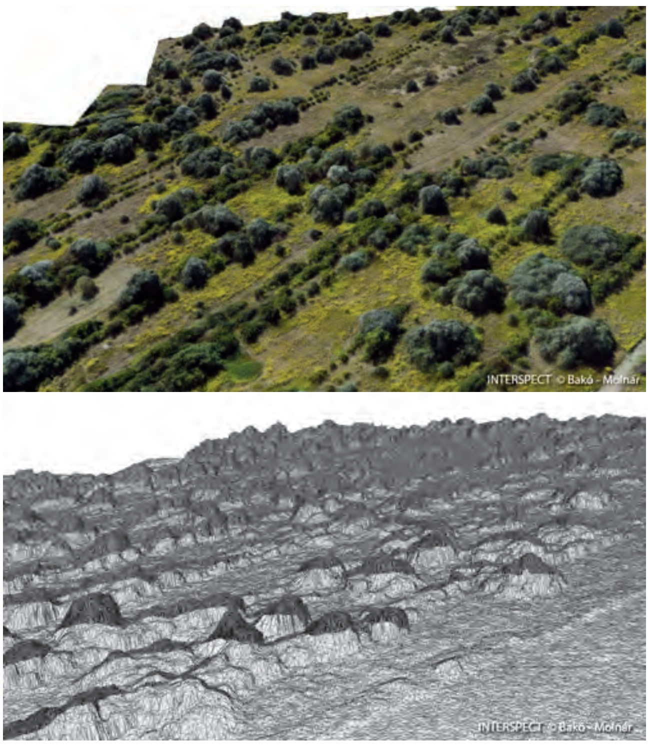

Fig. 7. Area infested with goldenrod and Russian olive on a high-resolution aerial orthophoto, and on a 3D surface model created in the course of image processing. (Images taken by Gábor Bakó with an Interspect IS 4 camera; photogrammetric processing performed by Zsolt Molnár; analysis and target map by Nóra Huber. Photos were taken of a former apple orchard abandoned about a decade ago in the outskirts of the city of Halásztelek)

Fig. 6. Winter aspect of an abandoned orchard infested with Russian olive. (Photo: G. Bakó)

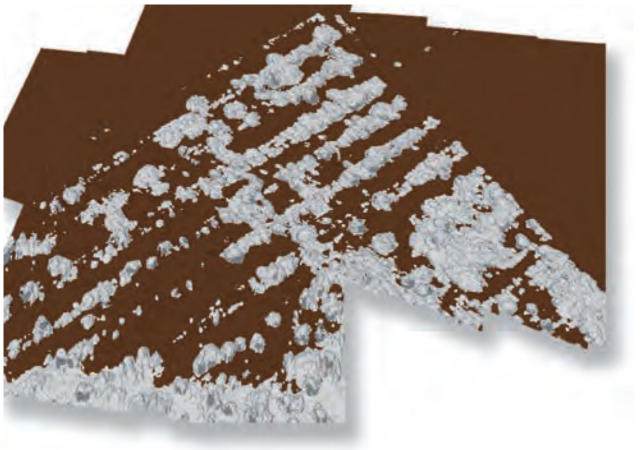

Fig. 8. Classification can be carried out based on the 3D surface model as well with the complex analysis of height and reflectance data. The figure illustrates the automated mapping of Russian olive. (Bakó and Molnár)

Fig. 10. Due to the lack of landscape rehabilitation on disturbed surfaces, goldenrod has spread throughout the outskirts of Sopron (Photo: G. Bakó, 2014). Infestation can be avoided provided that the area of the mine undergoes environmental reconstruction.

Fig. 9. Photos of a parcel infested with ragweed taken on site, and section of an aerial orthophoto-mosaic at 2 cm spatial resolution. Images were taken within the framework of the Interspect research program and both show the test parcel at the same time. Based on experience by the Interspect research team, the accurate RS mapping of ragweed requires multi-spectral imagery of at least 2 cm spatial resolution; however, conducting such surveys over large areas is not economically feasible.

Figure 6 shows specimens with thin foliage captured in the wintertime on a perspective aerial photograph.

The analysis of woody species is also supported by three-dimensional assessments, as information about the height of trees, along with spectral and textural information, offer another opportunity for separating the target patch type from its surroundings. Figure 7 shows a 3D surface model created during the processing of orthophotos, which is suitable for such analysis. Figure 8 illustrates how vector target maps can be derived from a surface model.

Common ragweed
(*Ambrosia artemisiifolia*)

The RS mapping of ragweed is significantly more difficult than that of the species mentioned previously. Identifying ragweed is much harder than mapping parcels covered with crops, as in most cases it occurs mixed in with the crops and weeds. The heterogeneous plant cover and the uncertain spectral characteristics of the species make the low-resolution multispectral detection of patches infested with ragweed almost impossible. Consequently, ragweed can only be detected in special cases, for instance, in infested soy plantations where the soy has already withered but ragweed is still in the growing period (Surek *et al.* 2013). These results are further supported by surveys carried out in the laboratory of Interspect and during airplane test flights (Fig. 9). Due to the limited capacity of sensors in space-based platforms, ragweed cannot be spotted on satellite imagery.

Planning the survey

As has been detailed in this paper, selecting the right spatial resolution for aerial imagery depends on which species is targeted. Table 1 shows the spatial resolution, scale and surveying method required for different invasive species.

Aerial and spaceborne remote sensing offer various passive methods for studying the surface: these are listed in Table 2. Besides passive optical methods, there are also active remote-sensing techniques (which include the emission of signals), such as microwave radar or the laser LiDAR technologies. The resolution of radar imagery created by space-based equipment available for non-military purposes is insufficient for species-specific surveys. Aerial remote sensing which uses microwave or laser technologies is not only harmful to the environment and hu-

Table 1. Parameters and relative costs of field surveys required for the successful detection of invasive plant species.

Invasive plant	Minimum spatial resolution (cm)	Scale	Accuracy of the target (m)*	Survey period	Relative costs
Goldenrod species	35	1 : 2400	1.5	July–August	$
Russian olive	14	1 : 1680	0.8	in growing period	$$
	6	1 : 720		without leaves	$$$$
Tree of heaven	7	1 : 840	0.8	snow free winter and early spring period	$$$$
Locust species	7	1 : 840	0.8	all year	$$$$
Common milkweed	5	1 : 600	2	June	$$$$$$

* = reliability of the map created for the management plan carried out.

Table 2. Comparison of remote sensing technologies.

	Surveying method	Spatial resolution	Spectral resolution (number of channels)	Relative costs	Advantages	Disadvantages	Example of measuring equipment
Aerial	Aerial survey with analogue camera	5–1000 cm	1 or 3	$$$$	High experience value	Need for digitalization No film supplies	Leica RC30
	Aerial survey with digital camera	0.5–1000 cm	3	$$	Quick reaction High spatial resolution	Low number of channels	Interspect IS, DigiCam, DIMAC, Intergraph, Leica RCD 30, Ultracam
	Photogrammetry of aerial video	15–1000 cm	3–4	$$	Quick reaction time	Low resolution Long processing time	Silvacam
	Multispectral aerial imaging with analog camera	5–1000 cm	4–8	$$$$$	High experience value	Need for digitalization No film supplies	Leica RC30, Zeiss RMK, Hasselblad
	Multispectral aerial imaging with digital camera	5–1000 cm	4–20	$$$$	High spatial resolution High spectral resolution	Long processing time	Interspect IS 4, IXA, Intergraph RMK D, DMC, Leica RCD 30
	Hyperspectral aerial imaging	50–10 000 cm	70–800	$$$$$	High spectral resolution	Low resolution Long processing time Expensive Requires atmospheric correction	HySpex VNIR és SWIR, Northrop Grumman HATI, DALSA, AISA
Space-born	High resolution	1.5–5 m	1–4	$$$	Quickly rectifiable	Dense medium effect Low resolution Requires atmospheric correction	GeoEye, WorldView, IKONOS, SPOT
	Medium resolution	5–30 m	4–8	$$	Covers large areas		RapidEye, ASTER, CBERS-2
	Medium resolution	30–60 m	6–9	$	Covers large areas Free		Landsat 8 OLI
	Low resolution	<= 60 m	20–40	$	High frequency time-series Free		MODIS

man health but also highly expensive, as in order to achieve the necessary detail and accuracy it requires imaging in very narrow scan lines. Thus, it is essential to carefully specify the parameters of the survey for the success of the analysis. The optimal surveying method may vary depending on the area. Willow-poplar floodplain forests and degraded reed beds are potential habitats for goldenrod species; forest belts with black locust create a favourable environment for the establishment and spread of common milkweed. Surface cover, site characteristics, terrain exposure, climate and the weather of the given year can all determine which invasive species infestation should be mapped, but in the case of introduced species and of species just starting to spread we can also plan the survey based on where the spread started. The surveying of plant species that are difficult to spot and have not yet spread to large areas, such as the nut grass (*Cyperus esculentus* var. *leptostachyus*) is recommended to be started at the place where the plant has gone wild; moreover, it is also possible to find the source of the infestation (where the species first appeared in nature) by defining spread vectors.

Invasive species also serve as indicators, as the large-scale appearance of sprout colonies is the indirect result of the inappropriate management of natural and semi-natural sites, and the lack of landscaping and site rehabilitation after disturbances (Fig. 10).

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A survey on populations of invasive plant species – applied methods and experience

István Szidonya and Róbert Vidéki

Achieving conservational goals in protected areas is often hindered by severe infestation of invasive alien species in Hungary. Due to the fact that invasive species have gained ground, the fulfilment of some Natura 2000 commitments is also in danger. This is why there are many invasive species control management actions in progress, which are partly self-funded, partly funded by various programmes (EEOP, LIFE).

The implementation of these actions shall be achieved without hindering conservation aims, and with the aim of conserving natural assets. The methods, progresses and location of the control actions shall be carried out following the principle of the least possible damage. This is a difficult task, especially if different parts of the area are infested to a different extent or with different species, sometimes interfering with the natural habitat. In some protected areas the infestation of invasive plants is so severe that only carefully planned, repeated, long-term intervention can be successful. Before controlling or eradicating the populations of invasive species, the population of these species shall be carefully surveyed.

The botanical survey and analysis methods that are widespread in Hungary (National Habitat Classification System, National Biodiversity Monitoring System) can be used effectively to survey the population of invasive alien species, or to monitor the environmental changes triggered by these plants. These methods are, however, only partially capable of creating plans to control invasive plant species. The extent and location of infestation in the areas was determined using common methods, such as habitat mapping and exhaustive on-site botanical sampling. The populations of invasive species were located using GPS technology.

However, knowing the exact location of infested areas is not enough to answer all important conservational and economic questions. Knowing the extent of infestation is required to plan the technology to be applied, the amount of chemicals used, the number of repetitions, etc. A so-called planning category system was established for each species (Fig. 1). This provides valuable help, as it makes the quantitative and qualitative parameters of infested areas easy to record on-site. This system is further supported by a five level vitality scale, which describes the vitality of populations; data regarding the average height of populations; a five level scale for describing the natural value of the grassland surrounding the invasive plant population, including the number of protected plants occurring in that area. In case of woody plants – based on counting or estimation, depending on population size –, technological categories are also determined based on trunk diameter (<5 cm diameter, 5–10 cm diameter, 10–15 cm diameter, etc.) (Figs 2–3).

The base of the infestation map was an EOV (Hungarian Unified National Projection) map with a scale of 1:10,000 and sections of orthoimage maps (of the surveyed areas) in a uniform coordinate system. The digital infestation map was created using the digital version of GPS information. The base maps show the population of each invasive species, indicated with identical legends on a thematic map.

After determining the data regarding the occurrence of invasive species, statistical data were defined (e.g. number of infestation patches, size of patches, etc.) The maps were processed using ArcView 3.3. (Figs 1–2).

The data set recorded during the survey was pasted into an Excel table which, apart from field data, considers further factors when estimating costs. In this table, planning categories (based on site details, accessibility and distance from contractor site) are added to a base budget which is calculated using expected costs (possible quantities multiplied by unit price) based on experience gained from previous projects, as in Table 4.

Table 1. Planning categories (PLAN CAT).

Code	PLAN CAT	Description
1	1	Sparse population of common milkweed (1–5 plants/m^2)
2	2a	Dense population of common milkweed (above 6 plants/m^2)
3	2b	Dense population of common milkweed (above 6 plants/m^2) occurring in agricultural areas (e.g. abandoned arable land, hayfield)
4	3	Old, mixed population (with a trunk diameter of 5 cm or more) of tree of heaven
5	4a	Young (max. 1–5 cm trunk diameter) population of tree of heaven with a height of 1 m or above
6	4b	Young (max. 0.5–3 cm trunk diameter) population of tree of heaven with a height of 1 m or below
7	5	Old, dense (>60% cover), mixed *Robinia* stands
8	6	Old, dense (>60% cover), homogeneous *Robinia* stands
9	7a	Heterogeneous, sparse (20-60% cover) *Robinia* stands mixed with scrub (especially hawthorn)
10	7av	– treated with cut stump method
11	7ai	– injected, standing dead trees (snags)
12	7bi	Old, sparse (20–60% cover) *Robinia* stands together with degraded, open, perennial, calcareous sandy grassland, treated with injection
13	8a	Young, dense (>60% cover), homogeneous *Robinia* stands
14	8av	– treated with cut stump method
15	8ai	– injected, standing dead trees (snags)
16	8b	Young, dense (>60% cover), *Robinia* stands mixed with native *Populus*
17	9	Young, sparse (20–60% cover) *Robinia* stands
18	10	Solitary *Robinia* plants (0–20% cover), injected
19	11a	Dense, closed population of Russian olive – homogeneous patch of an old plant and its root sprouts
20	11b	Dense, closed population of Russian olive – heterogeneous patch of an old plant and its root sprouts mixed with *Robinia* and native *Populus*
21	12	Isolated plant or small groups of *Russian* olive (0–20% cover)
22	13	Giant or Canadian goldenrod population
23	14	Dense population of false indigo
24	15	Sparse population of false indigo
25	16	Old, mixed population (with a trunk diameter of 10 cm or more) of black pine
26	17	Young population (1–2 m high) of black pine
27	18a	Dense, closed population of box elder, including old and young trees (homogeneous)
29	18b	Dense, closed population of box elder, including old and young trees (heterogeneous)
30	19	Solitary box elder trees

Table 2. Data of *Ailanthus altissima* stand in the case of various planning categories.

Patch or point ID	Trunk diameter categories (cm) (below number of individuals in a patch)											Area (m^2)
	0–5	6–10	11–15	16–20	21–25	26–30	31–35	36–40	41–45	46–50	51–55	
17.	100	6	32	17	32	6	2	1	5	1	8	4539.225

Table 3. Data recorded during the field survey.

ID	PLAN CAT	IND	ALT	Area	Cover	BORÍTOTT AREA	ATLMAG	INVVIT	INVSP	DNAT	Image name	Comment
11	7ai	20	40	12774.714	80	10220	15	5	*Robinia*	2	KEPSZAM_0002.jpg	3708
12	7bi	30	30	21407.892	10	2141	10	4	*Robinia*	3	KEPSZAM_0003.jpg	
41	8ai	200	15	3595.713	100	3596	6	5	*Robinia*	1	3671	

ID = Patch or point ID; PLAN CAT = Planning category; IND = number of specimens; ALT = average altitute; Area = entire area; Cover = coverage; BORÍTOTT AREA = actual value of coverage; ATLMAG = average height; INVVIT = vitality of invasive species; INVSP = invasive species; DNAT = degree of naturalness.

Table 4. Calculation table sample – injection of invasive woody plants of a 1 ha area of average accessibility. (counting with 0.25 ha/work team day [i.e. WTD, the amount of work performed by the average work team in one day] in areas belonging to planning category 6, 7ai and 8ai).

Use of resources	Base quantity	Unit	Required quantity	Net cost (HUF)
WTD (8hrs work of 4 people, rates and taxes included)	1	WTD	4	260 000
Liquid chemical (for injection)	5	litre/ha	1.5	47 237
Marker dye	1	tin/WTD	2	4 200
Preparation process (manual)	1	hectare	0.5	37 500
Petrol (for the generator)	4	litre/WTD	4	7 200
Travel costs of the work team leader	10	km/WTD	4	16 000
Travel costs for a week	500	km/work team week	0.8	52 000
Accommodation costs	1	WTD	4	14 000
	Total			438 137

Detailed description of planning categories

Category 1 – Sparse (1–5 plants/m²) population of common milkweed (*Asclepias syriaca*) (Fig. 3).

Usually a relatively new, loose population that appeared only a few years before. The infested area varies, but the plant usually lives in small (1–100 m²) patches. The vitality and reproductive ability of the stems also varies, the plants usually have few (<50%) blooming sprouts. Common milkweed infestation in most cases occurs due to the disturbance of the area, anthropogenic impacts (e.g. dirt roads, former military activity, trenches and explosion craters) or favourable microclimatic conditions caused by piled juniper branches. The plant is surrounded by open, perennial, calcareous sandy grassland, often with a number of protected species. The "fresh" establishments (with a size of 1–3 m², consisting of few stems) were surveyed as dots (based on area estimation). In case of populations larger than these, the area borders were determined using GPS technology. It is of utmost importance to survey this plant carefully, as it occurs in great numbers and the individuals are spread out, as opposed to large and dense populations.

The clearing of common milkweed requires special planning, as locating the patches may be difficult (GPS technology is often needed). Since there are protected plant species and grasslands in good condition in the area, invasive species are to be treated one by one (e.g. manual painting), without affecting adjacent plants.

Category 2a – Dense (more than 6 plants/m²) population of common milkweed (Fig. 4).

Older populations with the aforementioned density with above 50 percent cover per m². These patches are often hundreds or thousands of square meters large. Thanks to their good reproductive abilities, the vitality of these plants is average or good, sometimes excellent. Under these populations, only few earlier species remains, there is no or little sign of native communities. In case of patches with various categories (1–2a), a category proportion was provided together with the area value. A proportion of 70–30%

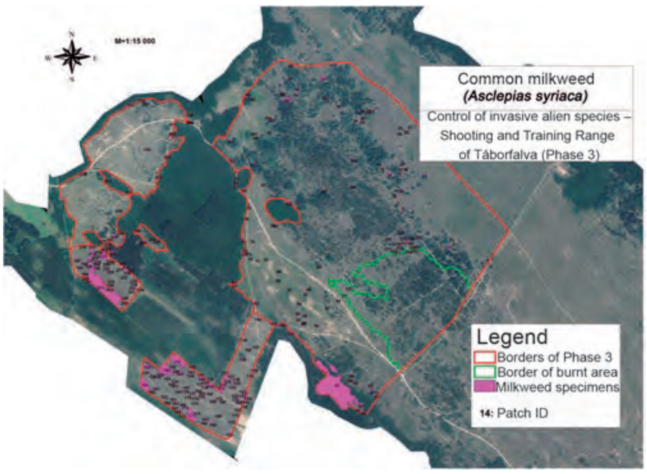

Fig. 1. Results of a field survey on common milkweed populations in the area of the Shooting and Training Range of Táborfalva (2014)

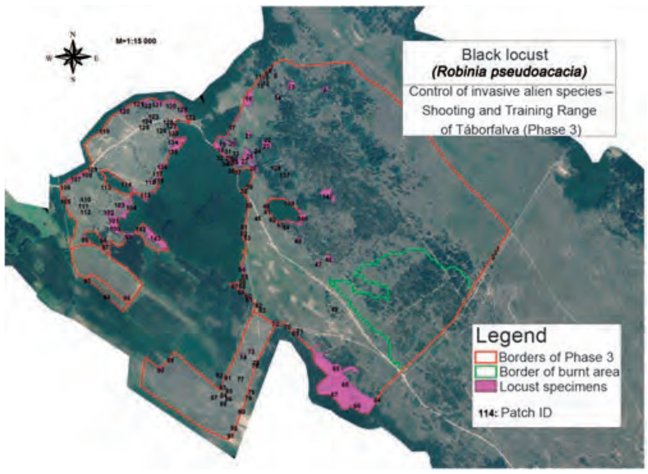

Fig. 2. Results of field survey on black locust populations in the area of the Shooting and Training Range of Táborfalva (2014)

Fig. 3. Sparse population of common milkweed (1–5 plants/m^2) (planning category 1). (Photo: R. Vidéki)

Fig. 4. Dense population of common milkweed (above 6 plants/m^2) (category 2a). In the background: old, sparse (20–60% cover) *Robinia* stands mixed with variously degraded, open, perennial, calcareous sandy grassland (planning category 7bi). (Photo: R. Vidéki)

means that 70% of the area is covered by a category 1, while 30% of the area is covered by a category 2a population. In case of mixed patches, estimation happens when the patch size is determined.

Category 2b – Dense (more than 6 individuals/m^2) population of common milkweed, located in agricultural areas (e.g. abandoned arable land, hayfield) (Fig. 5).

Older populations occurring in agricultural or former agricultural land with the aforementioned density with often above 50 percent cover per m^2. These patches are often hundreds or thousands of square meters large. Some "rare" category 1 populations also live in these areas. These are recorded separately or as belonging to mixed categories.

Category 3 – Old, mixed population (with a trunk diameter of 5 cm or more) of tree of heaven (*Ailanthus altissima*) (Fig. 6).

A population that appeared earlier, sometimes decades ago, covering varying patches, depending on age and soil conditions. Older individuals are usually surrounded by a close (above 1 m in height) or loose (below 1 m in height) population of young (1–5 cm trunk diameter) individuals. After determining the borders of the patch (using GPS technology), the counted or estimated number of individuals (above 3 cm trunk diameter) within a patch is recorded in a size category table. Patches consisting of various individuals are recorded as mixed (3–4a). In case of closed and hardly accessible patches with a size of several hundred square meters, trunk diameter data often contains errors. Isolated individuals with a trunk diameter of 5 cm also belong to this planning category. Patches of tree of heaven are often mixed with *Robinia* or bordered by common milkweed. If patches overlap, the populations of different invasive plant species are surveyed and classified separately.

Category 4a – Young (max. 1–5 cm trunk diameter) population of tree of heaven with a height of 1 m or above (Fig. 7).

Newly established young population with a trunk diameter of 1–5 cm. The plants sometimes get mixed with the loose population of very young (below 1 m) individuals. The populations are usually loosely

Fig. 5. Dense population of common milkweed (above 6 plants/m^2) occurring in agricultural areas (e.g. abandoned arable land, hayfield) (category 2b). (Photo: R. Vidéki)

Fig. 6. Old, mixed population (with a trunk diameter of 5 cm or more) of tree of heaven (category 3). (Photo: R. Vidéki)

Fig. 7. Young (max. 1–5 cm trunk diameter) population of tree of heaven with a height of 1 m or above (category 4a). (Photo: R. Vidéki)

closed. Since the area is not completely closed, the surrounding herbaceous vegetation often contains protected species that were characteristic plants of the area before the infestation. The original seed tree or seed tree group is usually near the patch, but these can colonise areas hundreds of meters away. After determining the borders of the patch (using GPS technology), the counted or estimated number of individuals (above 3 cm trunk diameter) within a patch is recorded in a size category table.

Category 4b – Young (max. 0.5–3 cm trunk diameter) population of tree of heaven with a height of 1 m or above (Fig. 8).

Newly established young population, usually of sprout origin, with a trunk diameter of 0.5–3 cm. It is usually mixed with individuals of the two other size categories. After determining the borders of the patch (using GPS technology), a rough estimate (tens, hundreds, etc.) of sprouts within a patch is recorded in a size category table.

Category 5 – Old, dense (>60% cover), mixed *Robinia* stands.

A partially introduced but chiefly spontaneous population that appeared earlier, sometimes decades ago. It is often mixed with native tree species, such as white poplar (*Populus alba*), creating closed, multi-layered populations. The shrub layer – which is usually hardly or not at all accessible – consists of native species, for instance juniper (*Juniperus communis*), wild privet (*Ligustrum vulgare*), blackthorn (*Prunus spinosa*) and common hawthorn (*Crataegus monogyna*). Due to heavy shading, there is either no grass level or only a cover of a low percentage, usually consisting of generalist species. The age composition of the patches is usually mixed. The old populations are often surrounded by loose patches of young species of seed or sprout origin, which originate from the old species. These are recorded in separate categories.

Category 6 – Old, dense (>60% cover), homogeneous *Robinia* stands.

Old, introduced population, usually homogeneous in terms of layer and age composition. The shrub and grass layer usually consists of nitrophilous species, such as black elder (*Sambucus nigra*), barren brome (*Bromus sterilis*), stinging nettle (*Urtica dioica*) and chervil (*Anthriscus cerefolium*). The grass layer is often mixed with common milkweed populations of various density. There is only sporadic remains of the former vegetation. The age composition is mixed, usually with a trunk diameter of 25 cm or more.

Category 7a – Heterogeneous, sparse (20–60% cover) *Robinia* stands mixed with scrub (especially hawthorn) (Fig. 9). A partially introduced but chiefly spontaneous population that appeared earlier, sometimes decades ago. It is often mixed with native shrub species (especially juniper or common hawthorn), creating loose, double-layered populations. These shrubs sometimes appear densely, rendering the patch hardly or not at all accessible. There are also some old individuals scattered in these closed patches. Small grass patches may also appear, where unfavourable abiotic conditions hinder plants in becoming woody. The age composition is usually mixed, but the patches are usually bordered by young species. Before treating the *Robinia* plants, the shrub layer of the area has to be thinned or completely cleared in order to make the trunks accessible. Depending on the goal of the treatment (e.g. further use of the wood), patches can be divided into two categories.

- Category 7av. After cutting and stump painting, wood will be removed.
- Category 7ai. In case of injection, snags are left on site

Category 7bi – Old, sparse (20–60% cover) *Robinia* stands together with degraded, open, perennial, calcareous sandy grassland, treated with injection (Fig. 10).

Fig. 8. Young (max. 0.5–3 cm trunk diameter) population of tree of heaven sprouts with a height of 1 m or below (category 4b). (Photo: R. Vidéki)

Fig. 9. Heterogeneous, sparse (20–60% cover) *Robinia* stands mixed with scrub (especially hawthorn) (planning category 7a). (Photo: R. Vidéki)

Fig. 10. Old, sparse (20–60% cover) *Robinia* stands together with degraded, open, perennial, calcareous sandy grassland, treated with injection (category 7bi). (Photo: R. Vidéki)

Large, introduced forest that is slowly dying out ("*Robinia* cemetery"). The tree layer is not fully closed partially due to unfavourable habitat conditions. Thanks to the loose tree layer, there is natural grass vegetation, an open, perennial, calcareous sandy grassland. Disturbance, however, caused common milkweed to spread quickly, so there are large areas covered by this species as well. The age composition is mixed, usually with a trunk diameter of 15–25 cm or more.

Category 8a – Young, dense (>60% cover), homogeneous *Robinia* stands (Fig. 11).

Robinia stands composed by specimens with seed or sucker origin. The plants are of about the same age with similar trunk diameter. The number of suckers can reach five per trunk. Due to heavy shading, the grassland consists of nitrophilous species (e.g. barren brome, stinging nettle, chervil). These areas are often surrounded by small patches of common milkweed. Depending on the goal of the treatment (e.g. further use of the wood), patches can be divided into two categories.

- Category 8av – After cutting and stump painting, wood will be removed.
- Category 8ai – In case of injection, snags are left on site.

Category 8b – Young, dense (>60% cover), *Robinia* stands mixed with native *Populus*.

Same as the previous category, but the populations are mixed with white poplar and black poplar (*Populus nigra*).

Category 9 – Young, sparse (20–60% cover) *Robinia* stands.

The origin and size is similar to young, dense *Robinia* stands, the only difference is density. The plants usually originate from root suckers, where roots belong to old individuals that were cut down or burned. There are still some signs of natural grass vegetation, but this changes later as the population grows denser. There are also thin *Robinia* stands surrounding the older and dense populations.

Fig. 11. Young, dense (>60% cover), homogeneous *Robinia* stands (category 8a) mixed with dense population (above 6 plants/m^2) of common milkweed (category 2a). (Photo: R. Vidéki)

Fig. 12. The common milkweed patches are easy to map during winter. Picture: mixed population (categories 1 and 2a). Sparse populations border the dense centre. (Photo: R. Vidéki)

Category 10 – Solitary *Robinia* plants (0–20% cover), injected.

Isolated individuals or small groups. Usually established spontaneously, or from seed or root sprout. It only differs from the previous category in terms of the number of adjacent individuals. The age of *Robinia* plants varies. As individuals tend to appear in small spots, it is often difficult to specify the size of the area. These are marked as dots in the surveyed areas. Their clearing requires unique planning.

Category 11a – Dense, closed population of Russian olive (*Elaeagnus angustifolia*) – homogeneous patch of an old plant and its root sprouts.

The age composition of the patch is mixed, it consists of an old plant and surrounding sprouts. The grass layer is featureless or missing due to heavy shading. There are only sporadic remains of the former vegetation. After determining the borders of the patch (using GPS technology), the counted or estimated number of individuals (above 1 cm trunk diameter) within a patch is recorded in a size category table.

Category 11b – Dense, closed population of Russian olive – an old plant and its root sprouts mixed with *Robinia* and poplar.

Similar to the previous category, but its populations are mixed with *Robinia*, white poplar or hybrid poplar (*Populus* × *euramericana*) plants. The survey method of the patch is identical to that of category 11a.

Category 12 – Solitary plant or small groups of Russian olive (0–20% cover).

The individuals are sometimes more than 10 years old, usually seedling stands or root suckers. The plants form impenetrable patches. The age composition of the populations is extremely mixed, there are one year old sprouts with 0.5 cm and old individuals with 30–50 cm in trunk diameter. As some patches are closed and impenetrable, it is often very difficult to estimate trunk diameters precisely. Solitary individuals are recorded as dots (without area size), while smaller groups are recorded as patches, using GPS technology to determine their borders. The number of plants under 5 cm in trunk diameter is estimated, while bigger individuals are counted (or sometimes estimated) and recorded according to their size category.

Category 13 – Giant or Canadian goldenrod (*Solidago gigantea*, *S. canadensis*) population.

Thanks to their good reproductive abilities, the vitality of these plants is average or good, sometimes excellent. Under these populations, only a few earlier species remain; there is no or little sign of native communities. Infestation in most cases occurs due to the disturbance of the area (afforestation) or other anthropogenic impacts (e.g. dirt roads, dirt piles, etc.). Canadian goldenrod often occurs together with other invasive species, such as common milkweed. The “fresh” establishments (with a size of 1–3 m^2, consisting of few stems) were recorded by points (based on area estimation). In case of populations larger than these, the area borders were determined using GPS technology.

Category 14 – Dense population of false indigo (*Amorpha fruticosa*).

Small (at least 8 plants) or large, dense patch of false indigo. The borders of the patch are recorded (GPS) without determining the number of individuals. It is difficult to measure the number of individuals in a thick, inaccessible scrub, but this data is irrelevant for planning the treatment.

Category 15 – Sparse population of false indigo bush. As false indigo individuals are scattered alone or in small groups (max. 7 plants), there is no area size determined in this category.

These are marked as dots in the planning areas. The number of individuals is recorded, however, their clearing requires individual planning.

Category 16 – Old, mixed population (with a trunk diameter of 10 cm or more) of black pine (*Pinus nigra*).

Old and thinned population originating from former introduction or spontaneous release of seeds. The plants are mixed with other woody species (trees, shrubs). Apart from seed trees, there are other individuals of different age groups. Solitary individuals are recorded as dots (without area size), while smaller groups are recorded as patches, using GPS technology to determine the borders. The number of plants above 10 cm in trunk diameter is counted (or sometimes estimated) and recorded according to size category.

Category 17 – Young population (1–2 m high) of black pine.

Mixed or homogeneous population of various density that originates from spontaneous release of seeds. The number of plants under 5 cm in trunk diameter is estimated, while bigger individuals are counted (or sometimes estimated) and recorded according to size category.

Category 18a – Dense, closed population of box elder (*Acer negundo*), including old and young trees (homogeneous).

The age composition of the patch is mixed, it consists of an old plant and surrounding seedlings. All age groups are present from seed trees to young seedlings. There are only sporadic remains of the former vegetation. After determining the borders of the patch (using GPS technology), the counted or estimated number of individuals (above 5 cm trunk diameter) within a patch is recorded in a size category table.

Category 18b – Dense, closed population of box elder, including old and young trees (heterogeneous).

This category is similar to the previous one, but the box elder populations are mixed with *Robinia*, white poplar or English oak (*Quercus robur*). The survey method of the patch is identical to that of category 18a.

Category 19 – Solitary box elder trees. Solitary individuals or small groups. Usually established due to spontaneous seeding. It only differs from previous categories in terms of the number of adjacent individuals. The age of the individuals varies.

As individuals tend to appear in small spots, it is often difficult to specify the size of the area. These are marked as dots in the surveyed areas. Their clearing requires unique planning.

Experience gained

The aforementioned methodology was used to survey the population of invasive species (Fig. 12) both in vegetative phase and winter leafless period (on snowless days). It turned out that in case of woody plants, the survey of patches was much more accurate and easier to carry out during the leafless period. In case of closed, hardly accessible patches, it was difficult to provide an accurate estimation or calculation during vegetative phases.

On the other hand, the results of common milkweed surveys done outside the vegetative phase, especially during winter, need correction. The population patches were easy to find if there were plants remaining from the previous year. However, some plants were lying on the ground, without leaves. This circumstance caused estimation error in the results of some patches when calculating percent cover. This error can be further worsened in years of drought when young sprouts along the border of the patch dry out during the vegetative phase. In winter surveys, most patch data will show sparse populations and the borders are likely to be inaccurate.

In case of herbaceous invasive species, monodominant patches are as frequent as heterogeneous populations. Diversified terrain, soil and hydrological characteristics often lead to multiple herbaceous invasive species (e.g. giant goldenrod or common milkweed) living together in little areas. Surveying the little "clear" patches that appear within a large patch of the dominant herbaceous plants is very time-consuming. Therefore, we named the larger patches after the dominant species and treated them as separate patches during the survey.

Conclusion

According to the current Hungarian procedure of tenders and public procurements, precise project costs calculation is required at an early stage. This enables a more accurate planning of the project budget. These surveys of course also have costs, but experience shows that defining a more accurate budget reduces the required safety margin for contractors during contractor tendering, hence lowering the overall costs. The present study was aimed at introducing our survey and planning structure based on 10 years of experience, and we also intended to shed light upon further directions of development.

On the authorisation of chemical treatments against invasive plants

Botond Mihály

The range of herbicides and chemicals used in invasive plant control is relatively narrow. The products applied in chemical treatments are mostly pesticides (herbicides) since they are used for controlling unwanted plants or plant parts, as well as controlling or preventing the unwanted growth of plants. Accordingly, when applying and distributing herbicides against invasive plants, one must adhere to relevant plant protection regulations.

A fundamental condition of applying herbicides is that the product used should have marketing authorisation and licence to use in Hungary. The relevant authorities decide on the conditions of use of the herbicides during the licencing procedure (marketing category, the range of permitted cultures, dose, queue time necessary prior to work or harvest, suggested health and safety tools, procedures to be followed in case of accidents, etc.). These conditions are determined by regulations laid down by the authorities after the data provided by the applicant/manufacturer has been evaluated. No herbicide application can be authorised if the safe use of the product cannot be confirmed based on current scientific knowledge.

The product can only be applied by persons possessing the qualifications required by the licence and used in complete compliance with the conditions of use specified in the licence. The above-mentioned requirements associated with herbicides are also displayed on the labels of the products. Instructions must be followed in all cases in order to prevent endangering people and the environment.

The most common products in the treatment against invasive plants in Hungary are glyphosate-containing chemicals with marketing authorisation and licence to use. The plant absorbs the glyphosate agent through its chlorophyll-containing green parts. The agent is transported from here to the roots, the stolon and the rhizomes. The effects of treatment (aging, dwarfism, the browning of leaves and sprouts) become visible 1–2 weeks following treatment. The process is irreversible; the treated plant will die. Since the glyphosate active substance is circulated through the plant all the way to the propagules, it leads to the death or long-term damage of even perennial plants. Depending on the dosage, glyphosate-containing chemicals are effective against perennial, germinating monocot and dicot weeds alike. Taking meteorological conditions into consideration, the glyphosate agent is most effective in the temperature range 15–25°C and in high humidity. For the desired effect to take place it is important that there should be no precipitation in the six hours following the treatment and the agent be able to be completely absorbed in the weed. The chemical is not selective; therefore, it is not to be dispersed onto those plants to be protected from the weeds, as they could also be damaged.

The herbicide Medallon Premium, for example, contains glyphosate agent and can be obtained without a professional qualification. It is authorised for use in agriculturally non-cultivated lands (roads, roadsides, dry drainage ditches, industrial facilities, filling stations, airports and railway tracks), as well as residential areas and garden plots, for total weed and shrub eradication in cemeteries and where it is not prohibited by other regulations. It can also be used in dry canals and breaches for weed control against reed, bulrush and other weed species difficult to control. Its recommended dose is 5–7 l/ha while the recommended amount of water volume is 250–300 l/ha. The plants can be sprayed a maximum of two times during one vegetation period and the two treatments must be at least 60 days apart. It can also be used for total weed and shrub control in forestry once a year at a dosage of 3–5 l/ha and 250–300 l/ha water volume amount. Two-time spraying with Medallon Premium is also permitted for sprout control in forestry felling with 3.5% dilution (300–400 l/ha water volume amount).

The authorized areas of application for glyphosate-containing herbicides are rather broad. However, they still do not cover several specific application methods (e.g. injection) that might also be required for invasive plant control. Provided that a planned application method or needed dosage is not displayed on the label of the product, further authorisation procedures might be necessary.

Limited and supervised application of herbicides can be authorized by EU member states for a maximum of 120 days if the product is not authorised in the given member state, or for the application in question if the treatment has become necessary for the control of a hazard that cannot be averted by any other reasonable means. This latter case is referred to as an emergency permit. The affected member state must inform the other member states and the Commission in a timely manner about the measures taken, providing detailed information about the situation and the safety precautions taken.

The first group of emergency permits involves products that are authorized for distribution in Hungary, but the planned application is not included in the licence of the product. A good example of such a case of the clopyralid-containing Lontrel 300, which is authorised for numerous arable land cultures (sugar beet, cereals, rape, mustard, fodder radish, corn, onion, flax, energy willow, energy poplar); at the same time its application against black locust sprouts is not included in the licence. Since there are no authorised herbicides for control against locust sprouts, and Lontrel 300 would be an effective solution, after evaluating the request of the stakeholders the authorities decided on issuing emergency permits in recent years. The Lontrel 300 herbicide can be applied in forest regeneration at a 0.7–1.0 l/ha dosage after the leaves of the trees have sprouted and acquired their waxy coating. Given that treatments are generally conducted at the end of the summer or in the autumn, a significant proportion of the locust sprouts die completely and the following year's resprouting is considerably reduced. If the forest stand is surrounded by vineyards, it is necessary to keep a minimum 100-m buffer zone in order to prevent phytotoxicity symptoms. Multiannual treatments in oak and turkey oak plantations can be effective in weed control against the mass spread of perennial weeds (*Cirsium arvense*), other asterales (*Ambrosia artemisiifolia*, *Senecio* spp.), Polygonaceae and germinating dicot weeds. In the case of mixed forest stands, a phytotoxicity test must be conducted prior to the commencement of the treatment. The permitted spray water volume for vaporised use is 50–80 l/ha, with the addition of anti-drift adjuvant (e.g. Mist Control 0.5% spray solution, Melius 2.0 l/ha). The product can be applied with the supervision of a plant protection professional authorised to purchase and use products in the marketing category I.

The second group of emergency authorisation involves planned interventions where the product to be applied does not have a valid marketing authorisation and licence to use. A good example for this is the triclopyr-containing Garlon 4E herbicide. This product is not unknown in forestry weed control as it was authorised in Hungary until 2012. The conditions of use in the emergency permit are the following: "25% oily solutions may be used against invasive tree species such as tree of heaven and black locust, applied with a long brush on the cut surface of the trees."

Emergency permits are issued at the risk of the applicant, while the products can only be used in the manner and on the areas determined in the permit.

Research and development experiments or tests involving the distribution into the environment of non-authorised herbicides or the non-authorised use of herbicides can only be conducted if the member state on the territory of which the research or test is to be conducted has evaluated the available data and has issued a permit for the experiment.

In Hungary experiments or research and development tests involving the distribution into the environment of herbicides and substances not qualified as pesticide and not authorised for the given technology (e.g. additives, adhesives, adjuvants or colorants) can only be conducted under controlled conditions, in limited amounts and over a limited area, following the issue by the authorities of an experimental licence. The experimental licence is valid for a limited time period for a specific area. If the experiments or test cannot be proven to be harmless to the health of people and animals and to the environment, the authorities can prohibit them or impose conditions that they deem necessary (isolation, destruction and other safety measures) in order to prevent potential harmful effects.

In conclusion, it is imperative to obtain up-to-date information about the specific requirements included in the licence of the product to be used prior to the commencement of chemical control. If the licence does not contain the planned method of application (e.g. injection) or the dose to be applied (e.g. painting with concentrated chemicals), one must contact the authorities before the treatment or consult the local plant protection authorities about further steps.

Useful links

https://novenyvedoszer.nebih.gov.hu/Engedelykereso/kereso.aspx

http://ec.europa.eu/sanco_pesticides/public/?event=homepage

A brief overview of technologies used for controlling invasive alien plant species

Márton Korda

The following article presents a short summary of various methods aimed at controlling invasive alien plant species. The main focus is on the technological details of applied methods, therefore specific species are only mentioned as examples where necessary. We also describe methods applied against woody or herbaceous species or both, as well as possible control methods with and without the use of chemicals.

Methods applied to control invasive alien woody plant species

Non-chemical methods

Natural withering

A method used in the case of invasive woody plant species. This means that we let the plant grow old, become weak and finally die. This "treatment" is necessary if the use of chemicals or cutting triggered sprouting should be completely avoided. It is important to underline that in this case the plants can continuously spread their seeds. As a result, this method can only succeed if the seeds of the given species only germinate in large quantities when damaged (e.g. *Robinia*). This also means that the method can only be used if the habitat remains completely undisturbed (often for decades).

Girdling (ring barking)

Girdling means the removal of the phloem and the cambium. This is done using a special girdling chain created from saw chain, but knives, machetes or chainsaws can also be used. The size and number of the removed bark rings may differ, but girdling is usually done at chest height and the removed bark ring is about 15–20 cm wide.

Manual uprooting

In the case of woody plant species, this method can be applied if the plant is young, only a few years old (depending on the species).

The aim is to manually uproot the invasive plants. Sprouts growing from seeds or the original plant are, however, hard to distinguish in most cases, and the roots of the latter are difficult to remove completely. The most effective way of using this method is when the seed-spreading plants have been removed.

Machine-assisted uprooting

Machines can uproot older plants in some cases (e.g. Russian olive because it has shallow roots). This is done by a vehicle pulling a wire rope fastened to the plant, or by a front-end loader tractor digging up the roots. It is important to underline that this method can only be applied under suitable site characteristics where the machine does not damage the habitat.

Stump extraction is another uprooting procedure. When the tree has been cut, a stump lifting machine attached to an excavator is used to uproot the remaining stump. Although this method disturbs the area, it has a milder impact than destumping with a bulldozer and stacking of stumps in windrows across the site or other stump removal techniques. The method is applied mainly in forestry and its main purpose is to prepare the site for forest restoration. Regarding nature conservation purposes, this procedure should be applied if the species sprouts easily from stump or root (e.g. *Robinia*). As roots may break and start sprouting, root raking is also required in certain cases.

Felling

Cutting down invasive woody plant species with saw. Depending on size, this can be done by hand-saw or mechanical saw (chainsaw, disk saw, brush cutter). Previous treatments revealed that this method (when not used in combination with other techniques) is futile in the case of most species, while in other cases (e.g. against tree of heaven), it triggers massive sprouting, further worsening the situation. This is why cutting down species is nowadays only used together with other methods, usually after the plant dies due to other treatments. Sometimes, however, it is used to utilise the aforementioned sprouting effects and create a homogeneous area before a comprehensive treatment with chemicals (if the site is severely infested and there are no significant natural assets).

Sprout control

Mechanical removal of sprouts of invasive woody plants. It can be done using a machete, brush scythe, brush saw or chainsaw. It is best to time this method and not to allow sprouts to grow woody before winter, so that they freeze. It is also suggested before a chemical treatment if we intend to create a homogeneous (approximately of the same height) set of sprouts that are easier to treat, or before grazing, if fresh, not woody sprouts are needed. This method can only be successful if used on a regular basis (usually for years).

Grazing of woody plants

Regarding woody plants, mainly young (non-woody) sprouts are suitable for grazing (e.g. black locust, common lilac, false indigo). Already woody plants should be cut out or forestry mulcher should be used, and then grazed. Experience shows that Hungarian cattle tend to graze on false indigo and *Robinia* sprouts, while sheep prefer common lilac and *Robinia* sprouts (Fig. 1). If grazing is preceded by mechanical treatment of the site, the mowed plant parts should be removed, so that animals can graze on the area. However, cattle can graze on untreated areas, such as dense false indigo groves. This way, the animals open up the area as they make way in the grove. Grey cattle can be a great help to control Russian olive because they scratch their bodies against the trunk of the plant, thereby making it accessible as they approach it through the thorny, arborescent crown. Dividing the infested site into sections further improves the effectiveness of this method.

Fig. 1. Hungarian Grey cattle grazing false indigo. (Photo: M. Korda)

Chemical treatments

Injection into drilled trunk holes

Above a trunk diameter of 5–10 cm (depending on species), chemicals are injected into a hole created by a drilling machine (Fig. 2). The holes can be drilled using electric or engine drills. When treating a great number of plants with electric drills, spare batteries are needed, as well as a place where empty batteries can be charged. A hole with a diameter of 6–8–10 mm and a depth of 2–4 cm (to reach the heartwood) is usually adequate. The hole should be drilled downwards, at a 45° angle to the centre line of the trunk. If the hole is not aimed directly at the centre of the trunk, but slightly in chord direction, the chemicals better affect the xylem, resulting in better absorption. There are various methods regarding the location of the holes, but drilling is usually done at a convenient height for the person handling the drill. The holes can be filled in many ways (e.g. syringe, wash bottle, automatic self-filling syringe), it is important however to ensure that the chemical does not flow out of the hole. The number of holes depends on the diameter of the trunk. (In practice, various numbers of holes turned out to be successful.) It is very important to seal the holes after filling (Fig. 3). This can be done using, for example, putty, modelling clay, tile adhesive, wound dressing or silicone. Silicone tubes have special applicator guns, while other materials are best applied with a spatula. Where there are many plants, treated species have to be marked (painted). This method is the least weather-dependent, it requires less chemicals, it is safe and effective, but also very expensive. The method is completely selective.

Injection into cuts – hack-and-squirt treatment

In this case, chemicals are not injected into a drilled hole, but into a cut that reaches the cambium. The number of cuts depends on the diameter of the trunk. Experience on tree of heaven shows that a trunk diameter of 25 cm requires one cut of about 5 cm in length and 3 cm in depth. There should be a space of 2–3 cm between cuts because too much stress triggers sprouting on the tree.

Partial bark stripping treatment

In the case of younger woody plants (up to 5–10 cm trunk diameter, depending on species), the bark is slit mechanically, then the wounds are wiped with chemicals. Slitting the bark can be done using various tools, including pruning knives, draw knives or chainsaws. In most cases, wiping should be done with a so-called radiator brush because this can reach the bottom of the container and the person doing the treatment does not accidentally come in contact with the chemical. Furthermore, the long handle of a radiator brush makes it easier to access trunks in dense

Fig. 2. The first step of injecting trunks is drilling a hole. (Photo: M. Korda)

groves. The chemical is supposed to be in a container with a wide hole. The ideal container has large capacity so it only has to be filled to a third of its capacity, and it is easy to carry. It should not be filled completely, as the chemical may spill. For easy monitoring and to avoid trunks being missed or treated twice, the chemical should be mixed with marker dye (possibly a type that fades slowly). It is of utmost importance to buy and wear protective clothing (e.g. protective PVC, nitrile or neoprene gloves). There is a number of different methods for bark stripping in terms of length, width and number per trunk. Bark is usually not removed in an entire circle around the trunk. Experience shows that removing the bark in a full circle disrupts circulation in the tree, thus preventing the chemical from reaching all parts of the plant. On the other hand, if the bark is removed from only one side of the trunk, some parts of the crown might survive. Depending on size, wounds of about 30–50 cm of length should be inflicted on two or three sides of the trunk. As painting is usually done at waist height, the dripping chemical only reaches the lower parts of the trunk, so the method is considered to be 100% selective.

Basal bark treatment without cut

Wiping/spraying young woody plants (up to 5 cm trunk diameter) without slit. This herbicide painting procedure is identical with the method of bark stripping treatment

Cut stump treatment

Chemical treatment of an invasive woody plant's stump. The surface of the stump is treated with herbicide to weaken the plant and to prevent sprouting. The selectivity of the method depends on the way of applying and the chemical (dose, mode of control) used. Wiping is usually done with brushes or sponges with handle, so this method can be considered totally selective. For easy monitoring and to avoid stumps being missed or treated twice, the chemical should be mixed with marker dye (possibly a type that fades slowly). It is important to wear protective clothing, such as protective gloves. It is usually not necessary to paint the heartwood, only the outer rings should be treated, as these are responsible for carrying nutrients and other substances. Treating the stump top should be carried out immediately (within 10–20 minutes) after the tree has been felled. In a forest where accessibility with vehicles is not important, it is advisable to leave high (about 50 cm) stumps because this makes sprouting stumps easier to spot, hence later treatments are easier to carry out. Nowadays, when chemical treatment is gaining momentum, this method is less frequently used, but it is still widespread in the case of certain species, e.g. Russian olive.

Fig. 3. After it has been filled with chemicals, the hole has to be sealed. (Photo: M. Korda)

Methods applied to control invasive herbaceous plant species

Non-chemical methods

Manual uprooting

This method is most effective against annual species (e.g. common ragweed, certain invasive *Impatiens* species), but it can also weaken the population of some perennials. It is important to underline however that manual uprooting triggers massive sprouting in the case of certain perennials (e.g. common milkweed). Invasive aquatic species are often removed by excavators (Fig. 4).

Mowing

There is a variety of solutions for mowing. Mowing with a scythe is very rare nowadays, it only happens in very vulnerable areas that are not accessible by vehicles. Clearing saws with nylon string heads are often used in small areas that are inaccessible by cars or bigger vehicles. In large areas that are accessible by machines, the most frequently used equipment is drum, disk or scythe mower, installed on tractors. The perfect time for mowing differs depending on species. Mowed plant parts are supposed to be removed from the area after mowing. In the case of certain species (e.g. goldenrods), baling is the easiest solution for this. This treatment has to be carried out on a regular basis.

Grazing herbaceous plants

Certain invasive herbaceous species (e.g. goldenrods) can be suppressed by regular grazing. The most experience is available in the case of cattle and sheep. Firstly, it has to be known (or tested) which animals are the best against certain invasive species. Experience shows that different animal species prefer different invasive plants, and this also depends on the phenophase of the given plant species. For instance, cattle and sheep species tend to eat goldenrod before blooming or during sprouting, but they avoid blooming plants. This treatment has to be carried out on a regular basis.

Manual removal of generative organs

If, for other reasons, eradication is not possible before the plants start fruiting, removing generative organs helps to prevent seeds being spread. This method is very time-consuming and it only hinders generative reproduction, so it cannot serve as a long-term solution.

Methods applied to control both invasive herbaceous and woody plant species

Non-chemical methods

Forestry mulching/flail mowing

The mechanical eradication method includes a vehicle (e.g. tractor) and a mulcher attached to it. Despite scythes or brush cutters, flail mowers shred and spread mowed plant parts. Depending on the area or the purpose, this can be a disadvantage, as during the eradication of invasive species, the aim is to remove all plant parts from the area. The ideal mowing height depends on the habitat. In some respects, this method is better than mowing because certain mulchers are also capable of mowing brushes or small trees. Thanks to this, forestry mulching can be the first step of clearing areas invaded by false indigo or Russian olive, and it is also an effective way of mowing new sprouts. The procedure is frequently used before grazing in an area infested by invasive woody species where the aim is to remove woody sprouts to clear the area for new, young sprouts. It can be useful before chemical treatment in order to create a homogeneous (plants of similar height) area which is easier to treat.

Habitat restoration

Experience shows that habitats in good ecological condition – as opposed to degraded lands – are less vulnerable to the infestation of invasive plant species. Therefore, restoring the condition of degraded habitats often leads to decreasing population of invasive species, and it prevents further infestations. After re-

Fig. 4. Eradication of water pennywort (*Hydrocotyle ranunculoides*), an invasive species in the Tapolca brook. (Photo: M. Korda)

storing the water condition of wetlands, the population of goldenrod decreased. Also, creating a forest of indigenous tree species from former hybrid poplar plantations resulted in dramatic decline of the homogenous false indigo population grew in the shrub layer. Experience shows that channel networks under grasslands act as a potential source of infestation outbreaks. Burying and treating these areas stopped issues caused by invasive plant species, and the water condition also improved.

Management of plant material created during the eradication

The question of managing dead plant parts arises after most treatments. In most cases, the aim is to remove hay, cut branches and trunks from the site. There are several methods used for this. This is usually problematic in the case of grasslands where dead plant parts cause degradation in the condition of the area, rendering it rich in nutrients. This effect triggers weed growth. When treating invasive herbaceous species, the best solution is to collect dead plant parts into bales after mowing, and then remove the bales from the area. Hay bales can sometimes be used to cover the soil (as mulch, as in Fig. 5), but only if mowing was carried out before generative parts are developed on the plants. There are many options when treating woody species. The best is to further use woody parts for other purposes. This usually means firewood, but certain species, such as false indigo, are also used in flood prevention or as building material for stork nests. Wood parts are often chipped (Fig. 6). Woodchips then have to be transported from the site. They are also used for heating or to create compost.

Fig. 5. The goldenrod collected from the Balaton-felvidék National Park is used as hay mulch on a grape farm of the Badacsony Wine Research Centre. (Photo: B. Mihály)

Another method – not favourable in terms of nature conservation – is burning the branches on the spot. It has to be underlined, however, that it is strictly forbidden to burn anything in an area infested by black locust as fire triggers sprouting. If the presence of dead trees (standing or fallen) poses no danger to the area, they can remain in the site to improve the condition of the area.

Chemical treatments

In the case of the following methods, for easy monitoring and to avoid stumps being missed or treated twice, the chemical should be mixed with a marker dye (possibly a type that fades slowly).

Spot spraying of sprouts, seedlings and herbaceous plants

During this method, spray is spread from a pinpoint sprayer. In practice, this has a number of widespread alternatives (e.g. backpack sprayers, sprayers with shoulder strap, hand pump sprayers with many different sprayer heads available). If the spraying and pressure is selected properly, the method is selective. If the pressure is too high, spray also hits adjacent plants. Before starting the work, the size of the tank has to be considered because too big tanks quickly exhaust the person carrying out the task. Experience shows that hand sprayers of a capacity of 2–6 litres are more effective in the long run than bigger backpack sprayers (which have a capacity of 16–18 litres). The method is highly vulnerable to weather conditions.

Foliar spraying of sprouts, seedlings and herbaceous plants with motorised backpack sprayer

In this case, spraying is done by a motorised sprayer. Its advantage is high performance, but the aiming of fine spray particles requires considerable skills to spread the chemicals evenly. A further disadvantage is the fact that selective spraying is very difficult to implement. In light of this, it is suggested in homogeneous popula-

Fig. 6. The eradication of invasive woody species results in woody plant parts. A woodchipper is often used for reducing these parts into smaller woodchips. (Photo: M. Korda)

tions or when using selective chemicals. The method is highly vulnerable to weather conditions.

Wiping sprouts, seedlings and herbaceous plants with chemicals

During this procedure, chemicals are applied to the plants from a bucket or other container using a radiator brush (or sponges, rugs, etc.) with handle. In some cases, the handle is itself a chemical container, and it distributes chemical when the operator touches the plants to be treated. It has to be added, however, that if the chemical contains adhesive increasing agent, the solution might dry out on the textile surface. The wiping sponge or rug has to be pressed against the wall of the chemical container before using, thus increasing the selectivity (reducing the danger of dripping) of this method. The chemical should not be splashed, only wiped. It is of utmost importance to provide the required protective clothing (indicated on the label or in the attached documents). Wearing these is obligatory. There are also initiatives to mechanize this process, such as experiments involving wiping devices installed on a quad.

CASE STUDIES

Control of invasive plants in the common sea buckthorn habitat in Újpest

Zoltán Bajor and Károly Penksza

Natural characteristics of the area

The Homoktövis (common sea buckthorn) Nature Conservation Area lies in the northern part of Budapest's 4th district, close to Dunakeszi and only about 70 metres from the left bank of the Danube (Fig. 1). The river leaves the mountains to the north and deposits sediment, and this is how a spacious dune habitat could have evolved in the northern part of the capital.

Dry grasslands interspersed with rows of gently-sloping mounds oriented northwest-southeast covered most of the Újpest area.

The existence of sea buckthorn (*Hippophaë rhamnoides*), which gives its name to the area, was first documented here in the 1850s. The city council declared 5.7 ha of the area protected in 1974. The protection was first expanded to 24.5 ha in 1999 in response to a survey conducted by Tibor Seregélyes and Ágnes Csomós on the then state of the habitat (Bajor 2009), and again to 40 ha in 2013 following the botanical research of Balázs Pintér: this remains the area currently under protection. Most of the soil of the area is sand, and this determines the special composition of the flora. The region belongs to the Pest plain, the average height of which is 110 metres with total annual precipitation of around 550 mm; this precipitation is easily absorbed by the loose sandy soil. The area's climate is characterised by extremes, with hot, dry summers and with winter temperatures below the average for the capital.

Its original flora was characterised by open, closing and closed grassland patches, with smaller forest-steppe forests with shrubs around them.

Main threats

Due to urban development the sand habitat has been gradually shrinking and being isolated in the past 100 years or so. Construction of highway number 2 on the western border of the area was the first larger intervention, together with the creation of the practice area of the Petőfi Barracks. During the operation of the facility, alien woody species appeared on the site. Black locust (*Robinia pseudoacacia*) and black pine (*Pinus nigra*) were planted. In that time Russian olive (*Elaeagnus angustifolia*) appeared in small quantities and box elder (*Acer negundo*) through Danube's mediation.

Around the time of the collapse of communism the lack of an army presence made the area a "no man's land"; this situation was worsened by other local investments. These conditions helped fragment the habitats, as did the localised but significant presence of other adventive species such as false indigo (*Amorpha fruticosa*), Canadian goldenrod (*Solidago canadensis*), common lilac (*Syringa vulgaris*), Virginia creeper (*Parthenocissus quinquefolia*) and common hackberry (*Celtis occidentalis*) (Pintér 2006, Bajor 2009, 2011).

These mostly woody species are responsible for the abnormally fast pace of succession processes (Figs 2 & 3).

Initial conditions

The Budapest Local Group of the Hungarian Ornithological and Nature Conservation Society (BirdLife Hungary) started its Budapest survey program in 1996. The main goal of this survey was to reveal those areas within the capital's administrative borders that were under local protection and discover others in need of protection. This survey ultimately led us to the once large habitat called the Homoktövis Nature Conservation Area, which at the time of the survey was in quite an unfavourable state (Verseczki *et al.* 2007).

A number of rare and protected plant species can be found in the sand grassland and there are currently 25 legally protected taxa living in the area. The two most valuable of these are the strictly protected sand saffron (*Colchicum arenarium*) and ephedra (*Ephedra distachya*), the latter having its most significant occurrence here of all areas of the capital. Other valuable species include *Peucedanum arenarium* and *Sedum urvillei* subsp. *hillebrandtii*, again the latter being more populous here than in the rest of the Budapest area. Further protected plants include Fastigiate gypsophila (*Gypsophila fastigiata* subsp. *arenaria*), *Dianthus serotinus*, the narrow-leaved helleborine (*Cephalanthera longifolia*), feather grass (*Stipa borysthenica*), the drumstick allium (*Allium sphaerocephalon*) and the dyer's bugloss (*Alkanna tinctoria*).

Succession processes due to spontaneously growing alien woody species mediated by human intervention threatened the mere existence of this valuable habitat by the end of the 1990s (Seregélyes *et al.* 1996–1997). By 2005 there were only two treeless grass patches of around 1000 m^2 north of the Szilas creek, another 2000 m^2 patch north of the water authority's reservoir (Vízműtelep) and 500 m^2 on the north side of where Megyeri Bridge now lies, which back then had not yet been constructed. In this period nature conservation activities were carried out by the Budapest Forestry arm of the Pilis Park forestry authority, commissioned by the municipality of Budapest. To avoid damage to wild game, the most beautiful buckthorn patches and the surrounding grasslands were fenced off. In addition, the spread of adventive and native woody species was controlled with the help of mowing. No treatment was performed in this period except on the two 1000 m^2 areas with remaining valuable sand grassland patches. As a result, the aggressive expansion of the black locust and the Russian olive and certain poplar species planted decades earlier threatened with extinction the grasslands outside the fence. In the course of our survey we discovered that in this period grasslands could be found at a number of places among young tree stands, although their transformation had already started due to the changing conditions. This was also reflected in the impoverishment of the species pool, as well as the appearance of some species not typical of sand grasslands (e.g. black horehound (*Ballota nigra*), European dewberry (*Rubus caesius*), etc.).

Methods used

Balázs Pintér, botanist of the Oak Association of Nature Conservation (Tölgy Természetvédelmi Egyesület) conducted a detailed floristic survey in 2006 in areas worthy of protection and of local interest for Budapest as entrusted by the municipality of Budapest. In the framework of this survey a clear picture of the Homoktövis Nature Conservation Area and its valuable plant communities, as well as the size of its plant species populations and species composition, was painted. In the course of these activities we worked in close cooperation with the contractor and thus were able to determine the bases of the long-term habitat treatment program, which had been in planning at the time. Prior to commencement of the work, the following important points (which at the time were lacking practical experience of) were determined:

- We decided to use only hand tools and powered hand tools due to the fragile nature of sand grasslands. Heavy machinery could only be used in wood shredding.
- The transporting of cut materials can only be performed by hand.
- The cutting of the alien woody and herbaceous species must be done slowly and gradually moving away from the most valuable treeless patches in a radial manner in order to avoid a possible population explosion of the invasive plants.
- Work can only be performed outside the vegetation period, that is, between the end of October and the beginning of March.
- Work would be initiated in the largest (13 ha) unit of the habitat, which can be found between the track of the Megyeri bridge (in the planning stages at the time) and the water authority's reservoir to the south.

After defining the most important criteria for managing the habitat, we resumed our series of actions aimed at habitat management treatment, which was first organised on 4 November 2006. Our most important goal was to build the process exclusively with volunteers, counting on the high number of members of the Budapest Local Group of the Hungarian Ornithological and Nature Conservation Society, as well as activists and others interested parties. Following our advertisement, around 50 volunteers took part in the project. The Budapest Birders' Association and the Budapest Forestry arm of the Pilis Park Forestry authority also aided our activities in 2006 and 2007 by providing tools. Shortly after the interventions of 2006 and November 2007, the Budapest Forestry, which also carries out nature conservation management under the aegis of the municipality of Budapest, contributed to our work; therefore, even the smaller scale intervention in the first two years led to significant results.

In the course of those two years, all treeless but partly isolated grassland patches could be at least partially connected to the others.

In the first years, in the interest of protecting the area, the interventions undertaken twice a year were exclusively carried out with the help of hand tools and powered hand tools (chainsaws and clearing saws), while explicitly avoiding chemical intervention. The exploited wood was deposited on the grasslands during this period; however, this proved to be a bad decision. One of the most important conclusions made during the first three years of the project was that the woody species cut down in 2007, but mostly after the rainy summer of 2008, sprouted so significantly that the usage of chemicals to dry off sprouts became inevitable to complement mechanical methods. Before the introduction of the new work stage we consulted the appropriate plant protection professional at Budapest Zoo, on whose instructions we started chemical intervention in July 2009. The first time we used a category III over-the-counter herbicide, Dominator (486 g/l glyphosate isopropylamine salt and 150 g/l tertiary amine ethoxylate adjuvant agent), which is a total-control herbicide with fast absorption and is excellent for drying off stands. We used the abovementioned chemical in a 3.5% concentration mixed with Nonit, which is a surfactant and cohesive agent that improves herbicide coverage by reducing the surface tension of the water used for spraying. We tried to carry out the chemical treatments in warm and sunny weather to further enhance the burning effect of the agent. Dominator is a chemical to be used explicitly during the vegetation period, and which is absorbed through the green parts of the shoots before reaching all parts of the plant. First, we used two-litre hand sprayers and paid extra attention when spraying the offshoots of previously-cut and later resprouting shoots of the alien woody species, making sure that the herb layer was as little disturbed by the intervention as possible. The use of protective equipment is of utmost importance during the treatment, since the chemical has a burning effect when it comes into contact with the skin. The treatment was performed on black locust, black pine, Russian olive, poplar species as well as the common privet and the spindle.

As a result of the chemical intervention we were able to extend the treatment to other open areas and, unlike previous years, we did not need to return to previously-treated fragments in order to control the sprouts. The central component of the organisation of interventions continued to be the exclusive involvement of volunteers. However, from 2010, when the municipality of Budapest did not entrust the Forestry with nature conservation management tasks, we organised our events twice a year in February–March and October–November, which were complemented by the above-detailed summer chemical procedures.

This methodology was followed until the end of 2013, with a high level of success in the area. As a result of the increasing pace of grassland opening, we were able to perform the treatments not only between the water authority's reservoir and Megyeri Bridge (which had been completed in the autumn of 2008) but also on the two separate foresting grasslands, amounting to a total area of 5 ha.

Following a review of our experiences and after recognising the shortcomings of treatment with Dominator, we decided to shift to injection of woody species as well as wiping of the stump surfaces with Medallon Premium in the autumn of 2013. Similarly to Dominator, Medallon Premium is a category III total herbicide in free circulation, the active agent of which is 360 g/l glyphosate (the agent's salt form is 439 g/l glyphosate diammonium salt). In the course of the intervention, we made sure that after the removal of sprouts and trees, the cut surfaces are treated immediately, while we also started drilling holes into alien trees through which the chemicals were injected. In order to avoid evaporation, the holes were sealed with Plasticine. The holes were drilled with a battery-powered drill and an 8-cm-long-handled tree drill. One hole was drilled up to 10 cm diameter, two up to 20 cm, four up to 30 cm, and five holes were drilled into the root collar of trees above 30 cm in diameter.

In the autumn of 2011 we started phytocoenological examinations by defining 70 2×2-metre quadrants in the area in order to research the effects of habitat treatment on the grasslands.

Experiences gained

Changes in the population size of protected species

The most important purpose of habitat management, beyond the conservation of valuable sand grasslands, is to maintain or even strengthen the populations of the plant species found in them. These fragile species are not only among the flagship species of the area's nature protection activities, but can also be used as indicators of the effectiveness of the intervention.

It can be generally concluded from continuous surveying that the density of protected and strictly-protected species in the regenerating grasslands is improving. Specific data on the subject can be found in Table 1.

It has to be added that in the natural and adjacent natural forests of the protected habitat other protected plant species can be found.

There is a stand of ten individuals of blackcurrant (*Ribes nigrum*) and five individuals of columbine (*Aquilegia vulgaris*) living in the English oak forest bordering the grasslands south of the Megyeri bridge. Their nativity, however, in the surveyed habitat is

Table 1. Changes in stand size of the protected plant species based on the last three botanic surveys.

Species	Size of stand (individuals)		
	1996–1997	2006	2014
Achillea ochroleuca	?	?	500
Alkanna tinctoria	300–500	250	800
Allium moschatum	–	2	2
Allium sphaerocephalon	20–30	10	500
Anacamptis morio	–	1	1
Centaurea arenaria	–	10	20
Centaurea sadleriana	200–300	30	300
Cephalanthera longifolia	60–80	–	120
Colchicum arenarium	30–50	10	*ca* 20
Corispermum nitidum	30–40	40	50
Dianthus serotinus	50–60	–	100
Ephedra distachya	approx. 50 ind. in two stands	400	800
Equisetum hyemale	–	100	100
Gypsophila fastigiata subsp. *arenaria*	50–100	200	2000
Hippophaë rhamnoides	100–150 ind. in 6 isolated patches	750	1000
Onosma arenaria	5–10	–	–
Peucedanum arenarium	150–200	1600	2000
Sedum urvillei subsp. *hillebrandtii*	–	30	500
Stipa borysthenica	100–200	2000	2500
Tragopogon floccosus	100–200	50	150
Vinca herbacea	20–30	3000	2000

questionable. Small-leaved helleborine (*Epipactis microphylla*) and white helleborine (*Cephalanthera damasonium*) can be found on the southernmost spot of the grasslands. A small population of violet helleborine (*Epipactis purpurata*) could earlier be found here; however, it has not been detected since 2007 despite dedicated searches. Meanwhile, the burning bush (*Dictamnus albus*) stand present in the 1990s fell victim to the construction of the M0 motorway.

Mechanical treatment

Mechanical treatment carried out in the area should be divided into two categories, and the experiences gained with woody and herbaceous species must be regarded separately.

Mechanical treatment of herbaceous species

The presence of herbaceous invasive plants is rather low in the Homoktövis Nature Conservation Area. The only significant species are the common ragweed (*Ambrosia artemisiifolia*) along the roads by the grasslands and the Canadian goldenrod along the old highway number 2.

Based on our experiences, mowing common ragweed at the end of June/beginning of July and, in the case of rainier summers, a follow-up mowing at the end of August/beginning of September brings about a favourable result both in terms of the prevention of maturation and the control of the stands. Fortunately, its settlement did not occur even temporarily in the treated areas. Common ragweed usually appears in border zones such as dirt roads used by vehicles, but certainly appears less and less due to the treatments.

Of the herbaceous invasive plant species the Canadian goldenrod poses the most severe problems; its presence, however, is not significant enough for its control to be hard to manage.

Some stands can be found at the edge of the grassland north of the Szilas creek as well as north of the water authority's reservoir, the total size of which is about 1000 m^2. The spread of the stands are to a high extent prevented by mowing in the beginning of July before blooming, and in some cases its control was also documented. At the same time, following the multi-annual survey started in 2006, the chemical treatments started in 2009 were extended to this species as a result of which the size of the stand is now about one-third of what it used to be.

Mechanical treatment of woody species

The most significant conservational problem in the area is the presence of non-native woody species. Four species in particular are cause for serious concern, the stands of which are the largest. These are the box elder, the Russian olive, the black locust and the black pine. Besides these, the common hackberry, the Virginia creeper and the green ash appear in smaller

Fig. 1. The 2014 state of the areas along the border of the Homoktövis Nature Conservation Area and the areas having undergone habitat management. (Map by: Vera Szabó and Zoltán Bajor)

Fig. 2. The spread of the most important non-native species in the Homoktövis Nature Conservation Area at the beginning of the treatments 2/1): 1 = Virginia creeper (*Parthenocissus* sp.); 2 = box elder (*Acer negundo*); 3 = false indigo (*Amorpha fruticosa*); 4 = Canadian goldenrod (*Solidago canadensis*); 5 = tree of heaven (*Ailanthus altissima*); 6 = honey locust, common hackberry (*Gleditsia triacanthos* + *Celtis occidentalis*). Yellow line: under protection since 2013, orange line: under protection since 1999

Fig. 3. The spread of the most important non-native species in the Homoktövis Nature Conservation Area at the beginning of the treatments 2/2): 1 = black locust (*Robinia pseudoacacia*); 2 = black pine (*Pinus nigra*); 3 = common lilac (*Syringa vulgaris*); 4 = Russian olive (*Elaeagnus angustifolia*). Yellow line: under protection since 2013, orange line: under protection since 1999

patches. Felling and mechanical sprout removal between 2006 and 2009 initially produced significant results. However, particularly in wet summers, like in 2008, some species reacted with vigorous sprouting, which made the maintenance and limitation of the spread of the artificially opened patches very difficult (Fig. 4).

As a result, the volunteer-based work had to be complemented with additional treatments before and after the larger interventions, mostly in the autumn period.

More effective and drastic interventions were needed after the Russian olive presented a sprout growth of 100–150 cm and the black locust a 300–400 cm sprout growth. This has necessitated chemical follow-up treatments in the period since 2009. All in all, it can be stated that in sandy habitats mechanical treatments are only effective when performed in parallel with chemical treatment.

Chemical treatment

We have experimented with a number of different types of chemical interventions in the course of the chemical treatments since 2009, while assessing and documenting the effects of certain technologies*.

First, the over-the-counter total herbicide Dominator was used against the sprouts in previously treated areas, the effectiveness of which was enhanced by the use of a cohesion enhancing reagent Nonit. The reagent is absorbed through the green parts of the plant and is most effective in summer heat. Its use must be restricted to the vegetation period, since sap circulation is needed for its absorption and spread in the plant. The effects of the treatments were monitored throughout 2009 with the subsequent conclusions broken down to each of the invasive and certain native species, 8 days after the first intervention (the total herbicide was used in a 3.5% concentration mixed with a minimal amount of Nonit according to instructions).

Black locust: This species was the most responsive to the chemical treatment after being sprayed. If the green shoots of a plant were completely covered in herbicide, it dried out down to the base of the stem in about a week and a half, while those exposed to less chemical or even inaccurate application also reacted quite favourably, with many of them drying out completely in the following weeks. However, with this species a second complementary treatment was needed in all cases. It can be generally concluded that by the end of the first treatment, 80% of the relevant patches died. It is of primary importance that, based on our findings, green shoots must be treated with the chemical and plants must be sprayed from at least

*Attention! Experimental chemical control methods described in this chapter are subject to authorisation! Their practical application requires an emergency permit issued by the pesticide control authorities for the given area and period!

Fig. 4. Groups of Russian olive shoots growing on a grassland subject to mechanical treatment. (Photo: Z. Bajor)

two angles (the same is true for all other sprayed tree species).

Russian olive: This species presented a lower scale reaction than the locust: several clumps of shoots started to dry out from the bottom. Only after two weeks following treatment is it possible to determine with a degree of certainty as to whether total eradication was successful in the relevant patch or whether the top sprouts will remain intact and stems will continue to grow.

It is interesting to see that drying-up starts at the top in the case of a number of plants (Fig. 5). Due to the first treatment, 70% of the relevant stand was destroyed and two interventions proved sufficient for complete success.

Box elder: Its reaction was similar to that of the Russian olive, both regarding the extent of drying-up and the success of the first treatment. Two interventions per stand were sufficient in the case of this species, too.

Black pine: Due to its special leaf shape and waxy surface, this tree species responds to the treatment to a lesser extent. One and a half weeks after treatment the only noticeable effect was the browning of certain leaves. However, when the herbicide is applied on the apical shoot, further growth of the tree can be stopped and the relevant plant will die very slowly, over a matter of months. However, success is only likely in the case of trees shorter than one meter.

Less common woody species: The common hackberry and the green ash are the ones worth mentioning from this group. These species reacted to the herbicide treatment with varying speed. By the end of the eighth day, the hackberry had almost completely turned yellow in the entire area, whereas in the case of the green ashes the effect was barely noticeable,

Fig. 5. Black locust and Russian olive (in the picture) proved to be the most sensitive to chemical treatment carried out with Dominator. (Photo: Z. Bajor)

Fig. 6. The spread of horseweed (*Conyza canadensis*) in the year following treatment with Dominator is always considerable but the following year shows notable reduction. (Photo: Z. Bajor)

with only a few cases of small-scale drying. When the species received a larger dose, the leaves dried off, while the smaller dose did not have such an effect. In the case of the green ash, the treatment should be carried out in two stages; in some cases with larger plants or because of unfavourable weather conditions, a third treatment is required.

During the treatments it became clear that the herbicide, when applied directly onto the end of shoots with 1.5- and 2-litre hand sprayers, harm only to a very small extent the protected herbaceous plants on the ground of the open sandy grassland (Fig. 7). After a number of surveys in the area, we concluded that if the treatment is applied carefully, only a few Poaceae species show small-scale drying. At first, we were mostly concerned about the drying and the decay of the native grassland vegetation, but after the eighth day we saw that there was only partial vegetation decay in a 25 cm radius around the treated plants, which was probably due to dripping herbicide. The remaining herbaceous plants will easily make up for the sporadic gaps, since their source of propagules is close to the treated areas in every case. In the case of Dominator, however, the chemical is still active through the following autumn and winter up until the spring, and the small amount of herbicide dripping on the ground was enough to make the undergrowth dry out in about a 50–100 cm radius of the treated area. The size of the dry circle depends on the height of the specific shoot: the higher up the chemical had to be sprayed, the more likely dripping became. Weed species appeared in small numbers in the gaps, such as horseweed (*Conyza canadensis*), common ragweed and pigweed (*Chenopodium* spp.) types (Fig. 6). Nonetheless, according to surveys carried out in the next vegetation period, it became clear that the opening of grasslands considerably accelerated the filling in of these “holes” with more valuable species characteristic of the habitat (Fig. 8).

In 2013 we started applying Medallon Premium onto the fresh cut stump surface of larger woody species as well as injecting Medallon Premium into drilled holes of living trees. The chemical was applied in its original concentration without dilution in each case. To facilitate easier traceability, we added red food colorant to the originally light yellow reagent and thus were able to see which cut surfaces we had and had not yet treated. After the treatments, we made the following observations in the case of the dominant woody species to be controlled.

Black locust: In the course of wiping following the cutting off of sprouts chemical treatment of the lo-

Fig. 7. Control of non-native species can be carried out without any additional damage if the treatment with Dominator is chosen and carried out carefully and spot-like at the right time. (Photo: Z. Bajor)

Fig. 8. July view of a treated and gradually regenerating part of a sand grassland. (Photo: Z. Bajor)

cust was seen to have been effective. Results show that applying the chemical right after cutting stops 80% of the plants from sprouting again. The treatment is most effective during the active sap circulation period; it can also be applied in winter but with significantly lower efficacy.

If the chemical is injected into the root collar, then providing it is done so during the vegetation period, treatment is even more effective. In this case, independent of age and size, 90% of the trees dried out and no later sprouting at the suckers was observed. After injections, locust plants needed 3–5 weeks until complete drying-out; this period depended on the stage of the vegetation period in which the reagent was used. The drying process was slower in early spring due to slower sap circulation, while the end of August and end of September treatments proved the most effective due to more powerful sap circulation in the pre-winter storage period.

It was concluded that following the second treatment the success rate was 100%.

Russian olive: In the case of Russian olives, given that the larger stands had been controlled by 2013, the injection procedure was not deemed to be necessary, as by the time the technology was introduced there were only smaller and younger stands alive in the area. As a result of the chemical painting treatment, there was barely any sprouting activity in the case of Russian olives and 80% of them dried up independently of age and size.

Box elder: The box elder can most commonly be found in more significant quantities on the edge of grasslands and in connecting poplar patches, the control of which has only been done to a small extent. The reason for this is that its presence is insignificant in the grasslands. Based on observations this species shows a sensitive reaction to the cut stump and injecting methods, with even larger trees showing significant drying after 2–3 weeks. Most plants dried up after a single cut stump treatment, while only an insignificant number sprouted afterwards.

Black pine: In the case of the black pine, no herbicide application was carried out due to the tree's high resin content and because this species does not tend to grow stem sprouts after cutting. Some plants, however, were injected as part of an experiment, the effects of which were then observed. Trees treated in the spring period showed minimal shoot tip drying, while during other stages of the vegetation period no other changes were observed.

The drying pace of pines accelerated in August, which meant that the leaves of most plants turned from green into brown in colour in the course of a few weeks. Presumably due to its high resin content, the effect mechanisms of the black pine are significantly slower, although after a sufficient amount of time almost all treated plants reacted to the reagent. Medallon Premium was not applied to other species until 2014, so we have no comments to report regarding other taxa.

In 2010, on the other hand, a number of selective herbicides were tried out, the subjects of which being primarily the box elder and false indigo. Following application, the only observable result was faster shrivelling of the top offshoots in treated plants than is the case when treating with Dominator. Unfortunately, the process came to a halt at this point and the shoots stayed alive in all cases. Effectiveness could not be sufficiently established, so we decided against further use of selective reagents.

Chipping of wood

Not enough attention was paid to the fact that one of the basic conditions for the survival of sandy grasslands is a significant reduction of organic materials over the territory. One of the most important means to achieve this is to remove the timber of exploited woody species from the treated area (Fig. 9). In the first few years of the actions organised by the Hungarian Ornithological and Nature Conservation Society, the Budapest Forestry arm of the Pilis Park Forestry authority responsible for the nature conservation management of the area chipped the piles of timber deposited in the sand grasslands on site. This inadvertently resulted in moderate spread of some weed species, e.g. evening star (*Oenothera biennis*) and wild goosefoot (*Chenopodium album*).

After this period, there were no further observed changes in the species composition of the sand grasslands. Up until 2010, woodchips was gradually and manually removed from the treated area to the side of the dirt road, stopping it from decomposing completely, which would otherwise result in excess organic matter content in the soil (Fig. 10). The consequence of this action was that the weeding process was prevented from accelerating (Fig. 11).

We paid extra attention in the years following 2010 not to produce more timber than we can safely remove to the side of the dirt road by the end of the day.

As a result, all the produced organic materials were removed from the opened areas by 2013, which had a favourable effect on both species diversity and species composition in the area.

The importance of volunteer work

Besides the careful planning and realisation of the treatments we paid great attention to raising awareness and environmental education, both of which have had a number of positive effects. Those volunteers answering our advertisements contact us out of enthusiasm and not for material gain, and the work they do is always very thorough. It is important to note that the completion of such tasks is a financial relief for the funding bodies in charge of the declaration of protected areas because they will then be able to allocate the saved funds towards the conservation of other areas. We combine educational activities with volunteer work; for example, the students of both Corvinus University of Budapest and Szent István University have taken part in the efforts to open grasslands in the form of field trips since 2010. The same is true for the now compulsory 50-hour community service in secondary schools. Even though students in this arrangement are not volunteers as such, they tend to work enthusiastically. In this way, we not only improve the overall state of the area, but also are able to promote the importance and significance of our work widely.

Nonetheless, working with civic movements has a few drawbacks. For instance, organisation can be problematic; since the number of staff available for a given day can never be determined in advance, this makes planning difficult. The different types and levels of background knowledge of the volunteers also have to be taken into consideration. On top of that, the degree of active participation can also vary amongst volunteers, being notably less enthusiastic in the case of high school students.

Fig. 9. During the first two years, timber waiting to be chipped was deposited on the sand grasslands, which proved to be a bad decision since the excess organic matter had an unfavourable effect on the herbaceous species composition of the valuable habitat fragments. (Photo: Z. Bajor)

Research results

We started phytocoenological examinations in 2011, at which time it could be seen that the changes occurring in the vegetation due to nature conservation treatments were positive. It has become obvious that the typical and dominant species of the sand grasslands are gaining more and more ground. A 6–8-year period is enough for the vegetation typical of the area to appear. The records from 2012 and 2013 show that the vegetation in areas where shrub control and follow-up treatments were performed 6–8 years earlier are becoming more natural, while the pace of change has slowed compared to areas treated 2–4 years before.

In accordance with the pace of treatment we defined ten 2 × 2 m quadrants on the cleared habitat fragment to monitor the changes in the vegetation. Since the survey was started in 2011, altogether sixty quadrants have been defined in the treated area from 2006, and another ten quadrants in the control area. The bottom left corners (northern orientation) of the quadrants were marked with the help of GPS and surveying poles.

The untreated areas were marked by the Roman numeral 'I', while the freshly opened areas were denoted by 'VII'. The control area, where the sand grasslands had been undisturbed for at least 30 years, showed the lowest number of species and showed no change during the years of the survey, with its species compositions remaining stable. In the sample areas II and III, where there had been treatments performed in the previous 7–8 or 6–7 years, the species composition of the grasslands remained similarly stable. In the areas V–VII, which were treated 5–6 and 2–3 years previously, the average number of species had increased.

The continuous survey and monitoring of alien woody species in the area is very important in order for possible new species to be detected early for rapid response.

Six invasive alien woody species can be found in the surveyed area: tree of heaven (*Ailanthus altissima*), box elder, black locust, green ash (*Fraxinus pennsylvanica*), common hackberry, and Russian olive. These species can be found from sample area V to area VII, while tree and shrub species native to the area can be found from area II, with a more significant occurrence from the quadrants of area V. The existence of weed is an important indicator of disturbance. Their occurrence becomes more common in areas III–VII, with the largest amount found in area VI (areas treated 3–4 years previously).

Weed occurrence is very high in areas VII and VI, while in area IV, where the shrubs were controlled 4–5 years previously, it has been reduced to a few percent.

Alien species are most typical in areas VI and VII, that is, those areas treated most recently. Plant groups

Fig. 10. In the course of habitat management the invasive alien woody species are removed manually. The produced timber is placed on tarp and taken off the grassland to a dirt road on the edge of the habitat. (Photo: Z. Bajor)

created by statistical analyses (ordination) can be also differentiated according to their occurrence (in which sample areas occurred). The most pronounced differences can be seen between the groups of sample areas I and VII, highlighting the regeneration and succession of sand grasslands in the area.

Alien species can also be found in sample areas V, VI and VII. Analysis shows, however, that they are gradually disappearing from the treated areas, while the similar species composition of groups I, II, III, and IV show favourable living conditions for sand species. Sample areas VI and VII are the ones most burdened with different weed and invasive species since in their case the regeneration of sand grasslands only started recently.

A short evaluation of surveys

The importance of habitat reconstruction activity is on the rise nowadays and more and more research has assessed the reconstruction of habitats through active intervention. At the same time, the habitat reconstruction of natural and nature-adjacent areas remaining in city environments is barely known in Hungary (Kézdy and Tóth 2013).

With the aim of accelerating the processes, undersowing with seed mixture is used in many cases to

Fig. 11. Removal of timber from the sand grassland with tarps. One of the most important goals of this activity is to insure that sand grasslands remain poor in nutrition, which requires reduction of humus production. (Photo: Z. Bajor)

reach faster results, but this might in fact be ineffective. Undersowing was not deemed justified in the case of the selected Budapest location since the fragments of the original plant communities were still present in the sample areas, this providing us with a good starting point (Pintér 2006).

In the surveyed Budapest area the changes in the vegetation over 7–8 years can be well traced; these changes have been positive in the context of our nature conservation goals given that the dominant species of sandy habitats have started to gain ground. If we compare this to previously recorded data, it is expected that continuing treatments will result in the formation of closing sand grasslands, the ratio of which is currently low in the surveyed area. The open sand vegetation tolerates degradation better, and this fact could be observed following the treatments. The spread of the latter community is the most spectacular at present.

With regard to the impact of years of nature conservation treatment on the vegetation in the area, the number of species, species diversity and species composition we can say that after gradual removal of excess organic matter produced by the invasive woody vegetation in the surveyed seven sample areas, favourable living conditions have been assured for the species of the opening sand grasslands in the long run. Due to follow-up treatments in the area, the grasslands have reacted favourably to short term mowing and shoot control, and this finding concurs with data from other sample areas; accordingly, prolonged application of such treatments is expected to further improve species diversity and species composition. This positive effect is complemented, and in some cases accelerated, by the types and combinations of chemical interventions used in the area.

According to the survey, the sand vegetation of the treated areas in the case of samples II and III, where the nature conservation treatment was performed for 7–8 years, is starting to revert to the originally typical closing sand grasslands. This finding was confirmed by coenological examinations. Elements of unwanted flora, weeds and invasive species are gradually disappearing from the protected natural area. Its species composition regarding sand grasslands is also becoming more and more favourable. In contrast to other data that suggested that reconstruction of grasslands following intervention can be a slow process, taking as long as 8–10 years or even longer (Török *et al.* 2008), the process has been faster in the surveyed areas. This is presumably due to the presence of remaining core areas and the favourable species pool.

As for tracing the changes in the dominant species in the assessed sample areas, we can say that, based on our observations, natural or semi-natural vegetation types have evolved in those stands where nature conservation treatments were performed 8 years ago. Invasive and weed species have practically disappeared in these quadrants. During our survey it was evident that the stands of both types of fescue (*Festuca vaginata* and *Festuca pseudovaginata*) are gradually growing due to the treatments. In more disturbed areas, it is not Festuca vaginata but another type of fescue that becomes dominant (Penszka 2003); this observation was confirmed by the results of our survey.

According to the survey, sample area VI is in a less favourable condition in terms of the number of species, diversity and relative ecological indicators than area VII, where conservation management actions were carried out last. Our survey suggests that this is due to the area having been covered in debris, with this encouraging afforestation and shrub encroachment. This was only discovered after the untypical shrubs were removed, since the area was fully covered with alien species, keeping the inert debris unseen. However, even after this discovery, we considered further treatment of the area important since, as with the follow-up treatments of other areas, renewed neglect of this area would make it a suitable breeding ground for the return and spread of alien species. Mowing has resulted in the positive results, and we have seen that, as is the case with sandy lands, the species composition has been successfully shifted towards native species, with the establishment of secondary grasslands and the exclusion of the box elder and black locust stands that were present before treatment.

Issues raised

It is clear that the experiences of the past nine years have resulted in the establishment of a clear habitat reconstruction technology, and this is in accordance with the strategies and goals of the management plan of the government regulation that declares protected areas. Nevertheless, these procedures cannot be completely accepted by the forestry and the forestry authority since legislation regulating forests often conflict with the requirements of nature conservation. This also calls into question the degree to which the stands of mainly alien woody species in the border zones, which are worthless from a forestry point of view, can be treated. From a nature conservation point of view, the complete removal of alien invasive species would be important, while the habitat classified as managed forests is to be handled completely differently from a forestry point of view; this contradiction is intensified by the fact that both considerations are backed by legislation. Moreover, the relevant areas include parts of forests where the age of maturity is planned at 999 years, which means the goal is to maintain a permanent forest which surprisingly is partly made up of an invasive species, specifically black locust. It is not yet clear how this double bind, one of the greatest problems we have encountered during our work, can be resolved. Further questions are raised by the presence of debris coverage made up of inert waste found during treatment. These piles of debris can mostly be found along the largest treated area as well as to the south of the water authority's reservoir. Their removal would be very costly but, nonetheless, essential in order to restore the area's original natural state, since it might be a potential breeding ground for invasive species. The winning and execution of a large-scale tender might resolve this problem.

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Tree of heaven control in the area of Alsó-hegy in Tornanádaska

Fanni Boldoghné Szűts

Natural characteristics of the area

Most of the Alsó-hegy of Tornanádaska is built up from Triassic limestone with patches of dolomite wedges. The rock-bed is pierced by gaps typical of karstic stones with varied meso- and micromorphology. The open, southern and south-eastern facing areas, formed by past forest use and grazing, eroded due to the trampling of the animals and the rainfalls and now, as a result of these, rocky skeletal soil covers the surface. Open xero-termophilous oak forests and calcareous rocky grasslands appeared as secondary on these. They provide habitat for several strictly protected plant and animal species, including the specially protected domestic population of *Onosma tornense.*

Initial conditions

The main threat in the habitat of *Onosma tornense* is the vigorous spread of tree of heaven (*Ailanthus altissima*) introduced in the barren area in the 1950s. This adventive invasive tree species can be found on the Alsó-hegy between Bódvaszilas and Hidvégardó on an altitude of 270–475 m. The coverage of this nearly 100 ha area is 30%. In the thicker soil at the bottom of the hill, seed-bearing trees grow in smaller groups, which can yield more than 300,000 anemochorus fruits per individual every year. On the skeletal soil of the southern, south-eastern region 1–2 m high sprouting trees take up a large area, including some 3–5 m high seed-bearing trees. In other areas, they are present in dense sprout colonies with thin trunks, on the edge in smaller or larger groups or growing from a seed into a solitary specimen. The seed bank in the soil can be some millions strong. The tree has anallelopathic effect on itself and on the other dicotyledon plants.

In order to protect the habitat of *Onosma tornense* tree of heaven control was started in the territory of Aggtelek National Park Directorate. As a first step, during the mapping of tree of heaven between 2000 and 2002, which was carried out parallel to the point mapping of *Onosma tornense*, habitats were marked on an EOV (Hungarian Unified National Projection) 1 : 10,000 scale topographic map without satellite positioning. 4–5 people examined the hill during mapping. Valleys, ravines, cart-roads, paths dividing up the side helped the E-W positioning. A VALT 17 leveller used by hang-gliders helped define the altitude of the given point with an accuracy of +/– 5 m. Today the accuracy and level of detail of these measurements could be highly improved by satellite positioning tools, so in 2010 a detailed GPS survey was carried out to map tree of heaven and *Onosma tornense* populations of Alsó-hegy. This map could provide a proper base for post-treatments.

Methods used

Finding an effective method for tree of heaven control

Tree of heaven starts sprouting vigorously due to the stress caused by cutting, so only a chemical treatment can be effective.* A series of experiments was

* Attention! Experimental chemical control methods described in this chapter are subject to authorisation! Their practical application requires an emergency permit issued by the pesticide control authorities for the given area and period!

started in 2001 to define the safest method for delivering the chemical and finding the most effective chemical concentration.

Ecologically acceptable premium herbicide has to be used during the experiments, while adhering to safety regulations. The seed-yielding period (between the end of July and the beginning of September) is the most effective time for performing the treatment, when the balance of nutrient transport favors the roots.

During the experiment we applied two techniques minimizing the drifting of the chemical (holding the foliage together and spraying, hack and squirt method) and a dilution line (5%, 15%, 25%, 50%). During the treatment we always recorded the plant species in a 25 cm radius of the trees and their coverage. We examined 50–50 trees of heaven by each combination, thus altogether 400 trees were treated with the herbicide. In the year following the treatment we checked if leaves or sprouts appeared on the treated trees and we examined the changes of species and coverage in the vegetation around the treated trees.

Based on the results of the experiments the following methods proved to be effective depending on the height of the tree.

a) Smaller trees (approx. 1 meter high): the foliage of sprouts should be spot-sprayed with a 15% chemical. The leaves should be held together in a bunch from below and then sprayed with a hand sprayer while wearing gloves. The spray shall affect 70–80% of the whole foliage. Required tools and materials: Medallon Premium, 2 liter spraying bottle, 5 liter cans to transport the mixed chemical and rubber gloves.

b) Bigger trees: we make a deep cut reaching the cambium at the bottom of the trunk and we inject a 15% chemical solution into that. The number of these cuts depend on the thickness of the trunk, according to experience so far a trunk diameter of 25 cm requires one cut of about 5 cm in length and 3 cm in depth. The distance between cuts shall be 2–3 cm at least, thus causing less stress to the tree than in the case of girdling, which leads to intense sprouting.

Required tools and materials during the treatment: mixed chemical (Medallon Premium), bushwhacker knife, a hatchet for bigger trees, 5 liter cans to transport the mixed chemical, injector (50–100 ml) and rubber gloves.

Elimination of tree of heaven stands (2002–2003)

At the beginning of the program the most urgent and important task was to remove seed trees as soon as possible. There were trees which started sprouting, but proved to be applicable with chemical treatment of the growing sprouts in the following years. The treatments were carried out by a contractor with 4–6 people, based on given criteria. The treatment started from the same place every year. People were standing 1–2 meters away from each other, while systematically going through the hill-side and treating the specimens of tree of heaven. The size of the treated area depended on the given year's characteristics, but as a minimum it extended from Komjáti to Tapolcka at Tornanádaska. The treatment was carried out at the end of the summer or at the beginning of the autumn at least for a month.

Post-treatment, monitoring (2003–2007)

In an effective program the post-treatment shall last for decades due to the root remnants and seed bank in the soil. Once the seed trees have been removed, 2–3 years can pass between the treatments after 5 years of continuous control, so seedlings can grow and become easier to treat and the controlled area can "rest" after the trampling and the use of chemicals. According to monitoring results, the effectiveness of preliminary treatments was around 80%.

Experiences gained

Experience gained from experiments

In the year following spraying with the 15% chemical 100% of the tree of heaven stands were eradicated, so there were no sprouts or leaves on the treated trees. However, despite the careful use of chemicals, the herbicide came into contact with the surrounding vegetation causing visible damage (especially grasses). The disturbed grassland became more open, some dicotyledon species – belonging to the original habitat – became temporarily dominant (e.g. white mullein (*Verbascum lychnitis*), blueweed (*Echium vulgare*), stickseeds (*Lappula* spp.)). Most of these grasslands have regenerated since then.

The treatment cannot be carried out in a windy or rainy weather. Applying 5% solution of chemical had good result (96%) as well. However, we examined deformed foliage and sprout development by some trees. If the number of tree-sized plants does not reach a significant level in the treated area, this technology and chemical concentration can be considered sufficient.

Injections into cuts were 86% effective using 15% percent solution of chemical (but by a 5% solution the effectiveness was only 51%). Its application is justified by the minimal damage of surrounding vegetation and the inaccessibility of the higher canopy. This method was used in the direct vicinity of *Onosma tornense* and by trees with a higher canopy.

Experience gained from the elimination of tree of heaven stands

As an improved application technique, the target surfaces have been wiped with bits of cloth soaked with the herbicide.

If both treatment methods (foliage treatment, cut stump method) are needed in the infested area, based on practical reasons it is advised to use only one type of the solution and to transport it in closed containers to the treatment area. The characteristics of the area shall be considered beforehand. On the Alsó-hegy of Tornanádaska the amount of larger trees were insignificant compared to the high number of trees needing foliage treatment, which required the chemical-heavy method of hack-and-squirt. After one year of working with two concentration types in field, the contractor only mixed in and used 5% chemical concentration by both delivery methods the next year due to practical reasons. This – as shown by later results – did not always cause the death of the trees treated with bigger cuts, but lead to their deformation only. (This was expected based on the results of the experiment as well.) The most effective technology would definitely be mixing in the two chemical concentrations for the different methods, if the chemical could be transported to the location easily and safely.

Daily chemical use from the 5% solution was 20–120 litres, depending on tree of heaven density.

On average, 1 ha was treated daily.

Due to dry summers the grass regenerated slowly. As in the heat of the summer the contractor's employees were not willing to wear gloves, we used liquid gloves in order to protect their health. It would be useful to carry out the experiment with a 10% solution as well, using both application methods.

It would be worth doing long-term experiments in the field, focusing on seed germination behavior after having been relieved of the allelopathic effect.

Experience related to post-treatment, monitoring

Unfortunately, due to a lack of resources and other factors the treatments were discontinued. As a result of this the distribution of tree of heaven did not drop significantly (only its coverage), in fact in some areas it even spread. Remaining trees developed further in the past few years and some of the treated ones recovered. Some of the trees left out of the treatment by mistake developed into a seed tree and infested the area even more. On several older trees that survived the treatment it is clearly visible that the phloem and the xylem was destroyed on the side of the cutting and chemical treatment, but the part of the phloem that was left intact started to regenerate and grew over the injured area. These trees started to sprout intensively from the stem or the side buds and created new trunks. Moreover, both left-out and surviving trees still develop root sprouts. Due to the weakening allelopathic effect the seeds in the seed bank started to germinate en masse.

It would be crucial to continue the treatment as soon as possible to stop the growing population, which otherwise renders the previous work and environmental load useless.

Most of the seeds arrive on the ground in an approx. 5 meter radius of the mother tree. According to scientific literature, the seeds are dormant for a period of one year, but no domestic research was carried out related to this topic.

Administrative issues related to the elimination of the tree of heaven stands

Based on Point g) of § 38 of Act LIII of 1996 the permit of the nature conservation authority is required to use chemicals in a protected area, which is requested by the manager of the estate.

To realize nature conservation treatment it is required to plan the felling of the treated amount of trees and the modification of the population structure in the annual forest management plan as an activity deviating from the management plan.

Control treatments of tree groups located in non-managed forests, scrubs, pastures and former ploughlands at the bottom of the hill should be inspected.

Acknowledgements

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The control of giant goldenrod in the Felső-Kongó meadows by Szigliget

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Natural characteristics of the area

This HUBF20028 Natura 2000 site (2339 ha) can be found in the Tapolca Basin within the Balaton-felvidék National Park. In 2007 we launched our three-year habitat reconstruction and grassland management programme (LIFE06/NAT/H/000102) in 455 ha of this area in the Felső-Kongó meadows (within the administrative area of Szigliget). The project site (Fig. 1) is bordered by Road No. 71 from the south, the periphery of the village of Szigliget from the north, the Tapolca stream from the east and the Világos stream from the west. The major part of the area subject to conservation management (443 ha) is in the land use category of grassland. The remaining 12 ha is composed of roads, water courses, associated ditches and very small forest patches. Thanks to the various microrelief, climatic and hydrologic conditions, numerous habitats of different qualities have developed in the Tapolca Basin. The semi-dry steppes at the feet of the hills and ridges of alluvial origin, the extensive humid hay meadows and pastures, the patches of bog and marsh meadows, the riparian zones of water courses, tree rows, and forest patches and shrubs provide home to a rich variety of wildlife, and almost all of these are protected areas (Fig. 2).

According to the climatic district distribution of Hungary, our area belongs to the moderately warm/moderately humid zone. It is a well-documented problem that in the past two decades the average temperature has increased and the quantity of precipitation has decreased; moreover, extreme weather events occur more and more frequently. The average annual precipitation is 700 mm.

The water condition of this area is influenced by several factors. Among these, the natural factors are: local rainfall, seeping waters, small water courses crossing the area, and the water level of Lake Balaton. Apart from the long-term drying tendency of the climate, we can also define human influences. For instance, the majority of the old artificial draining ditches weaving through the Tapolca Basin have been filled up; however, some can still lead water off the area. Another factor was the pumping out of karst

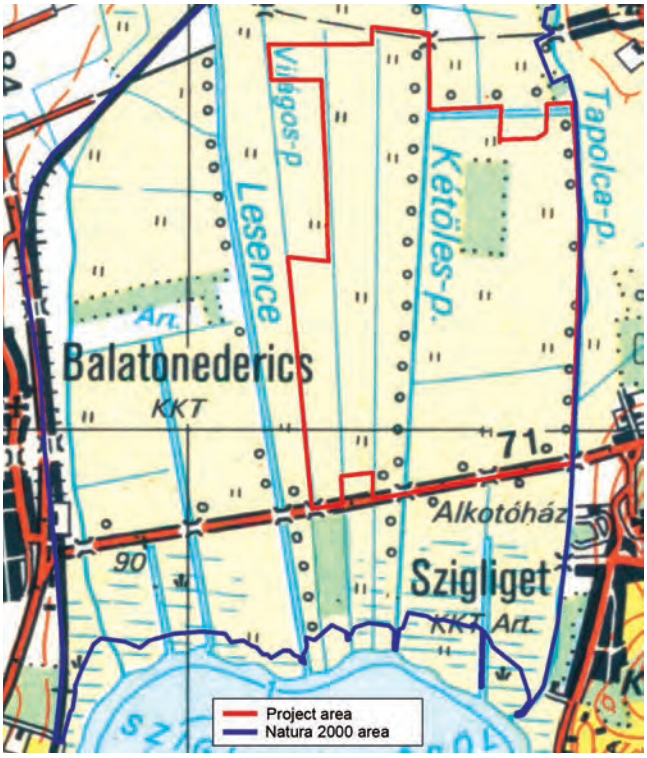

Fig. 1. Location of the project area in Tapolca Basin

Fig. 2. Overall view of the project area (the patches of giant goldenrod and shrubs are clearly visible). (Photo: J. Cservenka)

water to enable bauxite mining, which completely dried up a few small water courses (among these the Kétöles stream crossing the project area). To solve this problem, channels (in an east-west direction) were constructed to connect the streams (which run in a north-south direction). After the unreasonable exploitation of underground water ceased, the conditions were slightly settled, but the water conditions of the basin are still unfavourable due to years of drought and also to extreme precipitation conditions. Natural fluctuations in the level of Lake Balaton resulting from such extreme weather events have made it difficult to reliably maintain the level of the lake from season to season and from year to year through the periodic opening of the Sió-canal.

The largest part of the Tapolca Basin (and also of the project area) is at relatively low elevation; however, it has various microrelief conditions due to crossing water courses and alluvial deposits (with less than degree slope 0.5°) and slight depressions which are almost completely endorheic. The bedrock is composed of marine and terrestrial compact sediments. The most characteristic soil types of the sunken basin foot near to the surface are loose and of sedimentary character: lake, marsh, bog sediments; sand, aleurite, clay, gravel, bog, and lime mud types are present. The top layer of the soil is formed by meadow soil and bog soil with diverse and patchy transitional forms (due to the various bedrocks and deep soils).

Chiefly as a result of human activities, more and more rare plant species of special importance have disappeared from the former bogs and bog meadows of the basin, e.g. *Drosera rotundifolia*, *Pinguicula vulgaris* and *Pinguicula alpina* (the latter one became extinct from Hungary at the same time). The size of the bog meadows was decreased to fragments as there were no floods because of river control and because of the systematic drying-out of the meadows. However, in these fragmented habitats we can still find smaller or larger populations of very rare plant species, like *Primula farinosa* subsp. *alpigena*, *Senecio umbrosus* (in Lesencetomaj bog meadow), *Gladiolus palustris* (in Pénzes meadow) or *Gentiana pneumonanthe* and *Sesleria uliginosa* (in other bog meadow remnants).

Initial conditions

In a part of the Felső-Kongó meadows of Szigliget extensive grazing of the grasslands is carried out by the Balaton-felvidék National Park Directorate and leaseholders. The water conditions of the area have become rather unsteady recently. In drought years changes in the communities of humid habitats have been induced by the absence of a high water table in spring and autumn. In contrast, in rainy years grassland management has been difficult because there have been inland inundations, even in summer. As mowing was hindered at these times, one third of the project area became weedy and succession processes were launched (Fig. 3). Homogenous patches of alder buckthorn (*Frangula alnus*) and invasive alien giant goldenrod (*Solidago gigantea*) developed on the site (Fig. 4).

The project area is characterised by secondary humid hay meadows, marsh meadows, bog meadow remnants, and in the emerging parts, semi-dry grassland patches of steppe character; among the characteristic habitats of the Tapolca Basin there are also *Molinia* meadows. The needs of this plant community – which is fairly adapted to the natural fluctuation of water levels – are satisfied by the seasonal water level changes of Lake Balaton, which in turn strongly influences the groundwater levels of Tapolca

Fig. 3. Giant goldenrod and shrub stands unmanaged for years. (Photo: J. Cservenka)

Fig. 4. Homogenous goldenrod stand between alluvial willow scrubs. (Photo: J. Cservenka)

Basin. Ideal conditions for *Molinia* meadows is inundation by floods in spring or groundwater levels of a minimum of 30–50 cm, which then dries out in summer but remains above 1 m depth all year round. For the survival of *Molinia* meadows, extensive grassland management is also of vital importance. In the absence of management or in years of persistent drought, this valuable community becomes weedy and shrubby, and specifically is threatened by dense populations of invasive alien giant goldenrod. This species appears in masses in all the humid grass communities with optimal water conditions, and is found in continuous stands with high cover. Another problematic species of unmanaged *Molinia* meadows is a native shrub species, the alder buckthorn, which dwells in humid, nutrient-poor soils and spreads suddenly in these grasslands. It forms continuous, almost impenetrably dense shrublands, and it often covers the area together with giant goldenrod. The alder buckthorn suppresses the original grass-forming species through depleting nutrients and out-shading. In the framework of our project we eradicated this species by flail mowing and removing the shrubs.

Fig. 5. The channels constructed in the most infested area with giant goldenrod enable temporal flooding as well. (Photo: J. Cservenka)

Methods used

Improvement of water conditions

The two basic conservation problems of the project area are the very changeable water conditions (especially the drying-out in drought years), and the spread of alder buckthorn and invasive alien giant goldenrod. We aimed to conserve the humid habitats of Felső-Kongó meadows through regulation of the water supply and control of these problematic species. With the improvement of water supply and the increase in groundwater level, giant goldenrod can also be curbed; in rainy years the temporal floods are even more effective given that giant goldenrod does not favour persistent water cover (Figs 5 & 6).

We directed the water with the aid of a dam constructed on the Kétöles stream (Fig. 7) and two side channels (Fig. 8). For the rehabilitation of the area covered by invasive alien species we used grassland management techniques of active clearing and sustaining character. Sluices provide the water supply of the channels and its drawing-off; these are operated by the members of conservation ranger service. Changes in the groundwater levels are followed with the help of groundwater observation wells. In some of these, changes are registered by automatic measuring instruments.

With respect to groundwater levels, we need to consider the following principles for those habitats in need of plentiful water.

Molinia meadows

At the beginning of the vegetation period (from February to March–April) surface water cover is typical (Fig. 6). Between February and May at least the upper soil layer is saturated with water (the groundwater level is not below 30–50 cm). The water table should not decrease below 100 cm all the year round.

Marsh meadows

Continuously decreasing surface water cover, or at least water-saturated soil (groundwater level not below 30 cm), is required in the first part of the vegetation season, from February to April–June. The maximum surface water cover is around 50 cm, often only 5–20 cm. Later the water table decreases relatively fast and can even go below 1 m.

With the help of these established water management methods both the spring and autumn water cover of the grasslands and the lower water table desirable in the mowing season could be provided.

Fig. 6. Giant goldenrod does not tolerate flooding. (Photo: J. Cservenka)

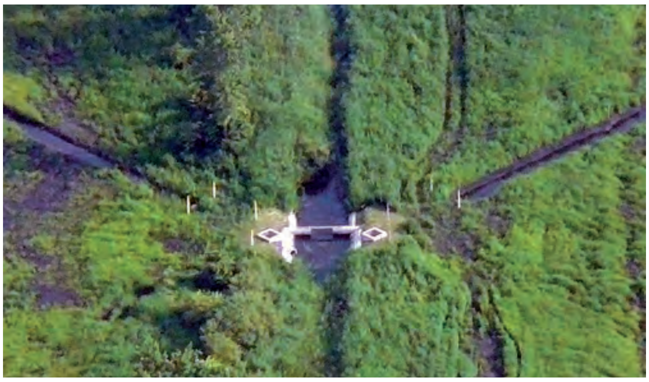

Fig. 7. Sluice (with boards) established on the Kétöles stream. (Photo: J. Cservenka)

Shallow depressions with slight slopes were developed both in the middle and at the ends of the new channels: these function as swampy patches in periods when water is abundant, providing excellent reproduction sites for amphibians. Perpendicular to the newly established channels, we constructed 20 groundwater observation wells at 25/100/200/400 m distances, in five rows. Four rows of groundwater observation wells are situated under the channel constructed on the west side of the Kétöles stream and one row is under the shorter eastern channel. The depth of the wells, which are made of PVC, is 3.0 m; their diameter is 200 mm. The lower two-thirds of the well is perforated and surrounded with a special filter texture called Terfil. The water table is measured every 4 hours by a digital liquid level measuring instrument in 12 wells (in every second row). In the other wells we manually documented data approximately once a month.

Clearing the area – Control of giant goldenrod populations

Flail mowing was used in the shrubby areas covered by giant goldenrod. Homogenous giant goldenrod stands can be mown, making bales so that the organic matter can easily be removed. In general, those areas heavily infested by goldenrod had to be treated

Fig. 9. Mowing of areas infested by giant goldenrod. (Photo: J. Cservenka)

Fig. 8. Channels and 'frog cradles' developed on the Kétöles stream. (Photo: J. Cservenka)

twice a year: once between the flowering and the seed-ripening period (usually in August) and once out of the vegetation period (between November and February). Whether a repeated action is needed was revealed in the next vegetation period. Shrubby areas infested with goldenrod usually can be mown after flail mowing two or three times (Fig. 9). To sustain and improve the state of the area and to avoid re-infestation, management (mowing, flail mowing) has to be repeated regularly (while respecting the conservation specifications). To avoid nutrient concentration and felting, the cut vegetation should always be removed from the area; even the windrows should not be left on the stubble for long.

The grasslands are mown by the directorate and leaseholders based on the specifications of the management programme compiled within the framework of the project. Besides the above-mentioned activities, comprehensive monitoring of the management results is of high importance. Apart from the staff of the national park directorate external professionals also participate in this action. It is also very important to promote the programme and the grassland management, together with their conservation aims, among locals and professionals. Organising forums and field trips for local farmers and other stakeholders, as well as information dissemination using brochures and posters, is an essential task of conservation today.

Experiences gained

With the aid of the dam constructed on the Kétöles stream and the new regulatory channels running eastwards and westwards from there, water levels similar to the natural fluctuations could be provided by the conservation ranger service. The effects of the water level increase could be observed even at a distance of 400 m. Thanks to the water coverage in spring, developed in the surroundings of the two channels, substantial transformation of the giant goldenrod stands began. Marsh vegetation developed rapidly along the channels and in the so-called 'frog cradles' of shallow waters. Following the abundant water in spring, the areas maintained by mowing could be mostly dried for the summer using appropriate water management methods. Thanks to the data analysis of groundwater observation wells the proper water supply of the Felső-Kongó meadows could be planned and provided in drier years. In the areas managed by regular flail mowing and mowing, grassland transformation processes were launched: the size of *Molinia* meadows multiplied during the period of the project. In those areas infested only by goldenrod, the hay was baled so that the biomass surplus could be removed. In this way the total area of grasslands suitable for farming and having conservation value increased by ca. 30% in the Felső-Kongó meadows within only a few years (Table 1, Fig. 10). Bush groups composed of native species and solitary trees were left intact to provide nesting and hiding places for birds. In 150 ha of the project site, clearing aimed the eradication of giant goldenrod facilitated the expansion of *Molinia* habitats. These actions were carried out according to rules set out in the management programme. The effects of these measures were also monitored. Within this framework we surveyed the vegetation on both sides of the channel, gradually moving away from the side in ca. 55 and 50 m long and 5 m wide sections (in 5 × 5 m size quadrants designated sequentially). At the beginning of the survey in 2008 (the year the channel was constructed) the cover of herbaceous species was ca. 100% in each quadrant. In 16 quadrants the cover of giant goldenrod was above 90%; however, in the quadrants this species was also present at a ratio well above 40%. The average species number was 6.76. Thanks to shrub removal, of the dicot species the cover of European dewberry (*Rubus caesius*) increased considerably. Apart from *giant goldenrod*, hedge bindweed (*Calystegia sepium*) and hedge bedstraw (*Galium mollugo*) were the most common dicot species in the coenologic relevés. Of the grass species, tall oat-grass (*Arrhenatherum elatius*), bush-grass (*Calamagrostis epigeios*) and tall fescue (*Festuca arundinacea*) had the most significant cover. The picture had changed slightly by 2009. That the state improved was evidenced by the following observations:

Table 1. Ratio of characteristic habitat types in the project area (2007–2009). The ratio of habitats of community importance or their equivalents (6440, 6410, 6510, 91E0) increased by 24% as a result of the habitat reconstruction (values are written in bold letters). The proportion of the areas highly infested with goldenrod decreased from 29.3% to 17.17% (written in italics).

Vegetation type	Á-NÉR* (2007)	Area (ha)		Area (%)	
		2007	2009	2007	2009
Humid grasslands, hay meadows (6440, 6510)	D34, D34xOA, E1, E1xOB	**194.6**	**207.52**	**42.49**	**45.61**
Homogenous Molinia habitats (6410)	**D2, D2xD34**	**0**	**9.14**	**0**	**2.08**
Grey willow scrub patches (91E0)	**J1a**	**5.5**	**5.6**	**1.20**	**1.23**
Willow-poplar forest patches (91E0)	**J4xRA**	**0.8**	**1**	**0.175**	**2.2**
Tussock and large sedge communities, alkali bulrush patches (partly 6440)	**B4, B5, B6, B5xD34, B6xB5**	**17.5**	**48**	**3.82**	**10.55**
Vegetation of the Kétöles stream and its littoral zone	BA, BAxS2xP2a	7.9	7.9	1.725	1.73
Weedy hay meadows	E1xOC, E1xOD	5.9	18.8	1.29	4.1
Uncharacteristic non-arboreal wetlands	OA, OAxP2a, OAxOD	8.3	8.52	1.81	1.87
Uncharacteristic dry and humid grasslands (locally with *Molinia*)	*OB, OC*	*59.4*	*52.2*	*12.97*	*11.47*
Grasslands and shrub encroachment areas highly infested with goldenrod	*OC, OD, ODxE1, ODxH4, ODxOC, ODxP2a,*	*72.2*	*53.31*	*15.76*	*11.71*
Goldenrod areas affected by shrub encroachment	P2axOD	62	24.86	13.54	5.46
Scrub of grey willow and alder buckthorn	P2a	1.4	3.3	0.31	0.72
Forest strips, tree groups	RA, RB, S2, S7	22.5	14.86	4.91	3.26
Habitats equivalent to Natura 2000 habitats, in total (6440, 6410, 6510, 91E0)		**218.4**	**271.25**	**48**	**61.67**

*Á-NÉR: *General National Habitat Classification System*

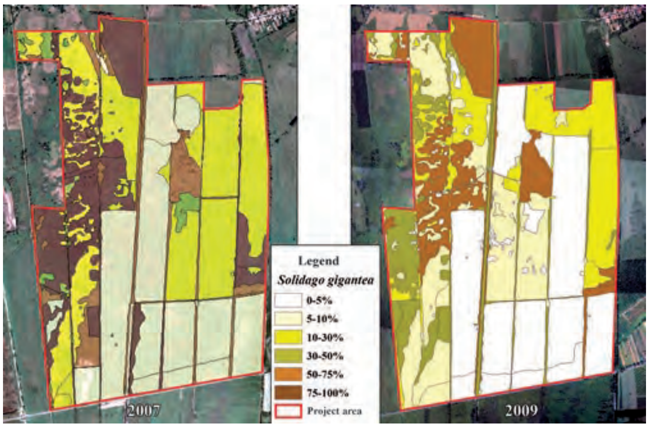

Fig. 10. Change of *Solidago gigantea* infestation rate between 2007 and 2009

the species numbers had increased in 8 of the 11 surveyed quadrants, in two quadrants it had remained the same, while in one it had decreased. The average species number was 9.76 in 2009. In certain quadrants the ratio of the sedges had increased; however, the area of the grass species had also extended.

Besides the survey on the *Molinia* meadows and on invasive alien species, point mapping of the protected plant species and zoological research also showed changes in the species composition of the area. The provision of a favourable water supply and the clearing that took place also had a beneficial effect on those orchid species that prefer the humid grasslands found in the project area, like Early Marsh-orchid (*Dactylorhiza incarnata*), military orchid (*Orchis militaris*) and loose-flowered orchid (*Orchis laxiflora*). In 2009 the strictly protected *Isophya costata* was found in the project area. This flightless, slow grasshopper species is endemic to Hungary and favours steppes: it is the isolation of their populations that seriously threatens its survival. The new channels and stagnant water bodies were invaded by large numbers of amphibians. The Danube crested newt (*Triturus dobrogicus*) became a permanent resident of those channels with a peaty base. In that year the presence of the strictly protected European mudminnow (*Umbra krameri*) was also indicated. New and rare dragonfly species that were once common in the Balaton region but which had almost completely disappeared resettled again; for example, the Yellow-spotted emerald (*Somatochlora flavomaculata*). The Ornate Bluet (*Coenagrion ornatum*) appeared in the area and the Scarce chaser (*Libellula fulva*) became very abundant after the project was finished.

Although the project has been completed, management is still necessary as the giant goldenrod has not fully disappeared from the area. Due to the various microrelief conditions, infestation sources have survived in the depressions of bumpy sites having alluvium and gravel. The vegetation of the former gulf of Balaton is strongly influenced by the water level of the lake, which is continuously and artificially kept high. As a consequence, in the lower areas large species-poor sedge communities predominate instead of the desired Molinia meadows. Furthermore, certain areas are occupied by reed beds. The high groundwater level has contradictory effects: it partly prevents the re-infestation of the area by giant goldenrod, but it also hinders the mowing of the vegetation. (The areas can often be mown in late summer-autumn, or even later, which aids the control of giant goldenrod and favours recurrent invasion of the native arboreal species in the higher elevation sites further from the channels. It can cause problems if the required maintenance cannot be performed in lack of physical staff and budget.

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Useful links

http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=3140&docType=pdf

http://87.229.7.113/oldal/az-ipoly-vizgyujto-vizes-elohelyeinek-komplex-felmerese-husk-0801-2-2-1-0066-lezarult-280.html

Control of black locust in the area of Valkó Forestry

Attila Csór

Natural characteristics of the area

Valkó Forestry is situated mainly in the Gödöllő Hills forest region. The bedrock of the hills is loess; this is topped by diluvial sand of varying thickness. Typical soil types are humic sandy soil among the skeletal soils, brown earth, rusty brown forest soil and brown forest soil, with carbonate rests among the brown forest soils. The quickly warming sandy soils provide favourable conditions for the development of cockchafer grubs. Depending on the thickness of the sand cover, different soil types can appear within small distances. In the southern part of the area the altitude ranges between 130 and 300 m. The group of hills with the highest average altitude is located near the settlements of Gödöllő and Valkó. On this a jagged surface has developed through the effects of erosion by former streams running from the peaks. In the sand-covered parts of Isaszeg the altitude is lower and the landscape is of lowland character. The surface is rolling with hills with height differences of 10–30 m located lengthwise. Due to the prevailing wind direction (generally NW), the hills are oriented in a SE direction. Given the unfavourable soil conditions, exposition is a very significant factor here, although the area has small relief variations. For practical purposes, the area of the Forestry can be divided into two explicit regions based on soil development: brown forest soils evolved on loess, and rusty brown forest soils developed on sand.

Average precipitation is 570 mm, sufficient for closed forests to be found here. However, there are strong fluctuations in temperature and precipitation within a year and also within the vegetation period. The average annual precipitation can fall to 60% of the average. In spring sudden strong warming is common (even to 30 °C). Sometimes whole reforestations of 1–3 years age perished by droughts.

The cockchafer grubs have a significant effect on the site. In the landscape unit the adults and larvae of common cockchafer (*Melolontha melolontha*) and forest cockchafer (*Melolontha hippocastani*) cause serious damage. The adults can leave the thinning or thinned forest stands leafless, which results in reduced growth of the trees and loss of crop. In both regions of the hills intensive mass flights can be observed each year. The chafer grubs consume the rootlets and the bark of the taproot of the sapling to the point that it is no longer connected to the soil (Fig. 1).

After the socialisation in 1867, the forest areas were managed by the royal manor. The cattle driven from the Great Hungarian Plain to Budapest were rested here to allow their condition to improve. The excessive rate of grazing had rather unfavourable effects on the vegetation, forests and soil. Grazing ceased when the area became state owned; nevertheless, its effect can be seen even today. At the same time, another negative factor emerged when the forest estate became the hunting area of the president in power. From that time on, management of the forest was determined by hunting interests.

With respect to phytogeography, the major part of the area is cultivated, with the remaining patches of the former Turkey oak and sessile oak-hornbeam forests covered by zonal vegetation. Interestingly, towards the Great Hungarian Plain the Turkey oak forests are not substituted by Tatarian maple-pedunculate oak loess woods (unlike in the warmer, lower parts of the Hungarian mid-mountains), but rather by zonal, dry oak woods with field maple and common hornbeam (*Acereto campestri-Quercetum petraeae roboris*) (G. Fekete 1961) (Fig. 2). This is comparable to the forests on the plateaux of the right side of Dnieper River; among the few occurrences found in Hungary its largest and most stable stands are found in the Gödöllő Hills. The second zone is a lime-oak forest (*Dictamno-Tilietum cordatae*), which compares to the forests of middle steppe woods of Russia; according to research in the 1960s this zone can be considered as a relict community.

In this chapter the black locust (*Robinia pseudoacacia*) control will be discussed.

The total area of the Forestry is 8887 ha, of which 8127 ha is covered by forest stands. In the forested area the stand ratios are as follows: 24% oak, 19% Turkey oak, 28% black locust, 16% other deciduous and 13% pine. Black locust stands are present over a significant area.

Fig. 1. Oak saplings chewed by chafer grubs. (Photo: A. Csór)

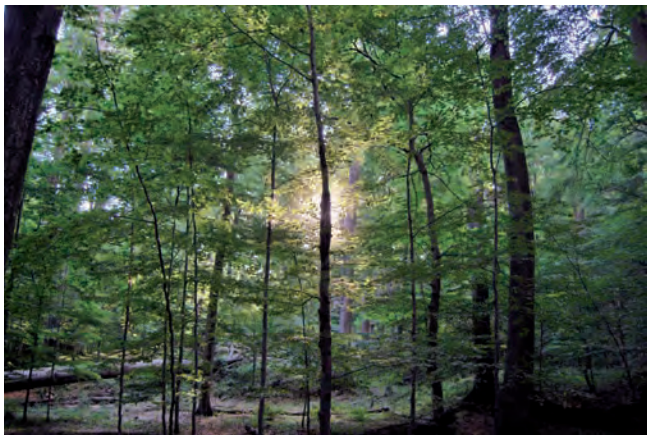

Fig. 2. Field maple (hornbeam)-oak forest. (Photo: A. Csór)

After the area became state-owned the forests were managed by regeneration cutting and coppicing. Artificial regeneration with saplings or seeds was launched in the 1900s. This was the period when the extensive black locust plantations were developed. After the oak forests were cut, the oak saplings (which grew more slowly) were mixed with black locust in rows. The idea behind this was that in the areas with large game stock the roe deer would favour the black locust saplings and spare the oak individuals. Sadly, these hopes failed as the black locust rapidly grew out of reach of the game, while the oak seedlings remained easy to reach. In these areas, black locust became a totally dominant species. Additionally, black locust plantations have been settled in treeless areas during the past 60–80 years, with their spread threatening other native habitats.

The characteristic forest management type used by Valkó Forestry in the 20th century was clear cutting. At the beginning of the new millennium the forestry commission again started to use regeneration cutting types. The chafer grubs and the spread of invasive alien plant species (due to anthropogenic effects) even threaten forest regeneration through natural regrowth processes. The forest tract is divided by a public road. Along this municipal solid waste is deposited and the spread of invasive plant species can be observed here, as well (black locust, tree of heaven (*Ailanthus altissima*), common milkweed (*Asclepias syriaca*), common ragweed (*Ambrosia artemisiifolia*)). Deriving from the past management, the native stands are homogenous and even-aged. As improvement cutting was previously carried out, vertical diversification is almost completely absent.

The Forest Reserve of Nagy Istrázsa-hegy can be found in the area of the Forestry. Our short-term objective here is to observe the forest dynamics processes of the unique forest communities typical of the hills (field maple (hornbeam)-oak, lime-oak woods) and to incorporate this experience into forestry practice. In other forest tracts of the Forestry with native and unique forest communities we aim to preserve the present state over the decade to come. In the medium term in these even-aged stands, our goal is to elaborate those forest management methods that provide the vertical and horizontal levels within the site and the stability of the rare communities.

Initial conditions

Black locust plantations occupy 28% of the area of the Forestry. The restructuring of the black locust plantations at the stand level is beyond the scope of normal management. Our forestry commission oversaw the restructuring of 77 ha black locust forests as part of the current 10-year forest management plan. The high additional costs of this activity can only be provided for by supported proposals. In the period 2008–2012 (over two phases) the Pilis Park Forestry Company launched a long-term complex habitat reconstruction programme called Park Forest Naturally, and its initial phase was implemented with the support of the European Union and the Hungarian State. The first part of the project started in 2008 and was aimed at the eradication of black locust by individuals and some ten hectares. The second part of the programme began in 2010 when we had the opportunity to remove the black locust plantations in ca. 30 ha, wedged between the native forests. These enclosures are each ca. 10 ha in size. After the black locust stands were logged, development of forests similar to the neighbouring native ones and typical of the region was launched.

Table 1. Actions and costs of black locust restructuring in Pilis Park Forestry Company (Valkó Forestry, forest region: Gödöllő Hills). Climate: sessile oak, Turkey oak forests. Physical soil type: sand. Tree species of former forest stand: A, tree species of new stand: KTT-EL. Origin: seed. Regeneration method: clear cutting.

		Input per hectare				Total cost
		Material/Energy			External assistance cost	
Year	**Action**	**Name**	**Quantity [units; litre]**	**Cost [thousand HUF]**	**Cost [thousand HUF]**	
0	Complete soil preparation				330.0	330.00
1	First implementation with saplings	SZNY, FTNY, RNY, CSNY, KTT, KST, CS saplings	15000 units	315.0	225.0	540.00
	Hoeing				80.0	80.00
	Nursing with herbicide	Lontrel 300	0.5 l	12.5	35.0	47.50
	Sickling				40.0	40.00
	Nursing with herbicide	Lontrel 300	0.3 l	7.5	35.0	42.50
	Hoeing				80.0	80.00
2	Sapling replacement + Weeding of plates (20%)	SZNY, CSNY saplings	3000 units	45.0	75.0	120.00
	Sickling				35.0	35.00
	Nursing with disc cultivator				15.0	15.00
	Nursing with disc cultivator				15.0	15.00
	Nursing with disc cultivator				15.0	15.00
	Nursing with herbicide	Lontrel 300	0.5 l	12.5	35.0	47.50
	Nursing with herbicide	Lontrel 300	0.3 l	7.5	35.0	42.50
3	Sickling				35.0	35.00
	Nursing with disc cultivator				15.0	15.00
	Nursing with disc cultivator				15.0	15.00
	Nursing with disc cultivator				15.0	15.00
	Nursing with herbicide	Lontrel 300	0.5 l	12.5	35.0	47.50
	Nursing with herbicide	Lontrel 300	0.3 l	7.5	35.0	42.50
4	Sickling				35.0	35.00
	Nursing with disc cultivator				15.0	15.00
	Nursing with disc cultivator				15.0	15.00
	Nursing with disc cultivator				15.0	15.00
	Nursing with herbicide	Lontrel 300	0.5 l	12.5	35.0	47.50
5	Nursing with disc cultivator				15.0	15.00
	Nursing with disc cultivator				15.0	15.00
	Nursing with herbicide	Lontrel 300	0.3 l	7.5	35.0	42.50
6	Nursing with disc cultivator				15.0	15.00
	Nursing with disc cultivator				15.0	15.00
7	Nursing with disc cultivator				15.0	15.00
	Nursing with disc cultivator				15.0	15.00
	Nursing with herbicide	Lontrel 300	0.5 l	12.5	35.0	47.50
	Altogether			**452.50**	**1475.00**	**1927.50**

SZNY: grey poplar, FTNY: black poplar, RNY: common aspen, CSNY: wild cherry, KTT: sessile oak, KST: pedunculate oak, CS: Turkey oak, EL: other deciduous tree species

Fig. 3. Stumping excavator with fork attachment. (Photo: A. Csór)

Fig. 4. Deep ploughing with distinct soil mosaics. (Photo: A. Csór)

Methods used

We have decades of experience in the control of black locust intrusion in hilly forest regeneration sites. The practical experience gained in the forests of the Pilis Park Forestry Company was implemented. Black locust control techniques are now summarised.

1. Soil preparation (Table 1): Restructuring of stands started in spring 2010. After clear cutting the black locust stands and transporting away the timber (and branches) stumping was performed. After the stumps were extracted, these were lifted and transported off the site for further usage. It is important to note that stumping was not carried out with a bulldozer blade but rather a fork attachment connected to an excavator (Fig. 3). This technique is used to prevent the development of stump windrows, which could be black locust re-infestation sources; further, the topsoil was not pushed together with the stumps.

Root raking was applied after stumping as black locust can readily generate root suckers. Subsequently, ploughing took place to 70 cm depth and the upper humic layer of the soil was turned over (Fig. 4). This expedient greatly improves the water conditions of the sand soils. The occasional root remnants on the surface were transported off and the area was smoothed in preparation for planting. No total vegetation control herbicides were used in the area. As in natural succession processes, the forest plantation imitated a medium state: we developed a primary forest, which was composed mainly of native pioneer tree species of the region (grey poplar (*Populus × canescens*), black poplar (*Populus nigra*), common aspen (*Populus tremula*) and wild cherry (*Cerasus avium*), and in a minor part the elements of the climax forest community of the area (pedunculate oak (*Quercus robur*), sessile oak (*Quercus petraea*), common hornbeam (*Carpinus betulus*), field maple (*Acer campestre*)) (Fig. 5). We used a 2.2 m inter-row spacing and 0.3 m in-row spacing. The nursing of the plantations is of high importance: in the first year we carried out intensive row nursing (hoeing twice and sickling once) (Fig. 6). The inter-row spacing is appropriately large to permit continuous mechanical nursing between the rows. For this task, an agricultural prime mover was used (with narrow gauge) which was equipped with a disk cultivator (Fig. 7). Continuous inter-row nursing for at least five years is very important. The plantation develops in different ways on different site mosaics in varying conditions:

Fig. 5. One-year-old mixed primary forest. (Photo: A. Csór)

Fig. 6. Two-year-old mixed primary forest. (Photo: A. Csór)

Fig. 7. Soil cultivation with disc cultivator attached to narrow-gauge agricultural prime mover. (Photo: A. Csór)

Fig. 9. Three-year-old mixed primary forest. (Photo: A. Csór)

while in-row nursing may be omitted, weak patches should be nursed further. The omitted in-row nursing can be substituted to a degree by inter-row nursing. More favourable results were obtained by planting tree species with differing rates of growth. The juvenile stand soon developed to a closed forest. This meant that warming of the soil was limited, thus avoiding significant damage caused by chafer grubs. The strong shading also prevented invasion by black locust, which has a high light demand. The seedlings and the root suckers (shocked previously by stumping and root-raking) could not reach the sunlight, and this meant that we needed to use herbicides in smaller quantities. Root suckers of black locust appeared

Fig. 8. Black locust sprout after herbicide treatment. (Photo: A. Csór)

in ca. 10% of the area. In the first three years of forest regeneration Lontrel 300 herbicide with clopyralid agent, selective for Fabaceae, was used twice a year by directed foliar spraying from manual backpack sprayers*. During the second treatment individuals either left out or having survived the first treatment were managed, and thus the whole process was less intensive, meaning that the whole area did not need any subsequent management. The second treatment should always be scheduled late summer or early autumn as the shoots surviving the second management cannot lignify near the end of the vegetation period and the autumn frosts cause serious damage in their stands (Fig. 8). Forest restructuring looked successful by 2014 (Fig. 9): black locust had been completely suppressed by the faster-growing species and the saplings of oak species underneath had developed well. In the future, we should roam these areas in every second year and the sprouts found should be killed by directed foliar treatment. With proper nursing of the primary forest, the decrease in individual numbers and the restriction in the lateral growth means that the species of the climax community can receive sufficient amount of sunlight so that the desired mixture ratio can be achieved. After 40 years the individuals of the primary forest can be removed and the stand can be completed based on nut production. With this, the favourable vertical structure of the forest develops. With the natural regeneration of the multi-species forest the black locust stands can be completely transformed into native forests befitting the heritage of the landscape.

We have chosen the complete soil preparation technique to provide the lowest possibility for the black locust shoots to survive. At the same time we expect that after the native stands develop, the wildlife of the neighbouring natural forests will gradually colonise the soils disturbed by the forest transformation.

*Attention! Experimental chemical control methods described in this chapter are subject to authorisation! Their practical application requires an emergency permit issued by the pesticide control authorities for the given area and period!

Fig. 10. Girdling of black locust individuals. (Photo: A. Csór)

In the landscape unit the transformation of black locust plantations was a goal even at the turn of the 21st century. In 2000, Valkó Forestry launched from its own resources a forest restructuring programme in a 10 ha black locust forest in the Gödöllő Hills that was also enclosed in native stands. (This target area is located some hundred meters away from the site subject to management today.) The Forestry aimed to restructure the non-native stand into a maple-oak forest with oak main species in one step, with partial soil preparation. Complete soil preparation and the positive shading effect of the primary forest were omitted; moreover, this partial soil preparation was not followed by soil cultivation. Only the above-ground shoot parts were subject to chemical treatment. From the root system remaining in the ground and above-ground reproductive structures the area is continuously re-infested by black locust. The restructuring can be considered successful; however, despite constant management we expect 5% black locust in the stand. As our experience shows, restructuring in one step has limited results.

2. As part of the programme we performed experiments for restructuring using non-chemical treatment. One old and well-known method is the so-called "drying out on foot", which means that the black locust specimens are left standing until they grow old and die. The renewal capacity of the old individuals is low; they can no longer sprout from stumps or roots. However, under this method the reproductive structures in the seed bank remain intact; because of this we should expect some seed germination (launched by natural or artificial disturbances) for the next few decades. In the NE part of Forest Reserve of Nagy Istrázsa-hegy there is a black locust stand whose further spread could cause problems. In this case we will apply the above-mentioned method from 2009.

3. A third method can be used if more stand structure factors are provided. Practice demonstrates that

Fig. 11. Black locust stand with dried foliage, next to a restructuring site with grey poplar. (Photo: A. Csór)

if the black locust inhabits a site that is not optimal for this species, flora elements of the original vegetation can be found. In this landscape unit the presence of field maple can be an advantage as it is a species that provides a good amount of shade. In the second overstory of middle-aged black locust stands (planted in the habitats of field maple-oak forests of compacted soil) a closed field maple carpet appears. This takes advantage of the loose foliage structure of the black locust, grows well and blocks the soil surface totally.

The bark of the black locusts in the first overstory is removed by the girdling method at breast-height (Fig. 10). After this treatment, the foliage dries out in the following year (Fig. 11). The tree reacts to the girdling by sprouting on the trunk, under the removed bark ring. However, these sprouts are shaded by the second overstory composed of field maple and so, in absence of light, remain weak. As roots were not damaged, root suckers are not likely to grow. However, if root shoots do appear, these are also damaged in a similar way. As the soil was not disturbed, the seed bank of black locust remained intact. For this reason, we should sustain shading for a long period, perhaps even for decades. At the stand edges and along lanes girdling needs to be combined with herbicide treatment, since the shading effect of field maple is not achieved here. We have four years of experience of this method, which is based on forest dynamics processes. Although initial results are promising, outright success has yet to be achieved.

The Forestry often encounters black locust in naturally or artificially regenerated stands. The method used here is to cut the shoots in spring, and direct foliar treatment with selective herbicide of clopyralid agent (Lontrel 300) in late summer-early autumn. Cutting off the shoots is needed to create re-growing shoots of a manageable size (max. 2 m). With this the black locust sources of different ages and states of development can be uniform. The herbicide use in autumn is necessary because of the previously mentioned shoot lignification phenomenon and the decreased regeneration capacity at the end of the vegetation period. Based on our earlier experience we tried the herbicide treatment in the flowering period as well; however, the regeneration capacity of black locust in the Gödöllő Hills is relatively strong and 30% of the sprouts revived.

Experiences gained

Using our previous experience of forest regeneration in the Gödöllő Hills, the initial phase of the habitat reconstruction programme was accomplished. The restructuring work in 30 ha forest seems to be completely successful. In our opinion, in this landscape unit of warming sand forest soils on the border of the closed forests, only partial soil preparation will not be successful.

Spot spraying of the individual black locust sprouts intruding into the regeneration sites has proved successful. As the selective herbicide is very expensive, we also have shown that it is possible to achieved good results using a glyphosate-based total vegetation control herbicide. The selectivity of the technique is provided by the different heights of the black locust sprouts and the saplings. With the cutting off of the sprouts (in spring and early summer), we can generate uniform re-growth. With further treatment at the end of the summer, regeneration is also avoided.

We have also performed experiments in restructuring without stumping. In these cases the low-cut stumps are treated with herbicide (Garlon 4 E with triclopyr agent) and the inter-row spacing set for 2.2 m. Following this, shoot control was performed using a narrow-gauge disc cultivator attached to a tractor. This method is still in the experimental phase: the first results are promising, but further experience needs to be obtained.

Issues raised

In the black locust control methods elaborated above, issues related to stand structure were almost completely disregarded. The fact that this species has a high light demand and has loose foliage allows us to plant saplings of shade-tolerant species underneath. Surveying the allelopathy of the black locust root system would be important as well. Advantages of succession processes during natural forest renewal should be also used. But it must be answered: how can we solve the shading of black locust by native tree species, and maintain this state for decades until the vitality loss of black locust.

Eradication of invasive alien plants in the southern Nyírség area of the Hortobágy National Park Directorate

László Demeter and Balázs Lesku

Natural characteristics of the area

The southern parts of the Nyírség region contains small areas with high forest coverage, at least by the standards of the Great Hungarian Plain. However, mostly due to human intervention, the natural sandy oak woods have largely been replaced by non-native plantations (mainly black locust forests). The more or less coherent forests are interspersed with agricultural land. The bedrock, soil and relief, which is defined by the acidic sandy soil, has given way to a typically "Nyírség-type" landscape. Apart from the forests, the ancient vegetation is preserved by inter-dune bogs and sand grasslands. Alongside a shortage of water in the region, the spread of invasive weeds poses a serious problem for both forest and grassland habitats.

The natural sand forest remnants consist of diverse mosaics of closed lowland steppic oak woodlands, open steppic oak forests on sand, and on the more mesic areas, transformed hardwood gallery forests. The grooves among the dunes typically contain bog and fen meadows as well as bog remnants. Sand steppe grasslands, sand pastures, transformed remnants of the forest steppes and secondary open sand grasslands occur in several parts of the region.

A substantial part of the area is characterised by shallow topsoil banded drifting sand soil on drifting sand bedrock. Its eolian reliefs is mostly defined by accumulative forms such as parabolic dunes with undeveloped western wings, and marginal dunes.

Drainage of the waters of the region started in the 19th century. Desiccation of the area has become widespread over the area, while annual precipitation is only around 500–600 mm.

Initial conditions

The following contains an account of experiences gathered from the eradication efforts on three species: black locust (*Robinia pseudoacacia*), black cherry (*Prunus serotina*), and common milkweed (*Asclepias syriaca*). Black locust is present over all the Nyírség region. It is known to occur in masses: this due to the fact that its planting, and the replacement of native sand forest populations with black locust plantations, has a long tradition in the area. The aggressive spread of black locust on valuable natural habitats (e.g. sand grasslands and sand steppe oak woodlands) is a conservational issue of some priority (Fig. 1). Black cherry is now, technically speaking, present on all woodland areas of the Nyírség, at least sporadically. However, it has achieved such high numbers in certain parts that it negatively impacts the production of the black locust itself. For the time being, the common milkweed occurs only in patches, but its spread has significantly increased in recent years and it can be found in more and more areas.

Eradication* is justified on the grounds of both habitat protection and species conservation given that these invasive alien plants play an integral role in the degradation and the transformation in the habitats of sand steppe oak woodlands and sand grasslands. The case of Hungarian iris (*Iris aphylla* subs. *hungarica*), occurring in steppe oak woods of the Nyírség, is a typical example; intervention serves to protect one of the habitats of community importance in Natura 2000 areas and the conservation of one of the species of community importance at the same time.

*Attention! Experimental chemical control methods described in this chapter are subject to authorisation! Their practical application requires an emergency permit issued by the pesticide control authorities for the given area and period!

The eradication of black locust

Methods used

Grazing animals are partial to the fresh sprouts of the black locust when its thorns are still soft. This fact provides an excellent opportunity to control the sprouting of black locust on the grasslands. The grazing method was first attempted in 2003 on the high sand dune over the birch bog area of Keszler-tag in Nyírábrány. The sprouts were previously controlled at the end of the 1990s; however, this resulted in a densification of the stand. The almost two-hectare coppice forest was cut in 2003. Following the clearing of the branches, sheep were allowed to continuously graze the area: this proved to be effective in controlling the black locust.

Ever since, this method has been used regularly in order to eradicate black locust stands on sand grasslands. It has to be noted that in cases of high density infestation, the trimmed sprouts (branches) must ideally be collected and removed, as the grazing animals tend to avoid thorny branches lying on the ground, which might then result in resprouting and re-infestation.

Where grazing is not possible, the black locust is controlled by chemical injection into holes drilled into the trunks of the trees (Fig. 2); areas treated in this way include areas with sporadic black locust trees located within or on the margin of valuable native forest stands, on the habitats of certain protected plants, or on non-grazed grasslands.

After a period of testing, the method was first used extensively in the rehabilitation of a cohesive patch of the Állóhegy steppe oak woods, one of the most beautiful steppe oak woods in the southern Nyírség. The project was subsidised by the Environmental Fund Target Program (KAC).

Electric drills powered by a portable generator and high-power battery-powered drills were used to drill holes into the tree trunks. The most commonly used drill was a size 8. The holes were drilled diagonally downwards where possible, 10–15 cm apart. Glyphosate containing herbicides were used: Medallon Premium, Fozát 480 and Glyfos. The chemicals were distributed into the drill holes with a plastic 'spray flasks' used in laboratories.

The cut stump herbicide method and hack and squirt treatment is used for treating thin sprouts (3–4 cm), and is often as a complement to the previously mentioned method. After trimming the sprouts, the stump or the cut surface is treated with the same high-concentration chemicals used in the drilling method.

Spraying of black locust is only used in exceptional cases, e.g. when treating stumps (after clearcutting stumps are stacked in windrows across the site) of black locusts during forest regeneration, carried out with complete soil preparation or shoot control due to lack of grazing. In such cases the above-mentioned chemicals are used in 3.5–5% solution in accordance with instructions and with the addition of adhesives (e.g. Nonit). Treatment was performed under low pressure with larger droplet size to minimise the risk of spray drift and maximise target accuracy.

Fig. 1. Without post treatment (grazing or chemicals), stump- and root sprouts of black locust trees cut on sand grasslands are about to take over the cleared land again. (Photo: B. Lesku)

Fig. 2. Treating black locust with chemical injections. (Photo: L. Demeter)

Fig. 3. Grazed sand dune on the Martinka-pasture eight years after the initial control treatment. The trunks were cut back to ground level. (Photo: L. Demeter)

Experiences gained

After two years of continued sheep grazing, black locust sprouting was completely eradicated over the two-hectare black locust coppice forest cut in 2003 in Keszler-tag. The considerable dry site conditions are likely to have played a significant positive role in the results.

Grazing has been successful in controlling the sprouting of eradicated black locust patches in several areas (Figs 3 & 4). Cattle and sheep have both proved effective in grazing black locust sprouts. Although particular attention was paid to the safe feasibility of grazing for a period of 2–3 years when planning the eradication, we did still encounter problems. We managed to handle a shorter suspension of grazing by cutting the growing, already hard-thorned sprouts with clearing saws prior to resuming the grazing. In one particular case, grazing was suspended for two years, as the treated sand dune virtually turned into an island in 2006 and 2007 during the great ground-water flooding. That issue was resolved with reasonable effectiveness by a combination of mechanic eradication (axe and chainsaw) and chemical treatment (glyphosate containing herbicides) (Fig. 5). It is important to consider that if the trunks are cut to ground level during felling, such an unexpected grazing suspension might also be solved by using a forestry mulcher. This, however, will involve extra costs, since cutting back the trunks constitutes an additional work process, while saw-ground contact will result in the intense chafing of the chain and the plate.

It should be noted that in case of high density, the cut woody sprouts must ideally be collected and removed, as the grazing animals tend to avoid the thorny branches lying on the ground, which might give way to resprouting and re-infestation.

The stumps of the trees remain in the ground in the case of grazing, and this has yielded unforeseen results. A few years later, rhinoceros beetles (*Oryctes nasicornis*) appeared in large numbers in the dead stumps.

Fig. 4. Grazed black locust grassland two years after clearcut. Due to the sparser tree stock and less-dry site conditions, grassland recovers more easily. (Photo L. Demeter)

Fig. 5. Black locust shoots after spot spraying. Treatment was necessitated by the suspension of grazing. (Photo: L. Demeter)

Fig. 6. A black locust forest with yellowing canopy due to the chemicals injected into the trunks (two weeks after treatment). (Photo: L. Demeter)

Fig. 7. An injected black locust forest patch a year after treatment. As can be seen clearly, certain treated trees still sprouted new leaves. (Photo: B. Lesku)

At the same time, mammoth wasps (*Megascolia maculate*) also appeared, parasitizing on the larvae.

In case of chemical injection into holes drilled in the trunks, we experimented with dilution of the herbicide. We concluded that 1:1 dilution achieved similar results as the concentrated chemical.

The effects of the treatment can be seen within one-and-a-half or two weeks (Fig. 6). For some reason a certain percentage of trees always survives the first treatment (Fig. 7). In 1–2 months they sprout new, mostly deformed leaves on some of their branches. Therefore, we try to wait a couple of months or until the next vegetation period before performing another treatment on the newly sprouted trees, which is then followed by logging. The best results were achieved in the second half of the summer and in the autumn. In those trees preparing for the winter hibernation, sap circulation shifts towards the roots, and this way the chemical can effectively spread through the entire body of the tree, including the root structure. It was obvious during the intervention in the Bátorliget grassland that in closed black locust stands, the amount of newly appearing root suckers can still be significant, even after cutting the seemingly dead black locust trees.

The cut stump herbicide method and hack-and-squirt treatment proved to be effective in times of draught, while there were more survivors in years with heavier rain. In the beginning we experimented with the cut stump herbicide method on larger trees as well. This proved effective against stump shoots, although it did not prevent the appearance of new root shoots, which is why they needed to be controlled by further treatment.

Eradication of black locust using the foliar spraying method (in the manner mentioned earlier) was only carried out in exceptional cases. Applying 3.5–5% dilution with adhesives (e.g. Nonit) proved effective.

It is important to note that the rate of germination from scattered black locust seeds, even after the removal of the trees, can also be significant in sunny, disturbed open sand surfaces when they get heated. The warming sand and the mechanical disturbance of the soil creates similar conditions to the scarification necessary for effective germination of black locust seeds. In certain cases the building and maintenance of dirt roads or other routes or infrastructure through the forests can cause significant problems. In such cases strings of black locust regrowth up to hundreds of meters in length can appear among the native stands or grasslands. (A similar incident occurred in the forest sections outside of Hajdúböszörmény and Debrecen due to the construction of the bypass road around Debrecen.) This is why it is important to monitor the conditions of the treated areas after the removal of the trees where possible.

Control of black cherry

Methods used

Cut stump herbicide treatment of black cherry started in 2002 in steppe oak wood patches, which serve as the habitat of the Hungarian iris. Concentrated glyphosate-containing chemicals were used for the treatment.

The chemical injection into drill holes treatment, as with the black locust, was also used here with positive results.

Spot spraying of the stump sprouts is used on rare occasions. It is used, for example, in the case of applying grazing for the control of black locust, since

Fig. 8. Girdling black cherry with double sawchain. (Photo: L. Demeter)

the sprouts of the black cherry cut together with the black locust are usually avoided by grazing animals.

Girdling of black cherry has been performed in larger volumes since 2007. We also conducted an experiment to evaluate the efficacy of girdling done by the chain of the chainsaw (Fig. 8). The experience gained from these experiments have been collected and written up in a thesis of a student who cooperated on the project. For the establishment of the girdle we followed the method laid down in the book titled Biological Invasions in Hungary – Invasive Alien Plants. In this method the phloem tissue, the cambium and the outer layer of the tree tissue was cut by a girdle made from the chain of a chainsaw. The treatment was performed in three groups. In the first group we created a girdle from a single chain; in the second group we used a double chain; while in the third group the bark was cut using two double chains 10–15 cm apart (Fig. 9).

The workers (mostly public workers) usually preferred a machete or a two-handled knife (drawknife) for girdling, when they debark the tree at chest-height, cutting rings 10–20 centimetres apart.

Young, small specimen (seedlings and small saplings), on the other hand, were simply manually uprooted.

Experiences gained

If the edges of the stump are wiped with herbicide precisely and evenly, the eradication proved to be close to 100% throughout the entire vegetation season for all sizes and under different precipitation conditions.

Injection treatment into drilled holes was also found to be effective during the entire vegetation season. Even smaller doses of herbicides than those used for the control of black locust resulted in an almost 100% elimination rate.

Fig. 9. Double girdle made by a sawchain on the bark of the black cherry. (Photo: L. Demeter)

Similarly to foliar spraying of black locust, the dilution suggested in the instruction of the herbicide also proved effective in spraying of black cherry. The application of adhesives is even more important for harder, leather-like leaves.

As expected, double girdling proved to be the most effective girdling technique, mostly resulting in complete eradication of trees. The tissues of larger trees often grew over the single girdle, and at least a part of the canopy survived, whereas the double-chained single girdle method yielded temporary results. The trees treated in February did not dry out until the beginning of the summer. Long water shoots appeared under the girdle, which also dried out following the death of the canopy.

The water shoots below the girdle did not dry out in those years with heavy precipitation; thus the lower sections of the trees survived, though the canopy was destroyed.

Precision is also important with girdling done by knives, as the tree grows new bark strips around the girdle from the thin bark remnants and thus survives the treatment. Subsequent to treatments conducted in the summer and the autumn, we often observed that the debarked surface was infected by a bluish, mould-like fungus. The destruction of such trees was inevitable.

Manual uprooting of small, young specimen played an important role in post-treatments performed in the years following the initial eradication. Although we did not conduct quantitative analyses, it was our impression that it took 3–4 years after the control treatment of seed trees for the regrowth to be reduced significantly, which suggests that in our experience, it is advisable to continue monitoring and post-treatment for at least this period.

Fig. 10. Common milkweed population subjected only to mechanical control. Sprouts appear even after years of successive mowing. (Photo: B. Lesku)

Fig. 11. Common milkweed settled on the disturbed slopes of sand dunes cannot be controlled mechanically: moderate grazing is not sufficient and the plant will spread over the whole grassland. (Photo: B. Lesku)

Control of common milkweed

Methods used

We first tried to control common milkweed in the 1990s by mechanical means. A relatively dense population was mowed and flail mowed over a period of ten years. Treatments were initially performed annually, and then twice a year.

In order to control milkweed certain areas were grazed.

We are currently using chemicals with glyphosate component for the controlling of milkweed (Medallon Premium, Fozát 480, Gyfos), necessarily with the simultaneous application of an adhesive (Nonit). The chemicals are distributed with backpack sprayers under relatively low pressure in order to minimise the drifting of droplets.

Experiences gained

Purely mechanical control treatment of milkweed proved to be ineffective, though this should no longer be considered a surprise given subsequent findings. The initial decade-long mowing and forestry mulching did little to destroy the population, as the plants resprouted after the mowing, often with a larger sprout count (Fig. 10).

Only one convincing example is known for the effective eradication of milkweed affected by grazing. On the pastures of the Martinka open sand grassland in the outskirts of Hajdúsámson, three 100-m2 patches were destroyed by a flock of sheep and goats. The animals grazed the plants down to the hilt. These patches have not resprouted ever since. The relative droughts of those years might have contributed to the results. We have observed in several other areas that during a drought, animals gnaw off the leaves of the milkweed, but these other populations always eventually resprouted (Fig. 11).

It is important to note that during chemical treatment we should make sure that the treatment is carried out when the temperatures are lower, because when the treatment was performed in open areas in hot weather, a part of the stand resprouted after the drying out of the plants. This is undoubtedly caused by the fact that the water contained in the spraying chemical evaporates too quickly, preventing some of the chemical agents from being absorbed into the leaves.

It is important that the sporadically appearing milkweed specimen or small patches over sand grasslands should be continuously monitored and immediately treated. This plant has a high volume of seeds that are easily carried by the wind and can infest an entire area very quickly, after which control is much more difficult and time-consuming.

Control of invasive and other alien arboreal species on the Tamariska-domb of Csepel: planning and implementation

Attila Gergely, Zoltán Bajor and Márton Korda

Natural characteristics of the area

Tamariska-domb is located in Csepel Plain small region, which is in the northern part of Csepel Island in district XXI. (Csepel) of Budapest. The hills covers only 5.22 ha in area; it is the last remnant of the sand hills aligned along a NW–SE direction that were once dominant in the region. The altitude of the site is 116.8 m, it being the highest point of Csepel. Humic sand soil has developed here. The average annual precipitation is 525–550 mm; the quantity and distribution of the annual rainfall is unfavourable, and this results in a lack of water for most of the year.

The 5.22 ha area was first declared protected (a protected area of local importance) in 1994. The aim of this act was to conserve the sand hill and its natural and semi-natural plant communities. The area became protected at the capital level in 1999, and in 2012 it was classified as a protected area of national importance.

Given the site's urban surroundings, anthropogenic effects are rather significant here. Before the area was declared protected, a private house and a nursery school was constructed at its edge. Additionally, an anti-aircraft bunker was built under the site in the 1950s. When it was constructed, a major part of the sand hill was mined off, and when the bunker was finished the sand was transported back on to the top of the building (Bajor 2009, Tenk *et al.* 2014). Nowadays, the area is administered as a forest under a management plan, but in practice it is used as a public park.

Vegetation

On the Tamariska-domb of Csepel we can find remains of the original steppe woodland vegetation of the Great Hungarian Plain. This manifests in a special mosaic of fragments of woody and herbaceous plant communities. The open sand grassland of calcareous soil (an endemic community along the Danube River and in the Danube–Tisza interfluve) represents a high conservation value. The small forest patches, predominated by white poplar (*Populus alba*), are the last remnants of the original sand poplar forests once characteristic of the region.

In the area ten protected species have been found so far: these are mainly plants typical of the sand grasslands. The smaller, semi-natural grassland patches are inhabited by *Stipa borysthenica*, *Gypsophila fastigiata* subsp. *arenaria* and *Tragopogon floccosus*, together with and other species. We can also find some individuals of *Astragalus varius*, which are found nowhere else in the area of the capital. Surveys on specimen numbers of the protected species show that *Stipa borysthenica*, *Gypsophila fastigiata* subsp. *arenaria* and *Alkanna tinctoria* have the most stable populations (Gergely and Tenk 2013).

Initial conditions

Although Tamariska-domb was declared protected area by the district in 1994 and by the capital in 1999, there was no conservation management for years to ensure the in situ protection of the natural values of the area. However, the site was managed as a public park and mown many times a year to control the common ragweed (*Ambrosia artemisiifolia*) masses. The fence once protecting the area went to ruin, allowing access to enduro and mountain bike riders.

The declaration as a conservation area of national importance in 2012 was a result of many and long negotiations full of conflicts. This act was preceded by conservation management, started in 2006, carried out by the Green Circle Association of Csepel, which cooperated with the municipality of Budapest and the local government of Csepel, District XXI. The association started to manage the site, which by that time had seriously degraded vegetation and

Fig. 1. Distribution of Russian olive on Tamariska-domb in 2012

which was formerly managed by clearing saw; being situated in a densely built-in garden suburb area, the site was under heavy environmental pressure.

The intensive removal of the woody IAS (invasive alien species) was launched in 2010. Our primary aim was to control Russian olive (*Elaeagnus angustifolia*), as this covered a significant proportion of the Tamariska-domb (Fig. 1). The second most frequent IAS was common hackberry (*Celtis occidentalis*). Its eradication was also begun on different occasions in the same year (Fig. 2).

The local Budapest group of the Hungarian Ornithological and Nature Conservation Society (MME-BirdLife Hungary) began its habitat reconstruction work in 2010 in the northern part of the Tamariska-domb Nature Conservation Area of local importance, specifically, along the fence of the former gas cylinder change yard and eastwards. The overall aim of the activity was to open the vegetation covered mainly by woody IAS. In 2010 along the fence of the gas cylinder change yard there was a sand grassland remnant of 1000 m^2 which was degraded but still had favourable species composition. Its two open patches were almost completely isolated from each other. The grassland patches were surrounded chiefly by Russian olive stands, in which also four-stamen tamarisk (*Tamarix tetrandra*), common hackberry and honey locust (*Gleditsia triacanthos*) individuals were scattered. This woody stand completely isolated the grasslands to be opened from the other open habitats of the protected area. In the herbaceous layer of the woody IAS, common ivy (*Hedera helix*) had become entirely dominant and had squeezed out the herbaceous species once typical of this site.

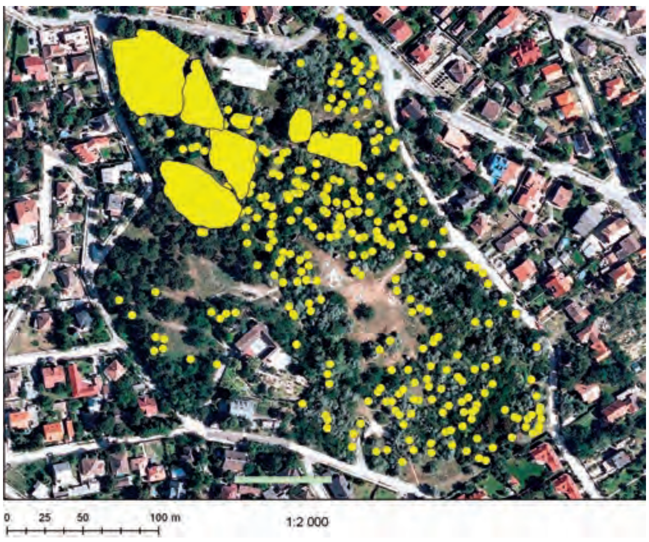

Fig. 2. Distribution of common hackberry on Tamariska-domb in 2012

Here, before the habitat management of MME, the Green Circle Association of Csepel removed 10–12 specimens of ca. 30-year-old Russian olives (ordered by the municipality of Budapest) during the early spring of 2010. Prior to this, there had been no conservation management for many decades asides from the control of common ragweed, which was carried out mainly for human health care reasons. As the next step, Russian olive, honey locust, four-stamen tamarisk and common hackberry specimens were removed from the completely forested areas. At the same time, we spared the native white poplar individuals and their semi-natural shrub layer. In those places where native and alien species appeared together, the alien ones were selected and removed. During the "action day" the undesirable plants were eradicated from 3000 m^2.

Our aim was to restore the original complex of white poplar patches and the more extensive open and closed sand grasslands between these on the northern part of the hill. Based on the experience gained in 2006 in similar habitats of the Homoktövis Sea Buckthorn Nature Conservation Area, we started to open the woody IAS stand gradually in a radial direction beginning from the survived precious habitat patches. Thanks to methodical management, there is now a lower probability that herbaceous IAS will reappear and spread.

After the first occasion in December 2010 in which we relied expressly on volunteers, MME organized a grassland opening action at the end of 2011. As a result the grassland fragment (which was originally only 1000 m^2 and was extended to 3000 m^2 after the first management) was further enlarged. Finally, the former two patches of open habitats were re-united and reached a total of 5000 m^2.

In 2012 we compiled a detailed habitat reconstruction plan under the guidance of the manager of the area. The primary aim of this plan was the conservation of the populations of protected species and natural habitats of the site, and the increase of their sizes through habitat rehabilitation. To achieve our goal, planning IAS and other alien species control was of critical importance. While planning we had to consider the following facts: the size of the area is rather small (5.2 ha), the well-preserved habitats are fragmented, and it is also an important recreation site. As the area is completely enclosed in the garden suburb of Csepel, the proportion of the non-native species is very high (34 species). These originate from spontaneous spread as well as deliberate introduction. Before the planning phase a precise map on the distribution of the alien species was compiled and their specimen numbers were estimated. This step was fundamental in the drafting of their eradication. The fact that the area is of small size allowed us to plan for not only the control of IAS but also of other alien plants to enable the regeneration of the natural vegetation in the largest possible area.

The characteristics of problematic IAS present on the site:

Box elder (*Acer negundo*): In our survey ca. 120 specimens were registered. It has sporadic occurrence over the whole site.

Tree of heaven (*Ailanthus altissima*): This species was present in a larger patch and also sporadically in the area (ca. 500 individuals). The majority of these were younger sprouts; however, there were also older seed bearers.

False indigo (*Amorpha fruticosa*): This invasive shrub species was scattered on Tamariska-domb with 70–80 individuals.

Common hackberry (*Celtis occidentalis*): This was definitely the most common arboreal IAS on Tamariska-domb. The total number of individuals was estimated at ca. 2000, at least half of which were saplings of a few years in age. There were also ca. 100 old specimens with rich seed production in the studied area.

Russian olive (*Elaeagnus angustifolia*): This species is very significant IAS on Tamariska-domb. Ca. 500–600 individuals were registered, half of which are "old" with abundant seed production and the other half being mainly "middle-aged". Young specimens are relatively rare.

Black cherry (*Prunus serotina*): We registered ca. 150 specimens of different ages scattered over the site.

Golden currant (*Ribes aureum*): Ca. 300 specimens are scattered in the area.

Black locust (*Robinia pseudoacacia*): This is a frequent IAS in those parts of the area covered by woody stands. Its population was estimated at 400–500 individuals, of which 200 were old or middle-aged seed bearers.

Common milkweed (*Asclepias syriaca*): During the survey we found 30 specimens in three locations of the area. However, this species is an aggressive invader in sand habitats, so it should be regarded as a significant IAS on the site.

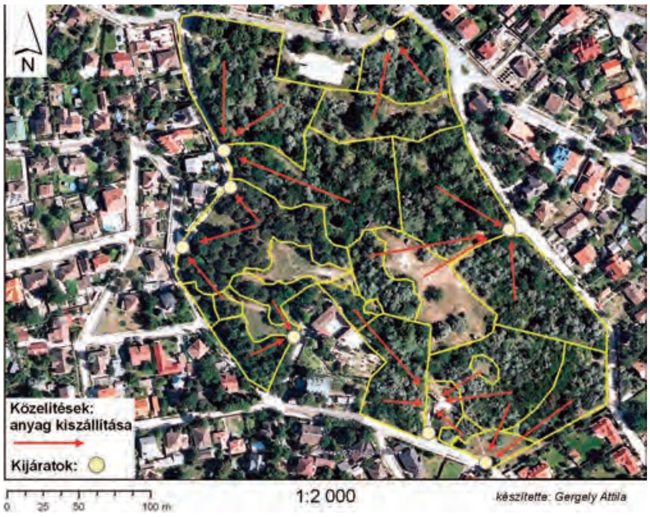

Fig. 3. Management units and transportation tracks on Tamariska-domb in 2012

Hybrid Japanese knotweed (*Fallopia* × *bohemica*): A smaller policormon of this species was found on Tamariska-domb; however, it has strong invasion potential and should also be regarded as a significant IAS.

Other non-native species of the site: *Aesculus hippocastanum*, *Cotoneaster* spp., Russian vine (*Fallopia aubertii*), honey locust (*Gleditsia triacanthos*), *Juglans regia*, *Koelreuteria paniculata*, *Lycium barbarum*, *Mahonia aquifolium*, *Morus alba*, *Parthenocissus inserta*, black pine (*Pinus nigra*), *Sophora japonica*, *Symphoricarpos albus*, *Syringa vulgaris*, *Vitis riparia*, four–stamen tamarisk (*Tamarix tetrandra*), *Thuja orientalis*, common ragweed (*Ambrosia artemisiifolia*), *Cenchrus incertus*, *Phytolacca* sp., *Solidago gigantea* and *S. canadensis*, *Tragus racemosus*, *Yucca filamentosa*.

Machinery cannot enter the site given the small size of the area and the fact that was fenced off even in the planning phase of the management. Consequently, all tasks were planned to be carried out manually. The most difficult task was to transport the exploited IAS off the site. In order to achieve this task, we formed several management units whose roles were to remove waste from the site by the shortest possible route (Fig. 3).

Methods used

The area was exclusively managed by the local Budapest group of MME, and executed with the help of volunteers after the event had been widely advertised. In both the conservation management actions of 2010 and 2011, a total of 30 participants worked from 9 a.m. to 4 p.m. To preserve the habitats the work was carried out outside the vegetation season. Our other limitation was that heavy machinery and vehicles were excluded from the area, so we had to rely on manual labour only, using hand tools and motorised hand tools. We used the following equipment: clearing saws Stihl FS 450, Stihl chainsaws MS 360 and MS 230c, loppers, hand saws, tarpaulins for carrying, and garden forks. Chemical treatments were not employed in any of the cases. Concentrated on mechanical methods, the invasive shrub and tree species were removed from the site on both occasions. The thinner shoots and smaller trees were eradicated with clearing saws (saw blade and brush knife) and, where necessary, the grassland was mown. Larger trees (especially Russian olive, honey locust and common hackberry) were felled with chainsaws. The timber was deposited at the edge of the protected area facing Hársas Street (Fig. 4). Within a few days it was transported off by the workers of Csepel Property Management Company (now Csepel Town Maintaining Company). We estimated that in 2011, 4 m^3 of tree trunks and thick branches together with 450 loose m^3 of thin branches were removed by the end of the day. In 2010, ca. two-thirds of this quantity was removed.

Fig. 4. Branches deposited at the edge of the area by Hársas Street (2010). (Photo: Z. Bajor)

Between 2012 and 2014, habitat management gained momentum (Table 1). Species in the vicinity of the gas cylinder change yard on Damjanich Street, primarily Russian olive, were eradicated, thus expanding and connecting the remainder of the grasslands. We designated tracks along which the exploited timber was transported to the exits gates that preserved the newly constructed fences and the grassland (Fig. 3). One part of the wood was chipped and used up as a trampling surface in the construction of the nature trail, which was inaugurated in 2013. Additionally, the branches were used as hedges to prevent erosion of the sand grassland. We also removed Russian olives at the edges of the two smaller sand grassland fragments, by doing so increasing the regeneration potential of the most valuable plant community of the hill. Common hackberry (especially the seedlings) was thinned out in the whole area. The other woody species (Russian vine, golden currant) were also removed from infestation sites on the border of the protected area (neighbouring Gesztenyés Street and Hársas Street). The seedlings of black pine were thinned in the whole area, but mainly in the central sand grassland next to Fenyves Street. (It should be noted that older black pine individuals were not cut the due to landscape and zoological reasons (Fig. 5). The eradication of the invasive alien herbaceous species (particularly common ragweed) had taken place continuously from 2006 and continued on several occasions a year. At first this was performed by volunteers from the Green Circle Association of Csepel, and from 2012 Csepel Town Maintaining Company,

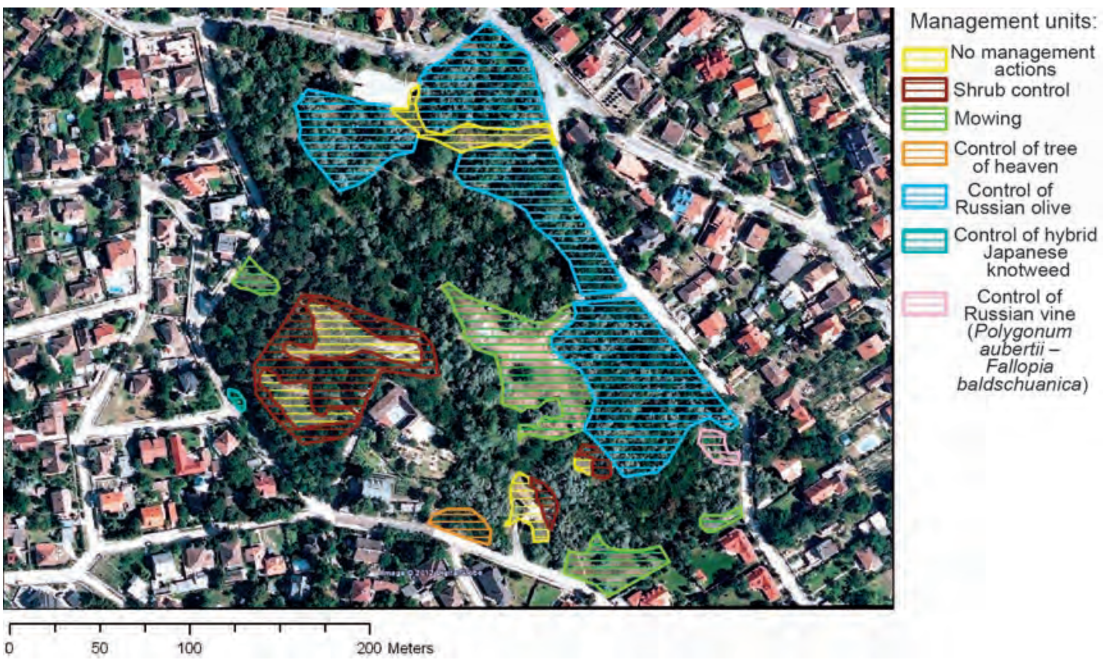

Fig. 5. Planned management units (activities) on Tamariska-domb. (Created by A. Gergely)

Table 1. Habitat management actions on Tamariska-domb of Csepel (2010–2014).

Time	Name	Number of occasions	Workdays/ occasions	Number of workers	Method used	Actions/results
Spring 2010	Logging of Russian olive	1	1	2–3	Chainsaw, hand saw, lopper	Sprouting; follow-up treatment is necessary with herbicide
4 December 2010	Logging of Russian olive	1	1	30	Chainsaw, clearing saw, hand saw, lopper	Sprouting; follow-up treatment is necessary with herbicide
3 December 2011	Logging of Russian olive	1	1	30	Chainsaw, clearing saw, hand saw, lopper	Sprouting; follow-up treatment is necessary with herbicide
Spring 2013	Thinning of black pine seedlings	1	1	2	Manual uprooting	Successful
Spring 2013	Eradication of Russian vine under black pine	2	2	2	Clippers, manual uprooting	Unsuccessful, re-sprouting; has to be repeated with herbicide
Spring 2013	Eradication of hybrid Japanese knotweed	1	1	4	Spade, pickaxe, manually	Unsuccessful, re-sprouting; has to be repeated with herbicide
Spring 2013	Eradication of golden currant	1	1	3	Uprooting individuals (after the roots were cut by spade)	Successful
Autumn 2013	Placing willow textures to protect the slopes	1	3	5	Hand saw, hammer, axe	Successful, plants start to settle; texture needs to be renovated each year
Autumn 2013	Logging of Russian olive	1	3	5	Chainsaw, lopper	Sprouting; follow-up treatment is necessary with herbicide
Winter 2013	Development of a sledge slide (in a spot negotiated with Duna–Ipoly National Park Directorate and Pilis Park Forestry Company)	1	2	6	Chainsaw, lopper	Sprouting; follow-up treatment is necessary with herbicide
Summer 2014	Machinery mowing after the eradication of Russian olive	4	1	6	Clearing saw	Weeding

Fig. 6. Cleared sand grassland with spared old poplar individuals (2013) (Photo: Z. Bajor)

by manual uprooting. This action was successful in clearing the open sand grasslands of this invasive herbaceous species; however, the work has to be repeated regularly.

The cost of these activities were not significant and amounted only to personnel costs (public workers, Csepel Town Maintaining Company workers).

Experiences gained

As a result of the harmony of habitat- and conservation management, the gradual eradication of non-native species and repeated activities on the part of workers, several protected plant species that have not been documented here before can now be found in the area. Thanks to the habitat reconstruction work launched in 2006, the plant populations of the sand vegetation have stabilized and increased in number and variety. Up to now, ten protected plant species have been found on the site, these being typical components of sand grasslands.

As a consequence of the two one-day habitat management actions (in December 2010 and 2011), the size of the partly degraded (in other words, split into two) sand grassland fragments on the northern part of the protected area was extended by about five times in size. Our primary aim was to connect these neighbouring but predominantly isolated grassland patches to decrease the unfavourable edge effects and promote their long-term survival.

By 2011 we were already able to observe native species slowly gaining ground on the alien taxa. To scientifically support these observations, a plant coenology survey was launched in 2011, and this confirmed our suppositions. Between 2012 and 2014 the central grassland of western exposition was connected with two smaller grassland fragments (Fig. 6). In this period, the valuable sand grassland by the entrance to the cellars was also cleared of invasive species. The survey has been continued in the area to verify the long-term results. The detailed evaluation of the data has yet to be carried out.

In summary, we can state that the conservation status of the managed area has become more favourable due to mechanical habitat management. However, only if management is continued will we be able to sustain this status and further improve it. The treatments have to be completed by chemical measures (e.g. drying out shoots, cut stump treatment and trunk injection) in a similar way to those at Homoktövis Nature Conservation Area, another sand grassland subject to habitat management, where work has been going on from 2006.

The pleasing fact that the population sizes of *Astragalus varius*, *Centaurea sadleriana*, *Dianthus serotinus* and *Tragopogon floccosus* has increased indicates that the habitat management actions have been successful and protection of the area has been fulfilled. In 2012 we conducted surveys on ten protected herbaceous species. At that time, we found that 40% of the protected species was composed of *Stypa borysthenica* and *Gypsophila arenaria*.

Issues raised

In those cases when the managed area is situated in a forest under management plan, significant legal and regulatory problems may arise, even if the invasive alien species appears spontaneously in the canopy layer of the stand. According to the current legislation, if the stand is understocked by 30% in a forest sub-compartment managed primarily as a production forest, forest regeneration liability comes into force. This figure is 50% in forests managed primarily for soil protection. However, in neither of these cases can the sub-compartment contain 0.5 ha continuous area with no cover.

Generally speaking, the conservation management of habitats is not aimed at enforcing forest regeneration; it can even be expressly harmful in several habitats (for instance, in certain sand forests). The point is that current forestry legislation often cannot professionally solve and manage the problem of the control of IAS in the canopy level of forests. In forestry and conservation legislation it should be enabled to carry out habitat management with explicit conservation aim in forests under management plans (in certain cases, like in a part of the steppe woods or scrubs). Certainly, the prerequisite of this would be an appropriate procedure for granting permits in which an expert's report justifies the necessity of the treatment and closure of the lower canopy.

Acknowledgements

We would like to thank all those members of the Hungarian Ornithological and Nature Conservation Society who volunteered to help out in the habitat management work. In addition, we must thank the mainly local patriot sympathizers who also helped to effectively open up the grasslands on Tamariska-domb. The volunteers from the Green Circle Association of Csepel (founded in 2003 and led by András

Telki) also actively contributed to the maintenance of the area and weed control of the grasslands.

We owe special thanks to the staff of the municipality of Budapest and the local government of Csepel, District XXI., particularly to Noémi Takács and Erika Kiricsné Kertész, for issuing the permits and performing all the administration. They enabled us to carry out the work according to the legislation on conservation. We also thank the members of Csepel Town Maintaining Company, particularly Gáspár Sölch, who made an active contribution to the conservation of the natural values of Tamariska-domb over the previous years.

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Eradication of false indigo from the territory of the North-Hungarian Water Conservancy Directorate between 2007–2014

Ágnes Kissné Uzonyi and Tamás István Miklós

Introduction

The increasingly intensive invasion of the false indigo (*Amorpha fruticosa*) represents a severe problem on the territory of the North-Hungarian Water Conservancy Directorate, as on any other floodplains as it crowds out all indigenous plants from the area and nitroginate the soil, which, subsequent to a potential control, facilitates the mass propagation of nitrogen-frequent species while making it more difficult for ecologically more valuable species to be introduced and spread. It is also a highly harmful species from a flood control point of view, as it collects the alluvium and the waste during a flood, hinders the recession of the flood and damages the structure of the dams with its roots.

Natural characteristics of the area

The two areas where false indigo clearing was carried out are in the Tisza–Bodrog–Sajó–Hernád and Maros floodplain forestry areas and belong to the 7/e upper section of the Tisza floodplain and are located on the right bank floodplains of the Tisza river.

The area involved in the previous, 2007 experiment was the 1.4-hectare area of Ároktő 0342/4 (plot number) non-cultivated, in the land use category of arable land. Its soil is alluvial forest soil, the topsoil is deep and the physical characteristic of the soil is loam.

The second area is Ároktő 0324 and 0326 (collective plot number), which is a 5-hectare peripheral plot. Its soil is humic alluvial soil, the topsoil is deep and the physical characteristic of the soil is loam, with medium-altitude situation.

Initial conditions

Prior to 2005, due to limit funds, our efforts of relieving the territory from false indigo, using the method of continuous mowing, were primarily concentrated around the dams.

The community work program launched in 2005 enabled the subsequent clearing of further territories. The contiguous false indigo shrubs were cut with small axes and hatchets, then incinerated on site. A mixture of red paint, 1 litre of gasoline and 150 ml of Garlon 4E was applied on the cut stumps, in accordance with nature conservation regulations*. (Since then the use of Garlon 4E has been conditioned on case by case request of an emergency permission issued by the National Food Chain Safety Office, Nébih). This method did not bring the desired result. Although the stumps were destroyed, the next flood wave spread the seeds all over the cleared area, resulting in 2–3-meter tall bushes within a year.

Since false indigo does not take well in shaded areas – under old, properly closed forests the plants that grow from seeds carried over by the flood die within 1 or 2 years – the idea of afforestation of the cleared areas was put forth as a last resort.

* Attention! Experimental chemical control methods described in this chapter are subject to authorisation! Their practical application requires an emergency permit issued by the pesticide control authorities for the given area and period!

Methods used

As the forest renewal around Tiszakeszi was unsuccessful, replacement afforestation was necessary at Ároktő (0342/4), which was complicated by the fact that the area to be afforested was covered by false indigo. A contractor made a proposal for cooperation including a joint experiment promising beneficial results. According to the agreement, the North-Hungarian Water Conservancy Directorate had the false indigo cut and bundled by community workers, then the contractor bundled the bales with stacker-bundler harvester mounted on a German MAN truck used in pine forests.

A part of the bundles were given to the water authority for dam protection to be placed on the slope of the embankment and fixed by flood protection stakes during times of flood or prior to the flood, which protects the embankment for example against slope scour. Such protection is needed in case of lack or insufficiency of protective forests on the waterside of the embankment.

The majority of bundles were given to the contractor in exchange for the work done. He had their calorific value examined in Austria with such favourable results that it raised interest from abroad. (We are not in possession of the specific results as the examination was ordered by the contractor himself and he did not share the findings with us). In Hungary no interest was shown in this kind of biofuel, except for the power plant in Kazincbarcika, which accepted a part of the bundles provided they were delivered at the Directorate's own expense.

One hectare of the cleared land was afforested with the help of a forest contractor. The above-mentioned Garlon 4E mixture was applied on the cut stumps, then the area was root-raked and roots were manually pulled out. 2-meter tall black poplars (*Populus nigra*) were planted after a superficial (20–30-cm deep) soil preparation so that they would have a better chance at withstanding the spring floods.

The North-Hungarian Water Conservancy Directorate had tried a different method in 2013, which also proved to be efficient. An AGRI-MASTER AF forestry mulcher worked on a 5 hectare area covered by false indigo, which was completed within 5 days. The resulting mulch remained at the site, facilitating the nutrition supply of the soil, while the larger pieces were manually collected by community workers. The soil was treated by rotary cultivators, the subsoil loosened along the planned rows and then grey poplars (*Populus* × *canescens*) were planted by hand.

Experiences gained

Rarely any false indigo grew on the first plot in the year following the afforestation. The false indigo grown from the seeds carried over by the river was significantly thinned by the full grown black poplars with their rather large canopy due to the unfavourable light conditions, while the occasional surviving plants were destroyed by thorough forest nursing. Unfortunately, the black poplar saplings had probably become infected at the plantation field, since during the summer of the second year there was a significant *Paranthrene tabaniformis* damage on the trunk of almost every black poplar tree. The trunks were trimmed, but then another flood covered the trimmed surface of the trunks with silt so that they could barely sprout until the forest was finally destroyed by drought damage in 2011.

Unfortunately, due to lack of sufficient interest here in Hungary, the contractor had no choice but to take the machine back to Germany.

After the clearing of false indigo in 2013 carried out by a forestry mulcher, the clear forest areas are continued to be nursed and to date, barely any false indigo has grown on it.

Tree of heaven control on sandy areas of the Little Hungarian Plain

Gábor István Kocsis

Natural characteristics of the area

The Kisalföldi Forestry Company won HUF 133 793 792 on an EEOP-tender to control patches of tree of heaven in the protected and Natura 2000 areas (and places close to them) of the Forestry of Győr. The project, conducted between autumn 2013 and 31 May 2015, has concerned 191 forest sub-compartments, located at seven village borders and belonging to six forestry districts.

The affected forest sub-compartments in the area of Bőny, Gönyű, Nagyszentjános and Győr belong to the Győr-Tata terrace lands forestry region and are either located in the Natura 2000 area *Gönyűi homokvidék* (sandlands of Gönyű) (HUFH20009) or in its vicinity. Ásványráró and Kimle belong to the Szigetköz forestry region and the affected forest sub-compartments are located in the Natura 2000 Szigetköz area and in its vicinity. The seventh village is Rábapatona, whose only affected forest sub-compartment is in the Rábaköz forestry region and in the vicinity of the Natura 2000 area that goes under the same name.

Given that 655.08 ha of the 681.33 ha affected by the treatment in the framework of the project is found in the Győr–Tata terrace lands and that tree of heaven (*Ailanthus altissima*) infestation is the strongest in this area, the characteristics of this region will be presented.

The majority of the affected forests are located under an altitude of 150 m, though not on a floodplain. A moderately warm, dry steppe woodland climate characterizes the area, where the mean annual temperature is 10.2°C, and the average annual precipitation is 553 mm. The site is characterized by a sandy soil class, a medium-depth surface soil, a hydrology independent of the effects of water surplus, and levels of gravels found during site excavations that also appear on the surface in some areas.

Given the aforementioned characteristics, closed woodlands are not typical in these areas; rather thinning populations, clearings and grasslands are distinctive, and these hold great conservation value. At the nearby Győrszentiván military practice range area and at the shooting range in Gönyű pannonic sand grasslands have also survived. The following species from the lists of protected species and species of community interest can be found in the area: pheasant's eye (*Adonis vernalis*), narrow-leaved flax (*Linum tenuifolium*), sand feather grass (*Stipa borysthenica*), locoweed (*Oxytropis pilosa*), baby's breath (*Gypsophila fastigiata* subsp. *arenaria*), dwarf iris (*Iris pumila*), Hungarian iris (*Iris variegata*), stemless milkvetch (*Astragalus exscapus*) and solitary clematis (*Clematis integrifolia*).

Initial conditions

Before submitting the tender, and with the help of forest rangers, we surveyed the infestation by tree of heaven in those forests we manage over the complete territory of the Kisalföldi Forestry Company.

During this survey the age of the trees in the given forest sub-compartment and the percent coverage of tree of heaven were recorded. This coverage was classified into one of five levels, with "1" meaning slight infestation and "5" indicating a completely covered area. This aim of this determination was to choose the necessary methods for clearing given the age and size of the trees and to estimate the amount of work and the expected costs based on the coverage. The protected or Natura 2000 areas of the Forestry of Győr and the infested forest sub-compartments within a 1 km protective zone of these areas were also included in the project.

Tree of heaven has been found here for decades and since the turn of the millennium it has posed a real problem. The forestry controls it regularly through its own means based on the following principles.

- Seed trees are not tolerated in the forests and are cut out.
- During clearing and thinning tree of heaven is removed.
- In clearcut areas the seedlings are sprayed, and in regenerations of two years old and upwards the remaining sprouts are sprayed individually, even when this means a one year postponement of the first planting.

Despite these actions tree of heaven can be found almost in all forest sub-compartments en masse in the forest at Bőny and in smaller patches in those sub-compartments further away. According to the survey, and based on the infestation classes, the 681.33 ha included in the project had the following territorial division:

- Infestation level 1: 435.81 ha (sporadic appearance, smaller patches);
- Infestation level 2: 135.05 ha;
- Infestation level 3: 69.65 ha;
- Infestation level 4: 18.63 ha;
- Infestation level 5: 22.19 ha (e.g. a complete, homogenous area of sprouts appearing after clearing).

The aim of this current project was the conservation of indigenous plant and animal species, the long-term preservation of their habitat, enabling nature-based forestry management conditions, and the improvement of forest naturalness. In order to achieve these goals, we aimed to control the spontaneous and aggressive spreading of this tree species so as to preserve and extend the current distribution of indigenous tree species. We know that the complete eradication of the tree of heaven cannot be achieved, as it is still present in great numbers in private forests, along public roads and in urban areas surrounding the forests managed by us, all these being a source of re-infestation. However, our aim was to drastically decrease its density with aligned management actions without any assistance in the territory of the forestry, and to push it back to a manageable level (Fig. 1).

Fig. 1. Common hop climbing on dead sprouts. (Photo: G. I. Kocsis)

Methods used

Depending on the level of infestation and the size of the trees, we used four different methods.

1. In the most infested areas, where tree of heaven covered the whole ground surface, we cut the stand of the species. These are mainly understocked Scotch pine (*Pinus sylvestris*), black pine (*Pinus nigra*), and black locust (*Robinia pseudoacacia*) forests, in which we also had to pay attention to the remaining population. Logging was carried out with a Stihl FS 350 trimmer equipped with disk saw adapter, then the branches were laid on the ground; in the case of larger quantities, the branches were piled up to make the area accessible later. In one particular scrub so many thin branches were gathered that we had to burn these branches as part of the site clearing. The aim of logging was to create a homogenous state over a larger territory and to be able to control sprouts and seedlings with spraying*. This method was employed on 22.19 ha. Originally we had planned to spray over a larger area, but the green authority specially requested that we minimize the spraying territory due to the present herbaceous plants and the risk of drifting. We therefore decided to use the basal bark method more often.

2. We planned to spray the areas subjected to logging three times. After doing mechanical sprout control outside the vegetative phase, sprouts appeared in the spring in May and June. When they grew to 30–40 cm, we started spraying. After this, seedlings are expected to appear by the end of the summer. 1–2 cm long plants growing en masse are already visible by the middle of August (Fig. 2); the second treatment is timed according to their growth. We planned a third spraying at the spring of the following year, since some plants will survive the first two treatments when there is such a strong infestation. Spraying is done with a backpack sprayer filled with a total herbicide (Medallon Premium) containing 3.5% glyphosate. We mix in an adhesion increasing agent (Silwet L-77) material for more effective absorption (Fig. 3).

*Attention! Experimental chemical control methods described in this chapter are subject to authorisation! Their practical application requires an emergency permit issued by the pesticide control authorities for the given area and period!

Fig. 2. Seedlings growing en masse at the beginning of August. (Photo: G. I. Kocsis)

In those forest sub-compartments where tree of heaven is found in smaller quantities, as single trees or in patches, we used the basal bark method for thin sprouts and inject the thicker ones (Fig. 4).

3. Basal bark treatment of the younger trees with a thinner bark was conducted over an area of 538.37 ha. The workers treat blocks defined clearly by roads and glades. The working group is 15–20 people strong; each of them is equipped with a 5 l can with a broadened spout, filled with the spraying mixture to a third-full so it does not spill on the often difficult, bushy terrain. A radiator brush with a long handle is used for painting; the brush reaches the bottom of the can without the workers having to smear their hands; this also enables them to access the individual trunks in thicker populations as well (Fig. 5). At the border of the forest sub-compartment the workers stand in a row with a gap of 4–5 m between them; they then walk through the forest treating trees of heaven at hip height on their way. For the painting Medallon Premium oleaginous, painted emulsion is used. The physical parameters of the solution (surface tension, viscosity, emulsion, stability) are set in a way that facilitates the absorption of the agent through the bark. Due to the marker dye mixed to the material, the workers can follow which trees have

Fig. 3. Effect of spraying on the pine population. (Photo: G. I. Kocsis)

Fig. 4. Basal bark method and trunk injection on trees standing next to each other completely destroyed. (Photo: G. I. Kocsis)

Fig. 5. Tools used for basal bark method. (Photo: G. I. Kocsis)

Fig. 6. Veterinary mass vaccinator used for injection. (Photo: G. I. Kocsis)

Fig. 7. Filling the drilled holes. (Photo: G. I. Kocsis)

already been treated, thus the chance of skipping a trunk is minimized and fulfilment of the treatment can be checked. Based on the average data from the work report, one hectare of 100% infested forest would take 5.2 working days to be treated by one person; 23.6 l of substance would be required for this treatment. The net price of the ready-to-use substance is HUF 2500/l.

In contrast to spraying, with basal bark painting the chemical does not drift away, thus minimizing the environmental load. As painting is carried out at hip height, the herbicide never reaches the ground. Even if the substance starts to flow downwards it only gets to the lower half of the trunk. If it happens to be washed down, the substance is broken down by the bacteria in the ground, where it is not persistent. Absorption is best through non-woody, green coloured bark, but sprouts with a thickness of a few cm can absorb it, as well. Green sprouts should be painted only on one side, but those thicker than 2.5 cm should be treated all around in order to kill them. If we treat a ca. 3–4-cm-diameter plant only on one side, the sprouts in the canopy, which are nourished through the untreated side, will not die. Using this method we expected some of the trunks to grow out again, thus we planned to perform the painting three times with a continually decreasing amount of sprouts. By the second step we expected two-thirds of the original amount and by the third step one-third of the original amount.

Fig. 8. Loading the batteries at the location. (Photo: G. I. Kocsis)

4. Older trees were treated by injecting the trunk; this was undertaken over a 274.2 ha territory which overlapped with the area undergoing bark treatment, since there are forest sub-compartments where both thick trunks and sprouts can be found. We expect that repeated treatment will not be needed in the case of injection as treated trunks will dry out without sprouts. However, if sprouts do still grow out, we will treat them using the bark method. In the bark of the tree workers drill 2–3 cm deep holes round at hip height 45° downwards with a cordless drill and an 8 mm drill bit, then they inject the chemical into the holes with a veterinary mass vaccinator (Fig. 6). On trunks of wrist thickness it is enough to drill two opposing holes; on thicker trees these should be positioned along a ring at a distance of 8–10 cm. Deep holes should not be drilled in order for the absorption to occur near the cambium. Finally, the holes are closed with siloplast so the substance does not evaporate (Fig. 7). At the injectors three people make up a unit. The first one marks the tree with a paint gun and does the drilling, the next one fills each drill with 2 cm^3 75% Medallon Premium agent with a veterinary mass vaccinator, and the third one seals the

Table 1. Territorial division of methods used in the infestation categories.

Applied method	Infestation categories					Total (ha)
	0–20%	21–40%	41–60%	61–80%	81–100%	
Mechanical removal					22.19	22.19
Spraying					22.19	22.19
Bark treatment	345.11	130.34	44.29	18.63		538.37
Injection	150.57	68.32	45.16	10.35		274.40

Table 2. Cost of treatments considering infestation, applied method and number of repetitions (HUF/ha).

Infestation and multiplier	1st basal bark treatment	2nd basal bark treatment (2/3)	3rd basal bark treatment (1/3)	Injection	Mechanical removal	1st spraying	2nd spraying	3rd spraying
"1" – 20%	66.704	44.469	22.235	59.700				
"2" – 40%	133.408	88.939	44.469	11.940				
"3" – 60%	200.112	133.408	66.704	179.100				
"4" – 80%	266.816	177.877	88.939	238.800				
"5" – 100%	333.520	222.347	111.173	298.500	75.000	201.320	201.320	201.320

hole. One person could inject a theoretically 100% infested forest in 2.9 days using a total of 7.4 l agent.

The batteries used for the drills deplete in 1.5 hours, so for continuous work a mobile aggrerator is needed. Each drill has an extra battery: while one of the batteries is used, the other can be charged. Concerning organizational issues, it must be highlighted that the generator cannot be left unsupervised, because it might be stolen (Fig. 8).

The territory undergoing each treatment is presented in Table 1; they are also classified according to infestation. The unit prices of the treatments are included in Table 2. These prices were defined for the most infested areas; they were then adjusted according to the percentage of the infestation. As mechanical treatment and spraying only happens in category 5 forests, the other cells in the table are left empty. In the case of repeated basal bark treatments, the decreasing unit prices reflect the continuously decreasing amount of sprouts. In the case of spraying, the complete area should be covered during all three treatments; thus there is no change in unit prices.

The contractor that performed the treatments was selected through a public procurement tender. This contractor organizes transport for workers and purchases the chemical as well. Workers have one crew boss; we keep in touch and discuss the necessary tasks for each forest sub-compartment with him. He transports the workers with a 9-passenger, four-wheel drive van in multiple rounds due to the high

Fig. 9. Tree of heaven sprouting from a stump not treated all the way around. (Photo: G. I. Kocsis)

Fig. 10. A deformed sprout appearing in the spring following treatment. (Photo: G. I. Kocsis)

Fig. 11. Deformed sprouts appearing on an injected trunk. (Photo: G. I. Kocsis)

number of people. Of course, workers wear the required protective gear (mask, gloves, etc.) in all three chemical-based treatment methods.

We started the first basal bark treatment in the autumn of 2013 and we completed this task fully on 31 May 2015. Due to the mild autumn weather we made fast progress in the first year. Tree of heaven specimens were still in leaf in October, so we tried to carry out basal bark treatment over the largest area possible; at the same time a group of six workers were injecting continuously. In the winter months clearcutting and site clearing were performed (in January and February); injecting and basal bark treatment were continued in March. We had finished the first spraying, injecting and basal bark treatment in the clearcut areas by the end of May 2014. At this point the basal bark treatment was paused since in the heat of the summer evaporation of the chemical is so significant that it would pose a risk to the remaining tree population, with European ash (*Fraxinus excelsior*) and black locust being especially sensitive to the chemical.

We started the second phase of basal bark treatment on 25 August 2014: unfortunately, we could not start earlier due to regular rainfall. With this treatment we controlled those trees that had survived earlier interventions or had been left out, as well as treated root suckers and seedlings appearing en masse at several locations (Figs 9 & 10). Our expectation is that their number can be reduced significantly with this treatment and with the one planned for the spring of 2015.

Before repeating the treatments, we tabulated the results of the first control, adding relevant photos, to enable us to get an overview of the effectiveness of the treatment and the factors influencing it. In this way we aim to make our work more effective.

Experiences gained

The most significant and positive experience is that injecting was almost 100% effective: there were only a few trunks that survived the treatment irrespectively of the timing of it (Fig. 11).

Basal bark treatment results are less straightforward and several factors influence its effectiveness. We have already mentioned that in the heat of the summer there are restrictions on the treatment due to the evaporation of the chemical. However, absorption is better in higher temperatures as the oil-based mixture becomes denser in the cold, significantly decreasing its effectiveness. We recorded the morning, noon and evening temperature during the treat-

Fig. 12. Root suckers appearing in understocked patches. (Photo: G. I. Kocsis)

Fig. 13. Grey poplar root suckers appearing in a sprayed area. (Photo: G. I. Kocsis)

ments. By comparing this data it became apparent that if the highest daytime temperature drops under 15–16 °C, the number of trees that survive the treatment and grow leafs or sprouts from the trunk increases. The age of the treated trees is also an important factor, as the bark of older trees is thicker, making the absorption of the chemical more difficult. One-year-old sprouts, which were treated under good weather conditions (that is, above 16 °C in dry weather) and on the green sprouting area were completely destroyed without further suckering, while with older populations some root suckers always appeared. However, even 15–20 cm wide trees died when they were painted around in a wide (40 cm) stripe. Basal bark treatment of these trees heavily increased chemical use, thus we suggest the use of injecting as often as possible. The appearance of root suckers is strongly influenced by ground shading. In the same forest sub-compartment we experienced strong suckering in sunlit areas, whereas in case of a closed overstory, no root suckers appear at all (Figs 12 & 13).

We would like to inform those interested in the topic about additional findings and important events related to the project are uploaded to the website of Kisalföldi Forestry Company (Kisalföldi Erdőgazdaság Zrt.). We are also happy to provide further information or hear your opinion and advice about the topic via email.

Useful links

On the website of Kisalföldi Erdőgazdaság Zrt. you can follow events related to tree of heaven control: http://kaeg.hu/

On the website of Fertő-Hanság National Park you can check the protection status of different areas based on their topographical lot number: http://www.ferto-hansag.hu/

In the online pesticide database of the National Food Chain Safety Office you can search for the applicability and other data of different substances: https:// novenyvedoszer.nebih.gov.hu/Engedelykereso/kereso.aspx

The transportation of different pesticides used for the project was carried out by SM Consulting Kft.: their contact information can be found on the following website: http://www.fadoktor.hu/

Control of Himalayan balsam in the Alsó Meadow by Kőszeg

Blanka Kóródi

Natural characteristics of the area

Alsó meadow (160 ha) is situated on the right side of the Gyöngyös stream near Kőszeg. As a part of the Kőszeg Landscape Protection Area, it has been a protected area of national importance since 1993. Its fen, marsh, hay meadows and large sedge communities home protected plant species like the globeflower (*Trollius europaeus*), *Iris sibirica*, *Dactylorhiza majalis*, *Achillea ptarmica*, *Gentiana pneumonanthe* and *Crocus albiflorus* (in Hungary it occurs exclusively in this area near Kőszeg). The climatic conditions of the site are strongly influenced by the vicinity of the Alps. The average annual temperature is 8–10 °C, the summer is moderately warm and the winter is mild. The area has significant average annual precipitation of 700–900 mm. Its alluvial soil is permanently affected by water; the topsoil is semi-deep or deep.

Initial conditions

The formerly huge grasslands were grazed and large areas were also managed as ploughlands. As land use changed and animal husbandry lost ground, parcels of land were abandoned, and shrub encroachment, forestation processes and the spread of invasive alien species began.

To mitigate these processes, in 2008 we launched an action together with the staff of the Őrség National Park Directorate with two main aims. Our primary goal was to protect a relatively isolated population of several hundreds of globeflower specimens whose habitat was increasingly threatened by Himalayan balsam (*Impatiens glandulifera*). Another goal was to inform the general public about this problem and give them insight into the practical work of conservation professionals.

Methods used

Announcing our action as *Let's protect the globeflower from the invasive alien species together!* we managed to eradicate Himalayan balsam in a ca. 0.5 ha area with the help of volunteers. We selected the simplest method for eradication – pulling out individuals manually – as this could be performed by children and adults alike. We collected removed Himalayan balsam specimens in piles containing one hundred specimens each, this way making is easier to determine the total number of destroyed invasive plants (Fig. 1). Each pile was then removed manually from the meadow. On the first occasion we counted 5000 individuals. Since this time, the action has been organised in May each year with the participation of 6–10 persons. The date of the programme at the end of May is optimal as the globeflower is still in bloom (thus it can be shown to the volunteers) but the seeds of Himalayan balsam have not yet ripened and the alien plant is not too tall, making it easier to pull out).

We have a regular group of participants to rely on, and there are always new volunteers who join the programme on any one of these Saturday mornings. As the number of participants is low, the trampling effect is slight and thus has little impact.

Experiences gained

In the first year the major part of Alsó meadow was covered by Himalayan balsam. We have achieved good results after six years with the removal of 5000–8000 Himalayan balsam specimens annually. This last year we were only able to find survived individuals at the edge of the meadow, under the alder trees.

Our method is definitely not the most effective defence against the invasive alien species; however, it is the cheapest one as it requires no equipment and, thanks to our enthusiastic team, it is enjoyable as well!

Fig. 1. Action for invasive alien plant control in Alsó meadow by Kőszeg (Photo: B. Kóródi)

The control of black locust in the Mátra region of the Bükk National Park Directorate

Gábor Magos

Introduction

Since 2008 there have been several attempts to control black locust (*Robinia pseudoacacia*) by chemical injection in several sites of the Mátra mountains under the property management of Bükk National Park Directorate (BNPD). These have sometimes been carried out sometimes using work contracts, but most have been within the framework of the public work programme of the directorate. Given the opportunity, project proposals are submitted that include both habitat restoration and conservation management.

Natural characteristics of the area

Area 1: This area includes former pastures (mesophilic hayfields) near Parád (Tariska pasture, Parád pasture) where the typical vegetation progress is scrub encroachment; we can also find beech forests and sessile oak hornbeam woodlands on Vár Hill.

The area is situated where the Parád–Recsk Basin meets the High Mátra at an altitude of 310 and 450 m above sea level. Unlike the main mass of the Mátra, this area has a heterogeneous geological structure (dacite, Oligocene clay and sandstone) covered almost exclusively with brown forest clay soil. The climate is moderately cool and dry; annual sunshine is 1860 hours. The average annual temperature is between 8.5 and 9.3 °C, and averages 15–16 °C in the vegetation period; the average annual precipitation is around 650 mm. Some parts of the beech forests are acidofrequent due to edaphic factors. In these areas moss species such as *Leucobryum glaucum* and also bilberry (*Vaccinium myrtillus*) are present. The lesser butterfly-orchid (*Platanthera bifolia*) is widespread, while the broad buckler fern (*Dryopteris dilatata*) is not so common, but it is still present in the area. It is a unique natural asset that sapro-xylophagous species and insects forming communities with them are present in the heterogeneous oak forests. These species include great capricorn beetle (*Cerambyx cerdo*), *Gnorimus variabilis*, *Eurythyrea quercus* and the European antlion species *Dendroleon pantherinus*. In mesophilic hayfields, we can find some patches of common heath grass (*Sieglingia decumbens*), matgrass (*Nardus stricta*) and maiden pink (*Dianthus deltoides*), and in favourable years some adder's-tongue (*Ophioglossum vulgatum*) populations also appear.

Area 2: Around the administrative border of Domoszló, on Pipis Hill, in the territory the directorate, we carried out control treatments in the Turkey oak population and a nearby clearing covered with some black locust. After this, within the framework of the SH/4/8 *Sustainable conservation on Hungarian Natura 2000 sites* project, we will do post-treatments in the aforementioned area around Domoszló, while we continue black locust control in a new site.

This area belongs to the southernmost parts of the eastern mass of High Mátra. The hill itself consists of andesite, and rhyolitic and andesitic tuff, chiefly covered with brown forest clay soil. On the southern edges, however, there are also rocky outcrops and patches of erubase soil. The climate is cold and wet here, but this is mitigated given that it is a south-facing area. The annual sunshine duration is between 1900 and 2000 hours. The average annual temperature is between 6 and 8 °C, and 12–15 °C in the vegetation period. The average annual precipitation is 600–840 mm. Common plant species are rose campion (*Lychnis coronaria*), pink barren strawberry (*Potentilla micrantha*), *Achillea crithmifolia*, Slovak Penny-cress (*Thlaspi jankae*), but there are also species characteristic of shrublands, including *Piptatherum virescens*, burning bush (*Dictamnus albus*), Violet Limodore (*Limodorum abortivum*) and Mediterranean onion (*Allium paniculatum*). Juniper skink (*Ablepharus kitaibelii*) also appears in some patches of this area.

Area 3: This area covers the central area of the Sárhegy nature reserve (Cseplye Peak) in Gyöngyös. Black locust patches in steppes and forest grasslands were treated in 2011, and there have been post-treatments ever since. We have also carried out black locust control within the framework of the *Restoring and treating meadows, grasslands, pastures in the territory of BNPD – EEOP 3.1.2/2F/09-2009-0007* tender.

In this project, we completed habitat restoration between 2010 and 2013 in the territory of the Bükk National Park Directorate (Nógrád–Ipoly region, Western Bükk region, Mátra region). The aim of one of these steps was to control black locust in the grasslands of the Mátra region (territory of the directorate, located in the Sárhegy nature reserve).

Sárhegy is an isolated hill located to the west of the central mass of the Mátra. It is the remains of the western caldera edge of a former volcano. Its peak is at 500 m, while the project area is located at an altitude between 310 and 340 m. This small region has a moderately warm and dry climate, the annual sunshine duration is over 1950 hours, and the average maximum of the annual precipitation is 600 mm. Accordingly, the dominant soil types are rankers and brown forest clay soil. Since the area is a promontory and exposed to sunshine, some parts of the Sárhegy are significantly drier and warmer than their surroundings. The infested area is located near Saint Anne Lake, and it is highly exposed to eastern and southern weather effects.

To the south, there are also some abandoned vineyards (now covered with shrubs), slope steppes, *Festuca rubra* hay meadows and pastures, as well as patches of thermophilous oak forests.

The history of the area is similar to that of "related" areas. The original vegetation was decimated when people started to grow grape, but this period ended at the end of the 19th century after a *Phylloxera* invasion (1875). The species that survived this period on the edges of vineyards later reclaimed the area, creating large secondary steppes. These were later utilised for grazing sheep and goats. Grazing started to lose its momentum in the 1970s, and it completely stopped in 2000. At the same time, natural succession accelerated and invasive species (primarily black locust) appeared. The area includes a wide range of species, but due to the lack of space we only include a non-exhaustive list. Common protected plant species include burning bush (*Dictamnus albus*), Jerusalem Sage (*Phlomis tuberosa*), pheasant's eye (*Adonis vernalis*), *Echium maculatum*, Slovak Penny-cress (*Thlaspi jankae*), green-winged orchid (*Anacamptis morio*), three-toothed orchid (*Neotinea tridentata*), *Iris pumila* and *Scorzonera purpurea*. There is also a great number of arthropods present in the area. The protected *Cortodera holosericea* is present here because of the squarrose knapweed (*Centaurea triumfettii*), but the hog's fennel (*Peucedanum officinale*) in rock grasslands attracts the specially protected fisher's estuarine moth (*Gortyna borelli lunata*). There are also rare sub-Mediterranean species, such as the golden egg bug (*Phyllomorpha laciniata*) or the recently discovered spider species *Nemesia pannonica*).

As in other abandoned areas, succession is advanced to different degrees in the site. This, of course, also means that invasive species started to spread, which is very dangerous to native communities. The aforementioned areas are now infested with almost homogeneous patches of black locust stands and in some cases with black locust stands mixed with field maple (*Acer campestre*) or Turkey oak (*Quercus cerris*). The aim of the management is to eradicate invasive species from the area, to stop their spreading and to enable future grazing (for its own use or as a source of income) in order to preserve grassland communities in the long run.

Initial conditions

Area 1: Old, homogeneous black locust stands were able to establish in a 30–40 m wide and 250 long patch on Vár Hill by Parád, on the edge of the heterogeneous population with beech and Turkey oaks. Some isolated individuals and smaller groups later mixed with the native population (from seed). The total size of the area was about 2 ha. Black locust also appeared from seed in mesic hayfields, but these areas were only sparsely covered with young heterogeneous patches mixed with native shrubs. The total size of these was 1.5–2 ha.

Area 2: Near a former clearing in Domoszló old black locust stands enabled the species to slowly gain momentum in the Turkey oak forest. The total area treated (including post-treatments) was 1.2 ha.

Area 3: The Sárhegy was (and still is) infested with scattered black locust stands. The homogeneous, middle-aged, circular population in an area of 1 ha was previously treated within the framework of the public work programme. Another 2 ha of land was later treated in this project. Half of that area was infested with a homogeneous, middle-aged population of seed origin, while the other half was covered with a native population (Turkey oak, field maple, field elm (*Ulmus minor*)) mixed with old black locust individuals. Additionally, there was a small patch with young black locust sprouts (0.2 ha).

Methods used

We decided to choose the trunk injection method from the available control treatments*. This is because spraying was not an option due to the outstanding biological value of the area, and cut stump treatment would have been less effective given that some trees were simply too big. This is why we applied only one method in the entire area. The best timing of the treatment is the second half of summer, when black locust starts to store reserves in its roots. During the treatment, we drilled 1 hole per 5 cm of trunk diameter (i.e. at least three holes in the case of a tree 15 cm in diameter) with a 8 mm drill head at an angle of about 45° towards the centre of the trunk. The length of the holes should be about 5 cm, and if the hole is not aimed directly at the centre of the trunk, the chemicals better affect the xylem, resulting in better absorption. We used Medallon Premium, a non-selective total herbicide containing glyphosate. About 2.5 ml of undiluted chemical was injected into each hole using a wash bottle. The holes were then sealed with modelling clay or other sealing compounds. The treated individuals were marked to make them easily distinguishable and so that plants were not accidentally treated twice.

Normally, the treatment is carried out by a group: one person handles the drilling machine (500 W), another injects the chemical, a third person seals the holes and paints the treated trees, and a fourth one moves the portable generator (0.7 kW). A generator is required as battery drills cannot be used for this work. This is because patches contain a great number of trees, and drilling holes into live trees requires heavy-duty machines. The treatment can be repeated on still living trees in the following year. Dried trees can then be logged (it is suggested in homogeneous populations), or in some cases they can be left as deadwood to provide potential habitat for the European rhinoceros beetle (*Oryctes nasicornis*) or other beetles such as *Cucujus cinnaberinus*. Among others, these two species belong to those rare elements of the fauna that can utilize black locust deadwood.

Experiences gained

The costs of the aforementioned treatments were fully covered by the EEOP tender.

The specific costs per hectare depend on a number of factors. The price of the chemicals (Medallon Premium – ~9 EUR/l; Fozát – a chemical containing glyphosate, ~5.5 EUR/l), the level of infestation, the size of trees to be treated and the success rate of the first treatment all influence the total costs. Spraying the sprouts is expensive because the use of total herbicides is not allowed here. Instead, a selective chemical (Lontrel 300) is required, which costs more than 115 EUR/l and can only be used by specially trained experts. Estimating the cost of labour is also very difficult because doing the tasks with contractors or within the framework of a community work programme has different costs.

In our experience, the treatment is very effective. About 90–95% of injected individuals died after the first treatment, and the sprouts of the surviving trees were severely deformed. A second treatment killed all the remaining individuals. Random sprouts can later be sprayed (taking into account the characteristics of the area). The biggest problem may be the presence of propagules in the soil. In the case of grasslands, grazing can be a perfect complementary treatment, and later it can help to maintain the conditions of the area. Post-treatment was necessary in our project, in which we injected chemicals into the surviving tree parts. Homogeneous populations were felled, while black locust stands mixed with other species were left as snags.

To summarize, over the last few years we have treated about 8 ha using the drilling and trunk injection method in the Mátra region of the BNPD. Experience (our observations, not surveys based on standardised protocols) shows that this treatment method is an acceptable way of controlling black locust in this region.

*Attention! Experimental chemical control methods described in this chapter are subject to authorisation! Their practical application requires an emergency permit issued by the pesticide control authorities for the given area and period!

Box elder control using chemical and mechanical methods in old hardwood gallery woodlands of the Ócsa Protected Landscape Area

István Nagy

Introduction

We carried out different experiments for the control of box elder (*Acer negundo*) at several locations in 2013. These interventions were instigated by the management of the state forest in the protected area for the control of invasive alien tree species. We carried out the control of box elder at several locations with different methods; the areas, methods and experience will be presented separately.

Natural characteristics of the area

All areas are located in the Ócsa Protected Landscape Area and all contain strictly protected populations.

Area 1: This area is a secondary forest with a clearcut reproduction system. The forest is around 85 years old, mixed in nature with clusters of trees or single individuals of narrow-leafed ash (*Fraxinus angustifolia* subsp. *danubialis*) (70%) and common alder (*Alnus glutinosa*) (30%). Individual English oak (*Quercus robur*), European white elm (*Ulmus laevis*), white willow (*Salix alba*), grey poplar *(Populus × canescens*) and black poplar (*Populus nigra*) can also be found in the area. The average height of the population is 27 m; the average diameter of the trunks is 38 cm, while closure is 80%. The undulating surface is covered by a fen soil under a permanent water effect. Higher places are characterized by narrow-leafed ash, while the hollows feature common alder. The latest tree utilization (probably increment thinning) was carried out in the area in 1991 . By the latest utilization a "bold" control was carried out with extremely poor results according to some opinions. However, in the past 22 years the herb layer has recovered, regrowth has appeared in created openings and currently an older (3–7 m high with a diameter of 5–15 cm), together with a younger (under 1 meter) narrow-leafed ash regrowth layer can be distinguished in patches.

Area 2: This is also a secondary forest with selection system in the buffer zone of the forest reserve. The 65-year-old population consists of the following tree species: narrow-leafed ash (68%), common alder (22%) and grey poplar (10%). The average height of the population is 37 m, its closure is 84%, and the average diameter of the trunks is 34 cm. The site is characterized by fen soil under a permanent water effect.

Area 3: Area 3 is also a secondary forest with a clearcut reproduction system. The 31-year-old population is characterized by narrow-leafed ash (100%) with individual English oaks. The average height of the population is 27 m, while its closure is 86% and the average diameter of the trunks is 20 cm. The site is also characterized by fen soil with a permanent water effect.

Initial conditions

Area 1: As with the main tree species, patches of box elder with older trees (3–7 m high with a diameter of 5–15 cm) and a younger (under 1 m) regrowth layer can be distinguished (Fig. 1). Most of the box elders have appeared on higher places under the narrow-leafed ashes in the forest sub-compartment. There are some individual older box elders (with a diameter of 15–50 cm) and also small patches in the second canopy layer.

Area 2: The previous forest manager thoroughly cut out the box elders with a diameter of 10–20 cm in the second canopy layer during felling. As a result

Fig. 1. Before beginning the treatment box elders formed a dense shrub-layer. (Photo: I. Nagy)

Fig. 2. Some of the mid-sized trees resprouted after the treatment. (Photo: I. Nagy)

of this each tree has been replaced by 10–20 sprouts with a diameter of 2–4 cm and a height of 4–6 cm. These sprouts are too big for spraying and too small for injecting.

Area 3: Under the population some new, continuous, closed and 100% dense box elder patches have developed. The height of the box elder seedlings is between 50 cm and 150 cm and they are 3–15 years old judging from their annual growth rings, while the size of the patches fluctuates between 100–4000 m^2.

Methods used

Area 1: We carried out 3 types of treatments in the area.

1. Manual uprooting of seedlings: It was difficult to find a contractor to carry out the desired treatment, as most deemed the work too hard to perform. We finally found a contractor who made an offer and subsequently carried out the task. The area was inspected in parallel strips and the box elder seedlings were removed. The best period to carry out the task would have been the end of April, as the box elder buds earlier than the narrow-leafed ash and the colour of its leaf is also a brighter green. However, due to tendering administration the work was only started in August. People recognized the trees easily after two hours, and collected the removed seedlings in bundles of 30.

2. Chemical treatment of trees: This was performed on trees too big for manual uprooting.* Treatment was performed at the same time as the previously described treatment. Each team had two men with hand-saws and one performing the chemical control. The staff carrying the hand-saws cut the 2–15 cm wide trees at a height of approx. 50 cm; the certified workman performing the chemical treatment applied a 1:1 mixture of Garlon 4E and fuel oil on the cut surface using a sponge-ended hand device for drop-free delivery. With this method less than two minutes passes between the cutting and the chemical

Fig. 3. The result of chemical treatment – deformed sprouts. (Photo: I. Nagy)

* Attention! Experimental chemical control methods described in this chapter are subject to authorisation! Their practical application requires an emergency permit issued by the pesticide control authorities for the given area and period!

Fig. 4. The controlled and uncontrolled areas are easily distinguishable. (Photo: I. Nagy)

Fig. 5. After the treatment the box elder was almost completely pushed back. (Photo: I. Nagy)

treatment. We used a cutting height of 50 cm so that we could quickly identify those trees requiring post-treatment the following year in the rapidly growing understory.

3. Cut stump method: This method was used to treat large trees and is a long-established treatment in the fight against invasive plants. We cut out the 15–50 cm wide box elders with a chain saw and then quickly wiped the cut surface with a 1:1 mixture of Garlon 4E and fuel oil. The cut-out timber was included in the dead wood stock of the forest.

Area 2: Clumps of sprouts 30–50 cm in height were cut off and the new sprouts treated with a herbicide containing glyphosate (Medallon Premium; 5 l herbicide in 300 l liquid) contained in a backpack sprayer fitted with a special head.

In areas where narrow-leafed ashes appeared together with box elder we tried wiping as well. In this case there is a sponge-ended application device (resembling a stick ending in a sponge) the handle of which is filled up with a glyphosate-based chemical. The chemical is delivered by "prodding" the young box elders with the sponge.

Area 3: Box elder patches were sprayed with a chemical containing glyphosate (Medallon Premium, 5 l chemical in 300 l of water) when the weather was not windy. The young box elders were standing so densely that the treatment did not harm the herb layer suffering from the shade.

Fig. 6. After removing the bigger trees large amount of narrow-leafed ashes regrowth appeared. (Photo: I. Nagy)

Fig. 7. The box elders standing among the patches of narrow leafed ash were wiped as an experiment. (Photo: I. Nagy)

Experiences gained

Area 1: After application of the first method (manual uprooting) there were virtually no seedlings remaining (an estimated 98% effectiveness); after the second method (chemical treatment) some post-treatment was necessary as approximately 20% of the trees had resprouted. Although other specimens resprouted, the sprouts subsequently wilted (Figs 2 & 3). Using the third method (cut stump) only a few larger trees sprouted (most likely more chemical needed to be delivered due to the bigger cut surface). The second and third methods yielded interesting results. Larger box elders had almost completely shaded the ground under them; the herbaceous vegetation beneath was scarce. After removing these bigger trees (Figs 4 & 5) a great number of seedlings appeared in patches under the canopy. 70% of these seedlings were narrow-leafed ash, approximately 10% were alder and some individual indigenous species were present (English oak, European white elm), as well as, unfortunately, approximately 20% box elder (Fig. 6).

Area 2: Spraying clumps of shoots, as described above, seemed to be effective and did not harm the surrounding herb layer (Fig. 7).

Wiping led to the complete eradication of seedlings.

Area 3: The herb layer was not harmed and recovery began the following year. Young trees appeared, such as the seedlings of the narrow-leafed ash (approx. 70%), which received light filtered through the overstory once the box elder was removed, box elder itself (approx. 20%), as well as other hardwood species (approx. 10%), mostly elms (Fig. 8).

Fig. 8. Chemical treatment did not harm the herb layer. (Photo: I. Nagy)

Occurrence and control of common milkweed and false indigo within the territory of the Körös–Maros National Park

Judit Sallainé Kapocsi and Tibor Danyik

Introduction

The Körös–Maros National Park in the South Tiszántúl was formed in 1997 as a result of the merger of nature reserves and natural areas previously declared protected. The national park has a mosaic structure made up of thirteen separate patches that are in many cases situated far from each other. Its territory covers a total of 51.125 hectares, of which 6.419 hectares are strictly protected. There are unfortunately many invasive alien species that can be found in the South Tiszántúl region, and these are spreading exponentially. There have been attempts to stop this spread; these attempts have partly been integrated in the regular nature conservation management activities, whereas others require special intervention.

In Hungary common milkweed (*Asclepias syriaca*) is listed in the classification of invasive plants as being particularly harmful to plants and animals. False indigo (*Amorpha fruticosa*), which first appeared in 1907, also currently covers large areas in Tiszántúl, especially in the flood plains, thus transforming the forest cenosis.

The green zone of a flood plain among neighbouring monocultures provides ample opportunity for the spread, reproduction and migration of a number of species. It seems that these zones provide an effective ecological corridor for "unwanted" alien species, such as the false indigo, green ash (*Fraxinus pennsylvanica*), box elder (*Acer negundo*), wild cucumber (*Echinocystis lobata*) and frost grape (*Vitis vulpina*). In the relevant agricultural areas, there are aggressive adventitious weed types spreading (including common ragweed (*Ambrosia artemisiifolia*), common milkweed and giant goldenrod (*Solidago gigantea*)), which apart from causing management and health problems, are also a great threat in the conservation of still-existing natural cenoses.

This article presents an overview of the characteristics of the common milkweed, which has been spreading at an extraordinary pace in recent years, and the false indigo, which covers a considerable territory, in addition to providing an account of how these two species have spread in the national park and what attempts have been made to control them.

Natural characteristics of the area

The national park lies on a large plain formed from an alluvial fan; rivers have played an important part in forming its natural conditions. These rivers are the Tisza, which borders the area from the west, the Körös river to the north and the Maros on the southern border. Smaller forks and streams have also played a role in forming the area's relief. The area is between 78–105 metres in altitude, from the low flood plains to floodless loess ridges. The area is not completely flat as it is typically interspersed with meander scrolls and the abandoned remains of river beds. The marshlands of Sebes-Körös, Berettyó Nagy-Sárrét and Kis-Sárrét have been significant in forming the scenery. 19th century river control, as well as the draining of swamps, have significantly transformed the landscape, with most of the natural habitats having disappeared. At present most of the area is covered by arable land and secondary salt steppes that were created for the purposes of flood control. Natural vegetation can only be found in fragments here, with only a few hectares of loess grassland remaining at hedges, tumuli and ridges. The area of open salt steppic oak and natural forests stands has significantly decreased. The remaining natural habitats are mostly halophytic, specifically *Artemisia* salt steppes, salt flats ("vakszik"), dens and tall *Puccinellia* swards and salt marshes.

The area is the warmest and driest in Hungary, with an annual average temperature of 11°C and an average annual precipitation of 490–580 mm. The country's best quality chernozem soil can be found here around 90 m above sea level, and this is mostly used as arable land. Over the protected areas along the rivers we can find alluvial soil; meadow soil can be found further from the rivers in the marshy areas, with solonetz alkaline soil in the treated areas (Fig. 1).

Occurrence and control of common milkweed

Initial conditions

The first stands of common milkweed in the South Tiszántúl were found by Éva Kertész in 1987 at the Berettyó dam on the border of Szeghalom next to Békés at the Dán-Fok; since the mid-1990 stands has been noted by a number of other authors.

It was around then that the species first appeared in nature reserves, and it has grown intensively in many other protected areas in the past ten years. Its settlement was most significant in fallows which have been taken out of cultivation in the past few decades. With respect to the ecological needs of common milkweed, it is thought to thrive in less compacted soil such as sand and sand loess. In the South Tiszántúl, however, it also settled in more compacted soil and established stands capable of reproduction. The species can be found on the more consistent soil of loess grasslands, the alluvial soil of floodplains and the clay-like soil of causeways.

The extent of milkweed infestation in the territory of the national park is not homogeneous, rather is it mostly scattered in small patches.

Not typically found on alkali grasslands, the species is strongly present on loess ridges and hedges, while it is practically absent from native forest stands. The species is common in alien forests, clear cut and forest regeneration areas, the mesotrophic wet meadows of flood plains, dams along rivers and in fallows at different stages of grassland recovery. It is more and more common in agricultural areas (especially wheat-growing areas), where it forms larger and more homogenous patches, up to 100 m^2 in size. While its spread has mostly been spontaneous, beekeepers have unfortunately also deliberately spread it as a plant to support honey production. Such activity has been evident in unprotected areas along the Fekete-Körös on the edge of the forests at the foot of the dam, where ripe fruits were also scattered under the tree stands in order to artificially spread the species. Its fruits are also used by florists and at one times bags of excess fruit and seeds were scattered over the protected areas of the Kígyós plain.

The areas most affected are the alien forest stands (*Populus × euramericana*), clear cutting areas, arable fallows, cart-tracks and flood prevention banks.

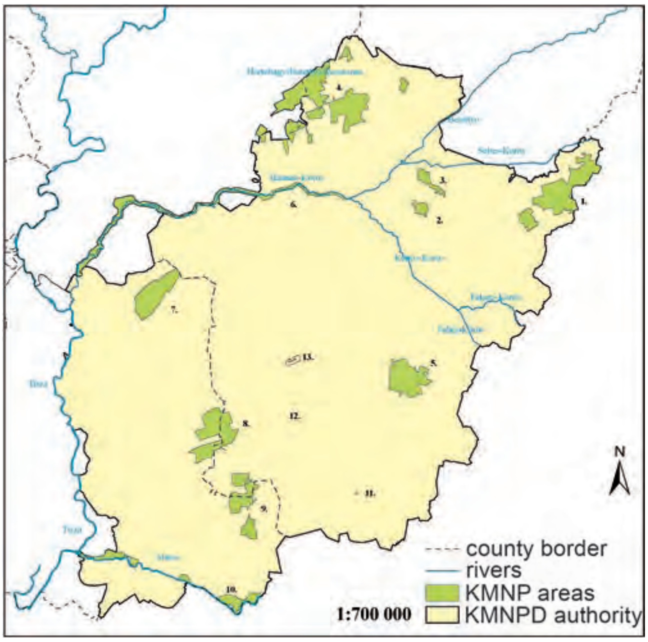

Fig. 1. Parts of the Körös–Maros National Park: 1. Kis Sárrét, 2. Bélmegyer Fás plain, 3. Mágor plain, 4. Dévaványa-Ecseg plains, 5. Kígyós plain, 6. Körös flood plain, 7. Cserebökény, 8. Kardoskút Fehértó Lake, 9. Csanád plains, 10. Maros flood plain, 11. Tompapuszta loess grassland, 12. Tatársánc natural grassland, 13. Csorvási loess grassland.

Fig. 2. Common milkweed spreads in many parts of the Maros flood plain's fen meadows. (Photo: J. Sallainé Kapocsi)

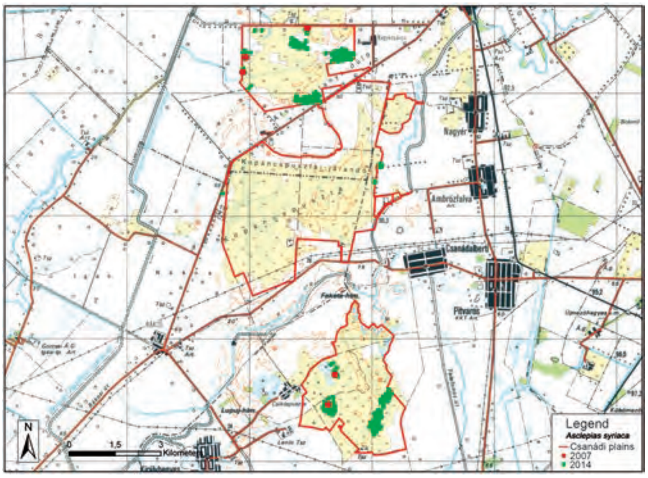

Fig. 3. Changes in common milkweed infestation in the Csanád plains in 2007 and 2014. (data from L. Kotymán and G. Balogh)

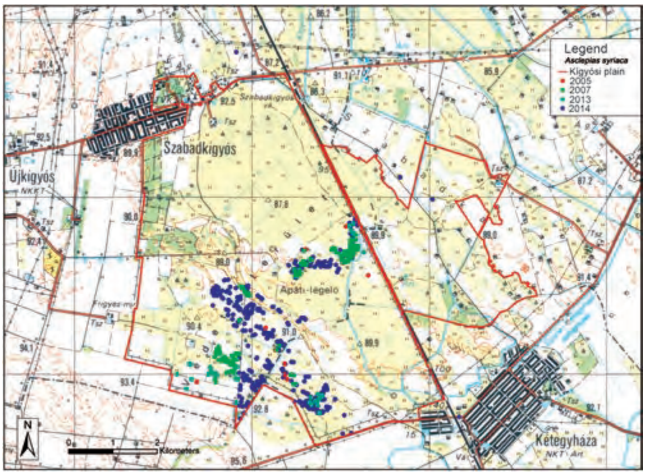

Fig. 4. Changes in common milkweed infestation in the arable fallows of Kígyós plain between 2005 and 2014. (data from B. Forgach and G. Boldog)

In these areas common milkweed can be found in a number of completely homogenous patches of hundreds of square metres in size. Smaller patches can also be found in flood plain fen meadows and Alopecurus pratensis salt meadows; almost all grassland patches are affected along the rivers (Fig. 2).

According to a survey conducted in the Körös flood plain in 2007, the species was present in Gyomaendrőd, Öcsöd, Nagytőke, as well as on the borders of Kunszentmárton, Mesterszállás, Mezőtúr, Szelevény and Tiszaföldvár, and at a number of places along the dams. In the Maros flood plain the infestation started towards the end of the 1990s, first in the Makó embayment, then in the Verebes's flood plain between 1997–98, where the number of individuals had reached around 100 by 2010 (data by P. Paulovics). The species appeared in masses after the floods of 2006, and by 2007 the whole flood plain could be regarded as infested. It can be found in large quantities under hybrid poplars, fallows, under dams, as well as more recently in natural and secondary grasslands. Its large-scale spread started after the 2010 floods and by 2014 the size of the infested area was over 300 ha. Control management action has to be performed here in cooperation with the neighbouring landowners given that the risk of re-infestation from areas not belonging to the national park property management can be quite high. Infestation on the Kardoskúti Fehértó unit started in 2000 from the middle of the plain; specifically, an arable land bordering Székkutas with the plot number 0259/12, which was an alfalfa field with a lot of open soil surface (due to the low germination percentage of the seeds). From here, nearby fallows were infested. The plant is only present in fallows up to 15 years in age; it is also present in stubble-fields, while its presence is insignificant on natural grasslands and older fallows. According to a survey conducted in 2007 the plant was found at seven locations on fallow lands (registered as arable land), whereas in 2014 the density of the stand was as large as 4200–4500 individuals in 41 spots. The first specimen in the Csanád plains was found on the Királyhegyes plain on the fallow next to the Liliomos marsh; however, it could not spread significantly on natural grasslands due to the low ratio of fallows to ploughed land. The Kopáncs and Királyhegyes plains were infested especially in the fallow areas: the density is estimated at 1500 pieces in 2013 in the two areas. In 2014 there was a detailed survey conducted in the whole protected area and this revealed that the species occurred at 446 places, with the density rate ranging from a single individual to 20–25 individuals/m2 in densely covered areas (Fig. 3). The first groups in the Kígyós plain were detected in 1998 along the rail tracks (data from B. Forgách). The first detailed survey was conducted in 2005 when the plant was present at twelve locations, most of which were only one-shoot plants with only one instance of an 8–10 m^2 patch on a fallow ploughed field. The occurrence had increased to as much as 175 instances on fallow plough lands by 2007, in which year the plants were effectively controlled by chemical treatment. Alongside the sites identified in 2007, the plant appeared on a further 47 places in 2013, in 2–3 m^2 patches exclusively in fallows on non-cultivated arable land. Plants were recorded in 441 patches in 2014, many of which were single individuals (Fig. 4). According to a 2007 survey of the Dévaványa–Ecseg plains, the plant occurred in two locations, while further surveys found five known places of occurrence on protected areas by 2013 (with 4–8 shoots per patch). However, since the protected area is made up of smaller mosaics, there is a constant threat of re-infestation from the non-protected areas. Unfortunately by 2014, it had appeared in many new places; for example, at the bottom of the dried-out lakebeds next to Hortobágy–Berettyó and in larger patches in fallow areas.

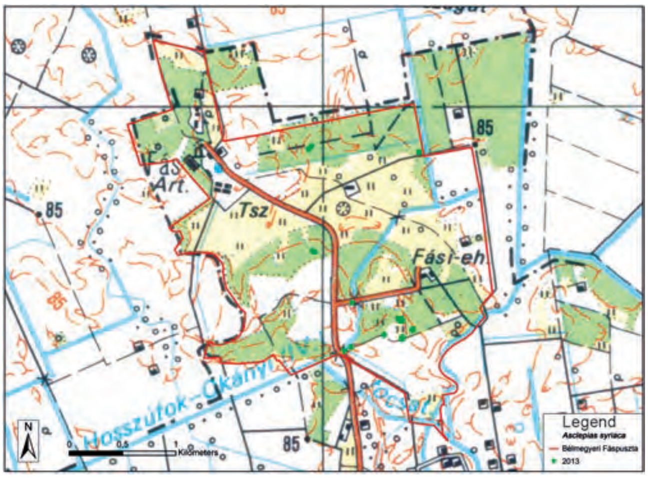

Fig. 5. Common milkweed infestation on the Bélmegyer Fáspuszta in 2013 only occurred in clear cut areas and oak reforestations

The plant was evident at 18 places on the Bélmegyer Fáspuszta in 2013, exclusively in clear cut areas and oak reforestations, which are smaller patches of 1–20 m^2. By 2013 the plant covered a total area of 140 m^2 (Fig. 5). These patches are usually present where the soil is more sandy and loose along former riverbeds. Common milkweed reached a height of 1.5 m in clear cut areas. The area with the least infestation is Cserebökény, where the plant has been present since 2010 at a few points in areas of a few m^2.

On the Kis-Sárrét unit in north-eastern part of the operational area, there was only one known patch of the plant in the area protected since 2007, together with three patches in the non-protected area in hybrid poplar plantations, sand gardens and arable fallow lands.

Methods used

The goal of the treatment is the conservation of natural plant communities and the control of the further spread of common milkweed in the protected areas. Treatment of the plants were carried out using mechanical and chemical methods in areas belonging to the property management of the national park*.

Mechanical treatment, which is less effective, must be used in areas which are part of the Agri-Environment Scheme (AKG) or are organic farms, since the use of chemicals is forbidden here. Mechanical treatment before blooming prevents seed maturation and spreading. This means the removal of the flower from each stand. One treatment per year is not enough, however, because the plant reacts with a secondary blooming. This method is difficult to apply in the case of larger patches since it is highly time consuming. In these large areas treated by mechanical methods mowing is the common practice in order to prevent blooming. To avoid re-growth of the patch in subsequent years, mowing must be done at least twice a year.

In the case of the AKG scheme the authorisation of chemicals for the control of invasive species would be justified. Chemical control is an effective method and was was carried out in the national park areas, as described below. On the Csanád plains chemical treatment was used in a few cases starting in 2005, and in all cases in 2011. At first a 10% solution of Glialka was used, which later proved to be too concentrated. A reagent called Gladiator was applied from 2011 at a concentration of 2–5%. 281 out of 446 patches in the Csanád plain received mechanical treatment, while chemical treatment was carried out in 165 locations.

In the area of the Kardoskúti Fehértó we tried to eradicate the plant by hoeing and manual uprooting in 2003; unfortunately, this proved to be ineffective. Later we tried flail mowing and selective mowing, as well as end-of-summer and autumn secondary mowing: these also proved ineffective. The shoots grew as a result of the mechanical treatment. Chemical treatment has become regular since 2004 using Medallon Premium and Glialka 480 Plus herbicide and spraying. The first treatment of the Kígyós plain was carried out in 2005 with Medallon Premium and Glialka 480 Plus using a 5% solution and manual spraying. Uneven results were obtained, meaning that the stand dried out in places while in others it survived. In 2007 common milkweed was present at 175 locations on arable fallows; these were successfully controlled with chemical treatment. In 2014 another treatment was carried out, partly mechanically and partly chemically. In the Bélmegyer Fáspuszta area and Kis-Sárrét chemical treatment was carried out in all stands in 2014 (Figs 6 & 7).

Chemical treatment may be carried out if authorised by a permit issued by the authorities. The method included first spot spraying in May, at the beginning of summer when the leaves of common milkweed are young (4–6 leaves phase). The sap flow is

Fig. 6. Chemical treatment of common milkweed on the Bélmegyer Fáspuszta in a young oak reforestation. (Photo: B. Forgách)

*Attention! Experimental chemical control methods described in this chapter are subject to authorisation! Their practical application requires an emergency permit issued by the pesticide control authorities for the given area and period!

typically intensive in this phase and the young leaves have thin cuticles. When the plants reach 30–40 cm in height, the surface of the leaves is sufficiently large in order to absorb an optimal amount of chemical, while the weather conditions are also favourable. Later in August or September another round of spraying is needed. Sap flow toward the roots is stronger then, and this helps transport the reagent; there is no possibility for the plant to sprout following treatment due to the coming winter. With the plant being weaker due to previous treatments, conservation is more intensive as weather conditions are more favourable for absorption and transport. Weather conditions play an important role in the effectiveness of chemical treatment. This is due to the physiology of the plant as well as the absorption of the reagent. It can generally be concluded that the conditions ideal for the treatment are the following:

– Fine weather (without rain), as the absorption of the reagent could take as long as seven hours, though this can be shortened with the help of cohesion enhancing chemicals, in which case three hours may be enough for the absorption of an efficient amount of reagent.
– Strong sun is not ideal since strong UV radiation can reduce the effectiveness of the reagent (before the absorption through the leaves).
– Humid (but not saturated) air helps the transportation of the absorbed reagent. In warm and dry weather the leaves' stomata close and respiration is reduced to prevent drying out. Circulation is slower as a result, which in turn slows down the circulation of the reagent and absorption is less effective.

The optimal treatment time is during warm and humid mornings. A manual sprayer as opposed to a backpack sprayer is ideal because spraying can be done with lower pressure and more accurately, thus avoiding drifting onto surrounding plants. The ratio of the solution sprayed in 2014 was the following: 20 litres of water with 1 litre of Medallon Premium (5% solution), 500 g of ammonium nitrate (reagent enhancing cohesion) and 4 decilitres of Hyspray (a reagent enhancing absorption). In some areas, due to different degrees of infestation, a varying amount of chemical and work was needed.

A follow-up survey of the treatment revealed:

– The herbicide is too concentrated if the plant dries out within a week (changes its colour to brown), in which cases only the parts above the ground are destroyed, while the reproductive root is only slightly damaged;
– The herbicide is too dilute if the plant's leaves partly turn yellow and while some leaves fall, the bare stem remains green;
– If the amount of the reagent is optimal in the herbicide, the plant will start turning yellow within 7–14 days, with all of its leaves falling and its stem drying out as well (according to the observations of Tibor Danyik).

Rangers recorded the size of the treated patches by collecting the following data: X EOV, Y EOV coordinates, the size of the patch in m^2, the date, the

Fig. 7. Offshoots reappeared on common milkweed (Csanád plains) even after chemical treatment. (Photo: J. Sallainé Kapocsi)

name of the person recording the data, as well as the method and time of the treatment.

Experiences gained

Chemical treatment did not prove effective in every case and was more successful in the case of smaller patches and plants with only a couple of shoots. Larger stool groups were harder to eliminate because the plant sprouted again in many cases with stronger and more extensive parts both under and above ground. These patches must be retreated yearly. Years with more precipitation, like the summer of 2014, were less successful regarding the treatment because in many cases the precipitation washed the herbicide off the plants and made it more dilute, thus reducing its effectiveness. Unfortunately, eradication confined to protected areas is insufficient since common milkweed is present in more and more significant quantities in non-protected areas, ensuring constant seed supply in protected areas. Abandoned arable lands on the loess grassland regions are sufficiently supplied with nutrition and thus stools settling in such places are more viable and more difficult to control. The plant can be controlled temporarily by grazing and mowing. Optimally timed mowing prevents blooming, while grazing animals trampling on the plant hinder its growth. Management actions are continuously needed in order to keep the status quo; this state can only be improved by more extensive workforce, better logistics and more funds.

The spread and control of false indigo

The mass spread of false indigo is partly due to the changes in traditional flood plain agriculture. Following the collapse of communism the flood plain's arable lands were abandoned and there was a significant decrease in grazing livestock, as a consequence of which false indigo spread further, covering any areas it found suitable for growing. In the course of just a few years its impenetrable shrubs formed a sort of "green ecological desert" in the flood plains. The spread of false indigo and other invasive species caused a problem in abandoned arable lands as well as forests, especially in those with a more open canopy. The management of the Körös-Maros National Park have been trying since its establishment to control the stands of invasive woody species, mostly through mechanical methods. The size of false indigo shrubs has shrunk from year to year. However, the greatest challenge is the recycling of these areas, since this provides the ultimate solution for control. In terms of nature conservation, the most favourable solution is reforestation or a grazing treatment of these areas as well as turning suitable area into hayfields.

Due to its strong sprouting ability, control of the plant is difficult. Flail mowing is used in areas that have been completely covered with the plant; these areas can then be maintained by mowing twice a year, alongside grazing. However, manual treatment has to be applied to areas by the edges of forests and channels because these are more difficult to access. Chemical treatment in flood plains eradicates invasive plant stands only temporarily since floods can bring constantly regenerating seed supplies from upstream.

Initial conditions

Regarding the South Tiszántúl, Rezső Soó's book titled *The Flora of Tiszántúl* published data on the false indigo from 1938 in the area of Sarkad (Soó 1938). It is later mentioned in connection with several parts of Békés county with sporadic frequency. In Tóth's research report on the Hármas-Körös's flood plain a number of methods concerning the control of false indigo are mentioned (Tóth *et al.* 1996).

The infestation in the South Tiszántúl is not a new phenomenon: the species has been present alongside rivers, channels and streamlets for a long time. Infestation is the most severe along the Tisza, Maros, Hármas-Körös, Berettyó, Hortobágy–Berettyó, Sebes-Körös, Kettős-Körös, Fekete- and Fehér-Körös rivers and smaller streams such as the Kurca, Kórógy, Veker and Száraz-ér. It is common in willow-poplar floodplain forests, hybrid poplar plantations and hardwood gallery forests and their edges, as well as the edges of abandoned arable lands, dirt roads and shrub patches planted as a shelter for wild game in the steppe environment on the Csanád plains.

The habitats of willow-poplar floodplain forests were reforested with different poplar and willow hybrids following final cutting. These areas provide an excellent habitat for the false indigo, especially in the shrub patches, due to their looser canopy structure. The areas most infested in the national park can also be found along the rivers, such as the flood plains of the Körös, Hármas-Körös, Maros, on the Dévaványa–Ecseg plains, as well as areas along Hortobágy–Berettyó. During floods the seeds of the false indigo also easily spread to grasslands and fallows in larger quantities with the help of the mud and alluvium cover. On the flood control dams, for example on the Körös flood plain after the 2006 floods, the spread of the false indigo became even more significant due to heavy propagule source deposit.

Infestation covered 50–80 ha on the grasslands of the Maros flood plain in the Makó and Bökény embayments in 2005. Stands are present in areas without more significant rivers as well, more specifically along the smaller watercourses in the Kis-Sárrét:

Korhány, Toprongyos, Holt-Sebes-Körös; in the marsh remnants, for example the fen meadows next to the Ugra meadow; as well as on the edge of the Vátyon forests.

The presence of false indigo is significant in Cserebökény in the plains, along artificial channels and ditches crossing the grasslands, as well as around natural watercourses, for example the Veker.

In the hedges alongside the railway tracks across the Kígyós plain the spread of stands pose problems; it appears in a larger patch in the Nagyerdő of Szabadkígyós and in a smaller patch in the shooting range of Kétegyháza.

False indigo be found at a few places bordering the channel on the Fáspuszta of Bélmegyer, though it has not been spotted in the Kardoskúti Fehértó area. A smaller stand can be found in the middle of the Csanád plains, in the eastern part of the Montág plain, which spread to the loess grassland in the 1990s after the neighbouring reforestation. The species has appeared in a number of alleys and forest belts. Here, fortunately, its weak stands are easily controlled by grazing.

Four km of protected area of the Dévaványa–Ecseg plains along the Hortobágy–Berettyó became infested in 2004 and 2005. Such extensive spread had not previously been recorded. The presence of the plant along the Hortobágy–Berettyó could be described as massive by 2007. It was controlled in the grasslands along the river by regular mowing, while stable stands were left along the unmowed banks. There are considerable stands in the ditches along the dirt roads of the Csordajárás area of Dévaványa, but it can only be found sporadically in smaller channels over protected areas.

Methods used

In the Körös–Maros National Park an important part of nature conservation is the control of the false indigo, which is a time consuming annual process that requires considerable financial resources.

Flail mowing, mowing and manual eradication

In the areas most infested with false indigo, which are mostly flood plain grasslands, the 2–3-m-tall and dense false indigo shrubs are first treated by flail mowing. The 1-m-tall false indigo stands sprouting following the first treatment were either retreated or mowed. Dense and tall false indigo stands were removed over 120 ha of unused area under the asset management of the national park in 2004. In the areas leased, flail mowing is the responsibility of the tenant, according to the contract. In 2007 intervention against false indigo was carried out over 60 ha in the Körös flood plain, specifically along the edges of the backwaters of Gyigerzug and Álomzug. False indigo eradication by the public workers of the national park was carried out in 2008 in the area of the Gyigerzug and Özénzug backwaters, as well as in Álomzug. In 2010 the national park performed thinning of the species with the help of the public workers of the local government of Gyomaendrőd. The workers of the water directorates have made headway in eradicating the invasive false indigo since 2011 in the 10-metre strip in front of the dam. These manual interventions often involve the use of beams, the positive effects of which were shown by the mass appearance of the summer snowflake (*Leucojum aestivum*) in the Gyomaendrőd region in the following year. In 2006 manual interventions took place over 2 ha in the Vátyon forest in Kis-Sárrét. Flail mowing of false indigo was also carried out in the swamp remnants of the Ugar meadow: over 10 ha in 2010 and 14 ha in 2014.

Public workers cleared a 1.4-km-long strip manually in the hedges along the rail tracks of the Kígyós plain in 2013, starting from the sluice of the stream. South of this area, towards Kétegyháza, a considerable amount of false indigo can be found along a 1.5 km strip.

Introducing grey cattle grazing in the areas of the Körös and Maros flood plains

Körös flood plain: Following the collapse of communism the amount of livestock fell, and this resulted in the significant spread of false indigo, with the development of dense and tall stands. Grazing was continued in some areas of the Körös flood plain, but private farmers had cattle grazing over only a fraction of the previously grazed land. From 2002 a herd of cattle belonging to a private farmer grazed the false indigo stands in Mezőtúr. At the beginning of summer in 2008 a herd of privately-owned Hungarian simmental cattle, with 120 head of cattle, started grazing the most infested areas. The scale of grazing in false indigo-infested grasslands by private farming increased in 2009: a Hungarian simmental cattle herd in Iriszló (Szelevény) following mowing in autumn, a 100-head grey cattle herd in Gyigérzug (Kunszentmárton), a Hungarian simmental, grey cattle, buffalo and goat herd in Békésszentandrás, and a herd of Hungarian simmental in Gyomaendrőd. The Hungarian simmental cattle grazes just as well as the grey cattle on the fresh sprouts of the false indigo following flail mowing. However, in older stands they only chew off the leaves of plants at first.

The herd belonging to the management of the national park, numbering 80 grey cattle, first started grazing the Álomzuhatag of Öcsöd in 2009, with an electric fence method (Figs 8 & 9).

The animals grazed from 2 July until 22 September. In the area of Álomzug we can find aged willow gallery forests within the fen meadow of the floodplain, with non-tussock tall sedge beds under these, as well as native white and black poplars, hybrid poplars and fallows. Infestation was most significant in the fallows, though it has been reduced by years of grazing and flail

Fig. 8. The treatment of false indigo with the help of grey cattle in the Álomzug of Öcsöd in the Körös flood plain. (Photo: J. Sallainé Kapocsi)

Fig. 9. Grey cattle grazing with the help of electric fence in part of Öcsöd's Álomzug infested with false indigo (grazed area on the right and untreated area on the left). (Photo: J. Sallainé Kapocsi)

mowing. In 2011 from 16 July until October, a 100-head cattle herd belonging to the directorate grazed in the same area, while in 2013 80 cattle grazed over 80 ha of land for 4 months. Another herd was deployed by the management in 2014 to the area by the ferry of Mezőtúr, where they grazed from 13 May to 13 July, while 100 3–4-year-old steers grazed in Álomzug from13 June until the end of October (Table 1).

On the area of the Maros floodplain: The grey cattle herd of the national park first grazed the Maros floodplain in 2009 in those areas belonging to the national park in the Bökény embayment and in Magyarcsanád. Due to years of continued grazing, false indigo has been significantly reduced, being a well-liked feed for grey cattle. Grazing partly starts at the beginning of May but the chosen calves are only taken to the area in July. This year's grazing is expected to go on until the end of November over an area of 156 ha (Table 2). Shrubs sprouting after grazing will undergo flail mowing under dry soil conditions, as this delays later sprouting.

The treatment of the Körös flood plain including the clearing up of the elevated channel tracks

During the tender period for the EEOP (Environment and Energy Operational Programme) elevated channels in the areas of the Körös, the Iriszló and the Brenazug (Kuunszentmárton, Szelevény), built in the 1970s, were dismantled. Along these channels, flail mowing and mowing of the false indigo was not an option due to the surface conditions. The aim, therefore, became the elimination of these disused channels. The redundant channels and ditches were successfully cleared in 2011 along a 70 km-long area.

Replacing the hybrid poplar stands with native forests

Due to their open canopy, there is a lot of light under hybrid poplar stands, and here the false indigo is able to form a homogeneous shrub layer (Fig. 10).

Table 1. Data regarding grey cattle grazing in the Körös flood plain between 2009 and 2014.

Area	Year	Period (m.d.)	Number of animals	Size of the area grazed (ha)
Álomzug (Öcsöd)	2009	07.02.–09.22.	80	80
Álomzug (Öcsöd)	2011	06.16.–10.05.	100	80
Álomzug (Öcsöd)	2013	06.23.–10.24.	70	80
Álomzug (Öcsöd)	2014	06.13.–10.30.	100 head of 3–4-year-old steers	80
By the ferry of Mezőtúr (Mezőtúr)	2014	05.13.–07.03.	40 head of 4-year-old steers	25

Table 2. The number of grazing animals in the flood plain of Maros between 2009–2014.

Grazing animals	2009	2010	2011	2012	2013	2014
Hungarian simmental cattle	123	145	58	173	158	250
Grey cattle, belonging to the Körös Maros National Park	130	86	108	214	286	343
Horse	0	4	5	0	5	0
Donkey	1	0	0	0	0	0
Sheep	70	130	83	106	98	0
Goat	12	0	0	0	0	0

Fig. 10. Under the open canopy of the hybrid poplars a homogenous false indigo shrub is able to form (Körös flood plain). (Photo: J. Sallainé Kapocsi)

However, if the hybrid poplars are replaced with native stands, e.g. white or black poplars, which are sufficiently closed, the false indigo is forced out of the multi-level forest due to the lack of light and will only survive on the edge.

The management of the national park started the replacement of hybrid poplars with native forests, black and grey poplars, English oaks and Hungarian ashes in 1996 in the areas of the Maros and Körös flood plains (Fig. 11). This replacement with native species was performed over 210.57 ha of the Körös flood plain and 269.79 ha of the Maros flood plain between 1996 and 2013. An annual breakdown of recent years can be seen in Table 3.

Table 3. The size of the native forests planted by the national park directorate in the Maros and the Körös floodplains between 1996 and 2013.

Year of reforestation	Körös floodplain (ha)	Maros floodplain (ha)	Total (ha)
1996	10.19	0.00	10.19
1997	8.48	0.00	8.48
1998	15.7	3.96	19.66
1999	1.38	1.03	2.41
2000	12.50	15.19	27.69
2001	18.85	12.10	30.95
2002	2.19	0.00	2.19
2003	5.99	36.66	42.65
2004	17.49	12.95	30.44
2005	17.85	16.25	34.10
2006	36.30	30.74	67.04
2007	2.80	33.54	36.34
2008	5.35	44.13	49.48
2009	21.74	3.00	24.74
2010	0.00	22.00	22.00
2011	16.31	0.00	16.31
2012	2.52	15.18	17.70
2013	14.93	23.06	37.99
Together	210.57	269.79	480.36

Permits for firewood collection in the false indigo shrubs of the Körös floodplain

Several settlements requested the directorate for permits to collect and cut false indigo around a number of settlements along the Hármas-Körös, starting in the autumn of 2011. The directorate issued individual permits, mostly to residents of Gyomaendrőd and Kunszentmárton, to satisfy firewood needs and control invasive species. A few requests were also submitted from Szarvas, Békésszentandrás and Öcsöd.

72 permits were issued authorising the clearing of false indigo, most notably in Gyomaendrőd and to a lesser extent in Kunszentmárton, Öcsöd and Mezőtúr. In 2013 the number of permits exceeded 100.

In the course of false indigo collection, the shrubs are manually removed and tied in a sheaf before being taken away, while taking extra care of the native tree populations. These interventions concern the false indigo shrubs by the embankment under native and non-native forests and other stands, as well as in pits that are difficult to access by mechanical means. Several summer snowflake (*Leucojum aestivum*) stands appeared in place of the cleared false indigo by the embankments, while in one instance a lily of the valley (*Convallaria majalis*) population was detected in 2014, this species being previously unknown to the Körös floodplain.

Experiences gained

The condition of the grasslands can be maintained and even improved to some degree by grazing, mowing and flail mowing. The false indigo stands have been significantly reduced in areas treated by grazing, and that it cannot grow back quickly, the young sprouts are easily grazed by animals in the following year. Thanks to grazing and flail mowing, the large,

Fig. 11. By replacing hybrid poplars to native forests the false indigo is forced out of the habitat due to the lack of light (Maros floodplain). (Photo: J. Sallainé Kapocsi)

dense false indigo shrubs are being gradually converted into grassland, with the remaining false indigo plants getting gradually smaller and less dense. Several of these newly-converted grasslands were able to be mowed by 2014. Canopy closure has been increased by replacing alien species with native forests, the areas with favourable light conditions for the false indigo are decreasing, which in turn reduces their coverage. The filling up of unused channels has enabled mowing of these grasslands. Here false indigo stands that supply seeds have disappeared. Manual intervention, flail mowing and grazing will be successful when repeated every year.

Summary

The first individuals of common milkweed appeared in the Körös-Maros National Park in the mid-1990s. There were comprehensive surveys addressing the infestation of the protected areas in 2007 and 2013. In the national park chemical and mechanical treatments have been ongoing since 2006, the latter in areas belonging to the Agri-Environment Scheme (AKG) in addition to organic farming areas. Chemical treatment is the only effective method, and this will be applied comprehensively from the beginning of this year in the protected areas under the asset management of the national park.

The directorate conducts different treatment methods for controlling the false indigo stands, such as manual intervention, flail mowing and grazing by grey cattle. Unfortunately, a continued intervention is needed in the case of this species, from expensive mechanical flail mowing to grazing. Moreover, floods covering the area every 5–10 years replant the seeds of the false indigo, thus re-infesting natural habitats as well as treated areas.

It must be emphasised that in the case of both invasive species, yearly intervention is needed, since skipping a year provides both species with the opportunity to spread, with the result that their subsequent control will be far more time consuming and costly.

Acknowledgements

We would like to thank the staff of the Körös–Maros national park directorate, in particular the members of the ranger service who took active part in the survey as well as the eradication treatments.

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Transforming false indigo-infested areas into grasslands

Viktória Siposs

Natural characteristics of the area

The activities were conducted over five sample areas, comprising grasslands and abandoned arable land, on the floodplains of the Hármas-Körös and the Middle-Tisza.

The floodplain of the Hármas-Körös:

Gyomaendrőd region: 120 hectares including areas in different conditions.

The floodplain of the Tisza:

Nagykörű region: 40 hectares with 5–6-m-tall false indigo (*Amorpha fruticosa*) at the start of the project.

Tiszajenő region, Nagy-rét: 210 hectares of grassland, which was exploited by mowing and subsequent grazing. The area was surrounded by 3–4-m-tall false indigo, which had caused the grassland to shrink year by year.

Tiszakürt region, Szigetmajor: 44 hectares, of which 32 were mowed with the exception of the tussock community and the edges, resulting in the continuous spread of false indigo. The other 12 hectares were of poor quality floodplain plantations containing less than 50% closure of *Populus* × *euramericana*. The *Populus* × *euramericana* forest was converted into grassland.

Tiszaalpár and Bokros region, Alpár-Bokros embayment: 600 hectares of mostly abandoned arable land, with the whole area being heavily infested with false indigo (Fig. 1).

The river floods up to four or five times a year, and at least once over the treated areas. The floodwater covers the area for 3–5 weeks on average.

The altitude across the areas varies by around 1–2 m. Due to the altitude and micro-relief conditions, there are endorheic patches with higher water-retention capacity, and areas that are covered by water even after smaller floods. As the areas differ in characteristics and in vegetation, the effectiveness of controlling the false indigo also varies.

Fig. 1. Cattle being herded into their winter quarters in the autumn. At certain arts traffic had to be stopped by the police (the Tiszaug-bridge on route 44). (Photo: V. Siposs)

Initial conditions

The treated areas were previously used as pastures or arable land on which the false indigo spread to varying degrees due to changes in land utilisation.

Management actions were performed over several different sample areas. These sample areas can be divided into the following categories based on their characteristics and the degree of false indigo infestation. (To determine the extent of the infestation, the population density of the false indigo and the height of the specimens were taken into consideration.)

A: Recently abandoned grassland with a maximum of waist-height 1–2-year-old false indigo specimens connected by cohesive grassland (Fig. 2).

B: Grassland abandoned years ago on which the false indigo is present in dense populations with specimens reaching 2–3 metres in height and connected by patches of grassland.

C: Abandoned grassland or arable land characterised by an absence of herbaceous vegetation with a dense false indigo population with 4–6-m specimens (Fig. 3).

Methods used

Treatment consisted of the combined methods of forestry mulching/flail mowing and grazing.

Grey cattle grazed on the leaves and the young, still soft shoots, while at the same time trampling on, scratching or rubbing against older stems. Over areas where the false indigo was dense with strong stems and the interspersed grassland was minimal or non-existent (categories B and C), grazing was carried out only after forestry mulching.

Fig. 2. Mildly infested area in the first year of grazing. Where there are patches of grass, the cattle graze alternately, which is why the herd must not be removed until the cattle graze false indigo leafless. The Hármas-Körös floodplain, Gyomaendrőd, November 2005. (Photo: V. Siposs)

Fig. 3. Highly infested area after forestry mulching. The Hármas-Körös floodplain, Gyomaendrőd, November 2005. (Photo: V. Siposs)

Flail mowing-forestry mulching

Mulching had to be repeated annually, which was performed during the autumn and winter periods, as in our experience this process is most effective during frost. A singular mulching treatment was also conducted during the vegetation period in highly infested areas. We also used the forestry mulcher over relatively clear areas as a way of maintenance mowing.

The choice of mulcher machine depended on the strength of the false indigo stems: a flail mower (used for corn stalks) proved sufficient for populations of woody yearlings, while the older populations necessitated the use of a forestry mulcher (with chainsaw or hammers). 4–6-m-tall false indigo brushes with around 10-cm-diameter stems were cut by a Stihl FS 400 and 450 clearing saw (using brush cutters and circular saw blades) (Fig. 4).

Fig. 4. Mulching also weakens the plant by opening it up to frost and infections. The Hármas-Körös floodplain, Gyomaendrőd, November 2005. (Photo: V. Siposs)

Grazing

The areas were grazed by a cattle herd in cells (a process of managed rotational grazing). The degree of infestation by false indigo determined the intensity of browsing and trampling required; parameters included the number of head of cattle per unit grazing area and the period of grazing. These parameters were not devised or evaluated scientifically; rather we relied on visual observations of the effectiveness of grazing in eliminating false indigo.

The size of the grazing area was chosen so that the herd would graze all the false indigo leaves over a period of 6–8 days. Electric fences were used in order to prevent the herd moving out of the grazing area until it was fully grazed. The herd grazed a given territory 3–5 times during one vegetation period, with a gap of approximately 3–4 weeks before the cattle returned to the same area, this time being sufficient for the false indigo to resprout and grow to provide enough green mass for further grazing. The number of head of cattle was different in the sample areas. The smallest herd included 50–60 adults, while the largest numbered 400 cows with their calves.

The goal of the method is to completely deplete the false indigo stems, as well as to increase the populations of grassland species over the area by opening up the land and eliminating rivals.

The electric fence used was tightly pulled 2 mm gauge double steel wire with high-voltage in order to deter the cattle from crossing.

Experiences gained

The category “A” land was successfully transformed into grassland over 2–3 years. From that point on the area was grazed according to the traditions of “normal” grazing and not to the point at which all leaves were removed, which means that the same number of cattle was dispersed over a larger area. Maintenance mowing or mulching was conducted after the grazing periods depending on stem thickness. Mulching was necessary for 2–3 years following the start of grazing due to resprouting, after which the false indigo stems were completely depleted and only water-borne seed-grown plants appeared, but these were effectively treated by grazing and mowing (Fig. 5).

The category “B” land was successfully converted into grassland after about 4–5 years. Forestry mulching was of particular significance in this case.

The category “C” land was similar to category “B”, but mulching proved more difficult; specifically, the area was densely covered by mulch where it was accumulated by flooding or wind. The clearing saw proved more effective in terms of the utilisation (sale) of the cut material, as it could be removed in bundles and utilised as an energy resource. The grassland was developed at basically the same pace as with the category “B” land.

The flooding of the river greatly influenced the effectiveness of the treatment in the case of categories “B” and “C”. In low altitude areas where stagnant waters remain for longer periods, the vegetation typically consists of species that can tolerate such conditions. A grassland developed over 2–4 years through systematic grazing and mulching may be changed in character in the event of a long-lasting flood, since it allows species-poor vegetation that can tolerate the compacted, damp soil and the stagnant waters to become re-established (species such as purple loosestrife (*Lythrum salicaria*), garden loosestrife (*Lysimachia vulgaris*), prickly burweed (*Xanthium*

Fig. 5. Highly infested area at the beginning of treatment (on the left, in November 2005) and after the 3-year grazing and winter mulching (on the right, June 2008). The species typical of meadow foxtail grasslands have appeared; the area is mowable. The shoots of the remaining false indigo are only one year old due to regular mowing. Flail mowing is no longer needed. The Hármas-Körös floodplain, Gyomaendrőd. (Photo: V. Siposs)

spinosum), while willow (*Salix alba*), autumn ox-eye (*Chrysanthemum serotinum*, protected), sea clubrush (*Bolboschoenus maritimus*), march mallow (*Althaea officinalis*), sorrels (*Rumex* spp.), and liquorice (*Glycyrrhiza glabra*). These areas, however, can also be utilised: grazing by grey cattle and water buffalo is a tested method, although it requires more organisation and planning on the part of the farmer due to the more compacted soil, the mud and the poorer yield of the area. However, it offers a great benefit to society as it keeps these areas clear from false indigo and other invasive species. Moreover, it is favourable from a flood protection point of view because it reduces roughness. For these reasons this activity is eligible for compensation and agricultural subsidies. If grazing is not feasible for some reason over areas with similar characteristics, it is advisable to consider the rehabilitation of natural floodplain forests, either artificially or based on natural regrowth.

False indigo control with this method started approximately ten years ago and continues to this day. Cohesive grasslands have been developed over the majority of the areas, which means that false indigo control activities have been replaced by traditional land utilisation methods. The above-mentioned low-altitude areas with stagnant waters will presumably never develop rich yielding, mowable grasslands that can be utilised for hay production, but they can be used for grazing, which also prevents the spread of false indigo.

Hungarian data on the sensitivity of tree of heaven seedlings to herbicides

Roland Szabó

Tree of heaven (*Ailanthus altissima*) is a woody neophyte originally from Southeast China and North Vietnam. In some biotopes, this species is very invasive and aggressive; it colonises territories in Hungary, rendering them into homogeneous tree of heaven forests. Due to its advanced adaptability, it is able to claim very extreme habitats: it is a perfect example of a "gap plant" (Figs 1 & 2). The species requires lots of sunshine, but at a young age it also survives in shaded areas. The most severe problem we face is that tree of heaven infests both protected areas and areas used for forest management. In my experience, the species avoids only zones with a high water table, seasonal wetlands and highly sodic soil. The invasion process is so rapid and strong that tree of heaven seedlings have already appeared in arable lands as a dominant species. In addition, my observations based on twelve years of experience in the field indicate that this species is highly herbicide tolerant (Tables 1 & 2).

In the cases listed in the tables, plantlets and/or seedlings were able to survive herbicide treatments well – sometimes even when herbicides were applied both pre-emergence and post-emergence during the vegetation period. In many cases, the plant survived three different herbicide chemicals, both post-emergently as seedlings or pre-emergently as plantlets. Growing tree of heaven appears to be highly resistant to HPPD inhibitors, ALS inhibitors and PSII inhibitors, which are frequently used herbicides, and even when these are used in combination. However, it must be pointed out that some active ingredients of these groups have been used with some success to control tree of heaven seedlings in forestry and in arable lands (with restrictions). The resistance of the plant is illustrated by the findings of an oriented experiment we set up on a short section of a railway track where there was no soil surface. To this area we applied a massive dose of herbicide combination (flumioxazin + topramezone): the first plant that started growing from seed after the treatment was a tree of heaven specimen. We have made similar observations on other sites (cereal stubbles) where we used other chemical combinations. To date, only the post-emergent application of four active ingredients has proved effective. These four, in order of decreasing efficacy are: metsulfuron-methyl, glyphosate, imazamox, and 2,4-D.

A further advantage of metsulfuron-methyl is that it was the only ingredient in the list that was success-

Fig. 1. Tree of heaven invasion in the Békés cemetery. (Photo: R. Szabó)

Fig. 2. Who wears the trousers in the house? It's a matter of perspective! (Photo: R. Szabó)

Table 1. Herbicide tolerance of tree of heaven plantlets and/or seedlings in the case of pre-emergent treatment, based on experience gained between 2003 and 2014.

Inactive* ingredient (pre)	Cultivated plant			
	Corn	Sunflower	Potato	Melon
terbutilazin+dimetenamid-p	x			
izoxaflutol+tienkarbazon-etil	x			
acetoklór	x			
oxifluorfen		x		
izoxaflutol	x			
mezotrion+floraszulám	x			
metribuzin			x	
pendimetalin			x	
linuron		x		
fluorkloridon		x		
klomazon				x

* = effectiveness was insufficient and/or unsatisfactory when used to treat tree of heaven seedlings

Table 2. Herbicide tolerance of tree of heaven plantlets and/or seedlings in case of post-emergent treatment, based on experience gained between 2003 and 2014.

Inactive* ingredient (post)	Cultivated plant		
	Corn	Sunflower	Potato
tribenuron-metil		x	
rimszulfuron+dikamba	x		
dikamba+bentazon+nikoszulfuron	x		
foramszulfuron	x		
rimszulfuron	x		
mezotrion+terbutilazin	x		
metribuzin			x

* = effectiveness was insufficient and/or unsatisfactory when used to treat tree of heaven seedlings

ful in killing tree of heaven plantlets pre-emergently. Moreover, the species is so vulnerable to this chemical that, at higher doses, it thins out saplings effectively (Fig. 3). This chemical is outstanding because native oak seedlings (*Quercus* spp.), with their waxy leaves, highly tolerate its active ingredients, at least up to an 8 g/ha dosage (Fig. 4). This enabled me to develop a method for controlling tree of heaven seedlings effectively in oak forest regeneration zones (Fig. 5). The method has been applied in an increasing number of areas after Sumi Agro Hungary Ltd. successfully obtained an emergency permit for its use.

Tree of heaven requires high temperature for germination, so its massive sprouting usually starts after the forest rehabilitation and/or after logging. Of course, this process is further enhanced by an increasing amount of direct sunshine and more favourable light conditions. These circumstances trigger a massive growth of late seedlings when the leaves of oak seedlings and saplings are already covered with a fine layer of wax. These factors all enable successful and effective treatment, because the phytotoxic

Fig. 3. Foliar absorption of Savvy hinders resprouting. (Photo: R. Szabó)

Fig. 4. Successful seedling control with Savvy in oak stands. (Photo: R. Szabó)

Fig. 5. Pre-emergent and post-emergent symptoms of Savvy on seedlings. (Photo: R. Szabó)

risk of seedlings is insignificant, while almost at the same time the target plants are all vulnerable. If applied in this period, 40 g/ha Savvy mixed with 100 ml/ha Spur (adjuvant) can kill tree of heaven seedlings through leaf absorption (up to a size of one span from the cotyledon, but the optimal size is cotyledon to 6 leaves); it is also capable of controlling sprouting of late-growing individuals through the soil. For the time being, this is the only and most successful solution under the aforementioned circumstances.

We have tested this product on other woody weeds that cause local forestry problems. The findings indicate that species of the Rosaceae family are also

Fig. 6. The results of the new technology on adult plants. (Photo: R. Szabó)

vulnerable to this treatment. The effectiveness in the case of leaf absorption decreases in the following order: dog-rose (*Rosa canina*), blackberry species (*Rubus* spp.), black cherry (*Prunus serotina*), howthorn species (*Crataegus* spp.)*.

Other herbicides with glyphosate as the active ingredient (e.g. Trustee Hi-Active) can also be effective when used carefully, but their effect does not last long in the treated area. Preliminary tests show that good timing of treatment and the combination of the two products (Savvy + Trustee Hi-Active) can control tree of heaven seedlings in young oak forests effectively.

In arable lands where the populations were spare, imazamox and 2,4-D were effective post-emergent herbicides against seedlings, of course, only where the use of these is allowed (e.g. maize: 2,4-D, Clearfield sunflower: imazamox). My own experience and observation suggest that a tree of heaven with cotyledon is most vulnerable to imazamox, while 2,4-D is most effective against individuals with two true leaves. These actives and methods can also be used in buffer zones of protected areas: of course, the conditions of the treated area have to be considered first.

Detecting and processing observations are not substitute for accurate quality-assured experiments, but they do outline some characteristics of the responses and tolerances of the plant. Procedures based on observations that can safely be applied in different crops or habitats are already being developed. However, many tests and experiments are required to prove their feasibility and effectiveness. For the time being, the most developed and widespread method is the single selective control of adult tree of heaven individuals. On the other hand, there are other highly developed methods in use in Hungary, such as cut stump treatment, basal bark treatment and injection, among others. Of course, we keep participating in the development of these technologies with our products and knowledge. This cooperation is already available to farmers. One of these methods is cut stump treatment, followed by cut stump sealing for even greater effectiveness (Fig. 6). We are more and more frequently faced with the massive spread and aggressive nature of invasive species, sometimes in areas, habitats or times where we have not found a way to handle the problem. In cooperation with the Kiskunság National Park Directorate, we listed and ranked herbicides to find a biologically effective active that has no serious effect on biodiversity in order to control cocklebur species (*Xanthium* spp.) which have been rapidly spreading in protected areas. The experiments have already started and there are some promising results.

It is clear that invasive plant species are gaining momentum, having to unfavourable biological consequences. Thanks to awareness-raising campaigns on the common ragweed (*Ambrosia artemisiifolia*), the phenomenon is now well-known in Hungary. It is important to monitor this field and to apply the results of experiments in practice.

*Attention! Experimental chemical control methods described in this chapter are subject to authorisation! Their practical application requires an emergency permit issued by the pesticide control authorities for the given area and period!

Control of invasive alien plant species in the Turai Legelő Nature Conservation Area

Valentin Szénási

Natural characteristics of the area

We were entrusted with the task of controlling invasive alien plant species in the Turai Legelő (Tura Pasture) Nature Conservation Area (NCA) as part of a major project between 2010 and 2012.

The NCA is situated southeast of the town of Tura, in its periphery. Its area is approximately 14 ha and is located next to River Galga, between ploughlands of large-scale agricultural production.

The reason for designating the Turai Legelő NCA as a conservation area was that the single known protected plant species of that time, *Bulbocodium vernum* grows here. Now we have much more information on the natural values of the area: it provides habitat for numerous protected plant and animal species and Natura 2000 species. Furthermore, the grasslands of the NCA are mainly closed sand grasslands rich in species which remained present only in rather small areas of the micro-region. We have to note that the Turai Legelő NCA and within this the habitat of *Bulbocodium vernum* is not part of the Gödöllő Hills region, in contrast with what the botanical literature published so far states. It is located exactly in the geometric centre of the Hatvan Plain micro-region, thus it forms part of the Northern Great Plain Alluvial Fan of the Great Hungarian Plain.

Its climate is moderately warm and moderately dry. The average annual precipitation is 540–580 mm, with an average of 330 mm in the vegetation period. From the southwest the protected area is bordered by River Galga, which has flood protection dykes on both sides.

In a section of the protected area and its surroundings a fish pond system operated from the beginning of the 20th century to the mid-1960s. Its remnants can still be found in the NCA, e.g. fill-up and lead-off ditches and the remains of the shut-off construction site in the middle of the NCA.

The groundwater level is 0.5–1 m in the deeper areas and 3–3.5 m in the higher parts. The general decrease of the watertable in the Danube–Tisza Interfluve in the last decade can also be observed in this region. This is less than the average 1.5–2 m because River Galga is close, however, the change can still be detected (temporary water cover disappears, changes in succession).

The micro-region (and the NCA within) is a terraced alluvial fan plain at an elevation of 99–209 m, which is formed by ridges emerging from the low wet areas and an articulate plain area of medium height (where also drifting sand forms are present).

According to the geomorphologic conditions of the NCA, its soil types can be divided into two larger units. The first group is formed by humic sandy soils rather poor in nutrients developed on the sand ridges of higher elevations. Here afforestation of low quality resulted in slight (eolian) erosion. The second group includes meadow soils and alluvial meadow soils, which developed in lower areas with higher groundwater levels and which are rich in minerals as well as nutrients. Between the two elevations, mainly transitional soils of sand physical character can be found, with occasional slight salinity processes. In other parts of the NCA there is nitrogen enrichment in the soils, which is well indicated by the thrive of nitrogen-tolerant or nitrophilous plant species like the common nettle (*Urtica dioica*) or hemp (*Cannabis sativa*).

Initial conditions

A part of Turai Legelő NCA is a forest maintained in line with a management plan (1.7 ha), where the Duna–Ipoly National Park Directorate is the registered forest manager. In the subcompartment maintained in line with a forest management plan patches of hybrid poplar (*Populus ×euramericana*), grey poplar (*Populus × canescens*) as well as stands of the principally common hackberry (*Celtis occidentalis*) can be found. Apart from these green ash (*Fraxinus pennsylvanica*), white mulberry (*Morus alba*), honey locust (*Gleditsia triacanthos*), black locust (*Robinia pseudoacacia*), box elder (*Acer negundo*) and eastern black walnut (*Juglans nigra*) is present one by one, representing well the arboreal invasive plant species characteristic of Hungary. Beyond the forests under forestry management, spontaneously settled black locust and tree of heaven (*Ailanthus altissima*) are also present in the area in smaller patches (0.3 and 0.5 ha). The northern border of the NCA is lined with a black locust row. Apart from the woody vegetation, there are also herbaceous invasive species, whose proportion is, for the time being, manageable in the grasslands comprising the vast majority of the NCA. Chiefly giant goldenrod (*Solidago gigantea*), common milkweed (*Asclepias syriaca*) and the herbaceous species spreading from the nearby ploughlands are present (hemp, common ragweed (*Ambrosia artemisiifolia*), burr grass (*Tragus racemosus*). We can state that the part of the project area which is covered by woody vegetation is practically composed of non-indigenous species, while in the herbaceous vegetation the proportion of the adventive species is considerably lower. In addition, the structure transformation and species exchange of the woody vegetation is longer by orders of magnitudes. For the above-mentioned reasons our main goal was to manage the woody vegetation. As the project period was relatively short, it was not among our goals to manage the whole area, but started to treat more 'compact' stands of invasive species and those that could be easily eradicated because of other reasons. (We hope to gain budget from other financial sources to carry on with this work in the future.) During the activity, we carried out experiments on large individuals of the main tree species (common hackberry) only outside the subcompartment maintained in line with a forest management plan. The subjects of the chemical treatments were younger individuals (at cleaning age). The Directorate had a 0.3 hectare meadow excluded from forest land usage in the habitat of *Bulbocodium vernum* by the general method required by the forestry authority (implementation of replacement afforestation). The eradication of invasive species in the area was permitted by the Central Danube Valley Inspectorate for Environmental Protection, Nature Conservation and Water Management as well as the forestry authority (on site, in line with forestry management in the manner previously agreed during the district-level forestry planning).

Methods used

We applied different methods of chemical treatment. The reason for this was partly that some of these were experiments and partly that we considered the physiological characteristics of each species.* We employed four full-time physical workers to carry out management tasks included by the project. The methods used are presented for each species separately.

Common hackberry

Common hackberry is the stand-forming species of the forests under forestry management plan in the area. The stand was planted in humic sandy soils of low or average quality. The most important aspect of planning herbicide use was that one of the significant populations of the specially protected *Bulbocodium vernum* (300–500 specimens) dwells in the herbaceous layer of this stand. This made the use of herbicides spread on the foliage (spraying) impossible, which led to a serious problem as in the herb layer of this forest subcompartment 1–3 cm high seedlings of common hackberry are abundant. Based on our previous experience this is an unobservable problem in those sections of the forest subcompartment where the canopy is more closed (because of the spontaneous thinning of common hackberry seedlings). However, at the edges and in those parts which became open or were opened the saplings started to grow immediately. In addition, 2–3 years old seedlings generate such a thick lateral root network even in the upper 2–5 cm layer of the soil that a spade cannot penetrate, so the problem certainly needed to be solved. In an experiment we sprayed herbicide Medallon Premium (360 g/l glyphosate) in 10% dilution proportion in areas valueless for conservation (covered by nitrophilous vegetation).

In the habitat of *Bulbocodium vernum* and its surroundings we uprooted the seedlings manually. On the common hackberry specimens at the edge of the stand (mainly at seed-producing age) cut stump treatment was applied with 50–50% concentrate mixture of herbicide Garlon 4E (480 g/l triclopyr) and water. The treatment was carried out only once in autumn and with approximately 60% efficiency. As a pilot scheme, certain seed-producing specimens of common hackberry were trunk-injected: 50% concentrate of Garlon 4E mixed with water and gas oil; immixed Medallon Premium; Garlon 4E and Medallon Premium; Garlon 4E and Medallon Premium and Mezzo (20% met-

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sulfuron-methyl) herbicide combinations were used in different mixing and dilution proportions. It was necessary because – as opposed to the other invasive species of the area – common hackberry was rather resistant to the various herbicides.

Black locust

In the forests under forestry management plan of the area black locust is a rare associate species and stand-forming species of spontaneous origin on a 300 m² site. This patch was made up of young sprouts and old specimens of 30–35 years which had to be cut before the new forestry management period. After felling them with chainsaw in the traditional manner, in autumn cut stump treatment was used with 50–50% dilution proportion of herbicide Garlon 4E and water. Due to the sprouting of the stumps and roots of the survived specimens, foliar spraying was carried out in spring and autumn with the mixture of Lontrel 300 (300 g/l clopyralid) herbicide with the suggested dilution proportion (10%). The regrown sprouts were treated in spring with the same herbicide. As the old specimens had to be cut, we didn't use the trunk injection method here.

Tree of heaven

In the forests under forestry management plans of the area, tree of heaven is a sporadic associate species and stand-forming in a 400 m² large spot of spontaneous origin. This patch is composed of young sprouts and 20–25 years old specimens. Based on our experience in other areas, the traditional cut stump treatment method was ruled out and in the case of older and seed-producing trees trunk injection was used exclusively (with a 1/3–1/3–1/3 proportion of Garlon 4E, Medallon Premium and water). The young specimens (with no corky barks) were not injected because of their narrow trunk. In these cases 50–50% dilution mixture of Garlon 4E and gas oil was wiped on the young sprouts. In certain areas older roots also emerged to the surface and were injected as well.

Box elder, green ash, eastern black walnut

In the area box elder, green ash and eastern black walnut are present with low cover and only sporadically. These species are discussed together because their management methods and sensitivity to herbicides are the same. The old specimens of these three species were treated by trunk injection also with the mixture of Garlon 4E, Medallon Premium and water. In the cases of box elder specimens with 2–2.5 m trunk diameters and eastern black walnut patches planted into and shading considerably the precious closed sand grasslands, the trees had to be felled. Following this, cut stump treatment was applied with a 50– 50% mixture of Garlon 4E and water. As eastern black walnut produces a very strong sap flow, the stumps were treated on the third day after logging.

Experiences gained

Common hackberry

The management using the herbicide Medallon Premium in areas valueless for conservation and covered by nitrophilous vegetation resulted in a 100% eradication of the seedlings. In the habitat of *Bulbocodium vernum* manual uprooting was a very time-consuming and labour-intensive process and in addition to the permanent brigade we needed to draw in additional manpower as well (university student trainees, organised field trips, volunteers). Especially the removal of 2–3-year-old saplings required more physical strength as the proportion of the stem and root is 1/3 : 2/3 in favour of the root. We have to note that none of the above-mentioned methods are effective on the long run, due to the fact that the seed bank renews each year – particularly under the stand. Specimens of common hackberry at the edge of the stand were felled and cut stump treatment was used with a 50–50% concentrate mixture of herbicide Garlon 4E and water. After the treatment approximately 60% efficiency was ascertained. 40% of the specimens sprouted again from the stump. We managed these with spot spraying (from backpack sprayers) using the mixture of the prescribed dilution of Medallon Premium in spring and autumn. These specimens were destroyed as well. We have to point out that all the specimens of hybrid poplar in the stand were destroyed following the same cut stump treatment. The trunk injection made in autumn (September–October) with immixed Medallon Premium and immixed Garlon 4E did not show visible results. Garlon 4E diluted with gas oil caused slight chlorosis in a few weeks and in next spring the specimens grew deformed shoots and leaves but the number of sprouts or the degree of vitality remained the same.

Among the mixed herbicides, combination of Garlon 4E and Medallon Premium generated intensive chlorosis in autumn and by spring certain branches perished. The symptoms induced by Garlon 4E, Medallon Premium and Mezzo mixture were alike, however, the specimens haven't died during the two years of the project (but the number of dead branches increased every year). For 2014, out of the 20 managed seed-producing trees, five perished completely, while the others survived with significantly decreased vitality and several dead branches. After the finalisation of the project, further trunk injection of the specimens could not be carried out (as herbicides were lacking).

Black locust

Following the felling with a chainsaw, cut stump treatment was carried out with a 50–50% dilution proportion of herbicide Garlon 4E and water. As a result of this, 70% of the trees died and other stumps began to sprout moderately, however, generating root suckers was more characteristic. Due to this, foliar spraying took place in spring and autumn with the mixture of Lontrel 300 herbicide, using the suggested dilution proportion. The results were only partly successful as a significant proportion of the sprouts regrew even after managed twice. However, in another site of Turai Legelő NCA with the same treatment – management period – herbicide eradicated 90% of the sprouts. (Here, it was necessary to manage the stand after timber was cut and stolen in winter.) In the latter area black locust individuals were prevented from sprouting by recurrent management in autumn.

Tree of heaven

In the case of trunk-injected specimens of tree of heaven the mortality rate was 90–95%. Subsequent to the management in autumn, these trees (on the verge of spontaneous falling) were felled manually and often revealed 80–100 cm long root plates. These didn't sprout, but from the roots we observed moderate sprouting with a rate that remained below our expectations. Due to the lack of budget, post-treatment failed. The young sprouts painted with the mixture of gas oil and Garlon E4 showed cca. 80% mortality, which seems to justify the use of this method in these age group. Owing to the above-mentioned fact, there was no post-treatment even in this case.

Box elder, green ash, eastern black walnut

The specimens reacted well to trunk injection, thus in 2–3 weeks there was a spectacular loss and there was no resprouting even in spring. Box elder and eastern black walnut specimens showed good results also in cut stump treatment. However, eastern black walnut requires a slightly different technology because of the strong sap flow (typical of *Juglans* genus). In the initial phase the stump was immediately treated after the logging (like in the cases of other species). However, due to the intensive sap flow all the herbicide was washed onto the grassland surrounding the stump in the next 1–2 days. (We could observe this phenomenon easily because the herbicide was coloured.) For this reason we treated the stumps on the 3rd day after the felling, when the rather strong sap flow stopped. Although we hadn't tried, it would have been worth observing what happens if we cut the trees and use no herbicides: the intensive sap flow could have been lethal to the logged individual. (This is a well-known fact for common walnut, and this is why it is not pruned – pruning in an unfavourable period can easily lead to serious sap loss and the death of the tree.)

To sum up the experience gained so far we can state that common hackberry is much more resistant to the used herbicides (unlike the other invasive woody species). However, we can eradicate this species effectively as seedlings with the traditional free traffic herbicides. The cut stump treatment of black locust was successful, while we used Lontrel 300 (selective for this species) with mixed results. The chemical treatment of tree of heaven surpassed our expectations: it was successful both for seed-producing older trees (trunk injection method) and young sprouts (painting) and the rate of resprouting was also negligible.

Despite our long-term objectives, we didn't have the opportunity for chemical treatment after the project duration. However, according to our estimations, this activity has to be carried out 8–10 years longer in this area.

Experience gained from the control of giant goldenrod in the Őrség National Park

Mátyás Szépligeti, Róbert Kun, Sándor Bartha, László Bodonczi and István Szentirmai

Introduction

As agriculture has become industrialised, the methods of grassland management have greatly changed over the last century, not only in the territory of the Őrség National Park, but also in other regions of the country. Due to the changing socioeconomic circumstances, the majority of family farms disappeared, and these lands were afforested or became weedy. The most widespread weed of abandoned or ill-managed – sometimes very valuable – grasslands is giant goldenrod (*Solidago gigantea*), which is to some extent present in every mowed and unmowed mesic grassland in the area of the national park.

Although goldenrod has been causing problems especially in Transdanubia since the second half of the 19th century, there are only few publications (Hungarian or international) about experimental analysis or the reactions to control treatments. It is known that this plant can be treated effectively with mechanical methods, but our experience shows that the way and the speed it establishes and spreads in an area and its reaction to control treatments greatly depends on the history and water conditions of the given area, as well as on the intensity and timing of the control treatments. The following experiences and observations are based on a mowing experiment we have been doing for eight years.

Natural characteristics of the area

Our observations were made by surveying two sites (about 0.64 ha each) that were divided based on different control methods. Both sites are located along the Szentgyörgyvölgyi stream, 250 m away from each other, with a 100 m wide forest and some hayfields of average condition between them. The two sites are located between the stream and a parallel dirt road, and the area declines slightly (2–3%) towards the stream. The altitude is about 210 m.

The soil of the area is closed, moderately cold and slightly acidic. The average annual precipitation is between 750 and 850 mm.

In the second half of the last century, owing to some river engineering works, the Szentgyörgyvölgyi stream carved itself 1.5–2 m deep in its basin, this is why it often runs dry in the summer. However, this reduces the groundwater level of the surrounding grasslands. The water condition of Area No.1. is mesophilic, while Area No. 2 is more humid, in rainy periods surface water appears locally. These circumstances are further nuanced by terrain characteristics. Higher places are not influenced by excess water, but both areas are plain in the centre, where rainfall can remain close to the surface for longer periods. This is well indicated by the presence of slim sedge (*Carex acuta*) in Area No. 1 and tussock grass (*Deschampsia caespitosa*) populations in Area No. 2. Closer to the stream, soil water conditions are usually drier as the stream is deep in its basin and water flows in that direction. This is why drought-tolerant species characteristic of drier grasslands are common here.

The study sites are surrounded by riverine ash-alder forests that run along the stream, but there are also areas afforested with pines, as well as spontaneous forests, fen-meadows, bog meadows and hay meadows. There are small and large patches of giant goldenrods close to the experimental areas, but also in the trenches along the road, and on the forest edges.

The vegetation of the experimental areas is as follows: species of *Arrhenatherum* hay meadows are the most dominant, but – depending on the terrain and water conditions – there are elements characteristic of *Molinia* meadows, *Festuca rubra* hay meadows as well. Protected species occurring in high numbers in the area are western marsh orchid (*Dactylorhiza majalis*), adder's-tongue (*Ophioglossum vulgatum*), sneezeweed (*Achillea ptarmica*), and marsh gentian (*Gentiana pneumonanthe*). The former two species are more common in Area No. 1, while the latter two occur more often in Area No. 2. In Area No. 1, we can also find some small tufted-sedge (*Carex caespitosa*) and umbrosa sedge (*Carex umbrosa*) plants, and there are small populations of lemon day-lily (*Hemerocallis lilio-asphodelus*) in Area No. 2.

An outstanding faunistical value of the study sites is the fact that three large blue butterfly species (*Maculinea teleius*, *M. nausithous*, *M. alcon*) are present together. The mowing experiment was initially started in order to observe the response of species to the treatments, and it was done by the staff of the national park lead by István Szentirmai (Kőrösi *et al.* 2009). Some individuals of the specially protected corncrakes (*Crex crex*) also appear in this area every year.

Initial conditions

What we know about the study sites and the surrounding meadows is that these were used as grasslands since the 1940s (probably earlier too). People mowed these areas twice a year, and the aftergrass was even grazed in autumn. The areas were mowed – depending on the weather – between May and June, then between August and September. Hedges and road edges were grazed, too. After the early 1960s, when farmers were forced to join farmer's cooperatives, there was no grazing, only mowing twice per year. When the amount of livestock started shrinking in the 1990s, people abandoned most of the lands.

After the end of the decade and until the beginning of the experiment, the area of the study sites was randomly treated by mowing once per year. Giant goldenrod was already present sporadically and in small patches. The former botanical relevés made in experimental area No. 1 in 2008 show that once early mown sampling units close to the road have 40%, 25% and 4% of goldenrod presence, but once late mown sampling units close to the road and the centre of twice mown treatment stripes also had a presence of 10% or above. Regarding Area No. 2, when we recorded the initial site conditions, all treatment unit types had a high presence of goldenrod, especially those in the centre and close to the road. In the rest of the units, however, there were hardly any goldenrods present. The alternating values suggest that the overall results of the experiment were only slightly influenced by the initial state of infestation. Area No. 2 had been untreated for some years before the start of the experiment. This was a great opportunity for goldenrod to establish and spread. 50 meters away from this area there is a gas well. The necessary earthworks to build this also enabled goldenrod to spread faster. Area No. 2 is not only more humid than Area No. 1, but it is also more severely infested by giant goldenrod.

Methods used

We examined the response of giant goldenrod populations to mowing, while we kept changing the timing and the intensity. For this purpose, in 2007 we established two study sites near Magyarszombatfa (Fig. 1).

The two study sites were both divided into 16 sampling units of 20 × 20 m in size, all marked with wood stakes. These units fell into four categories: single mowing in early June; single mowing in early September; mowing both in June and in September; unmowed. This results in 4 sampling units per treatment type in both areas. In Area No. 1, the sampling units are ordered according to sections perpendicular to the stream, while those of Area No. 2 are organised into two rows between the stream and the road – the sampling units are mixed here. Management of the study sites has been carried out by the Őrség National Park Directorate, used RK-165 type drum mowers, leaving a stubble height of 8–10 cm.

The first botanical survey of the study sites was conducted in August 2008 (Bodonczi 2008), and we repeated it in 2014. During this, we took cenological relevés in the NNW corner of each 20 × 20 m sampling unit in a 2 × 2 m quadrant. The quadrants are always in the corner of a sampling unit because it makes them easier to find. Our experiences and suggestions are based on the relevant data of these rel-

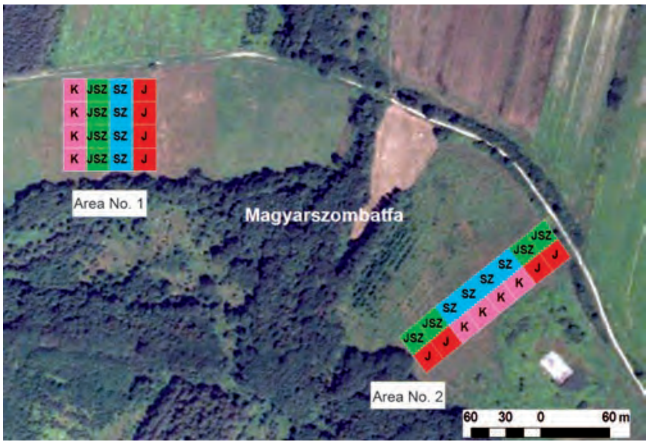

Fig. 1. Position of the study sites and the sampling units (K = untreated; JSZ = mowed in both early June and early September; SZ = mowed in early September; J = mowed in early June).

evés, but we also mention the response of protected plant and animal species present in the study sites. We also wanted to know if our experiences gained on these small-sized sample plots lots could be used on a larger scale under different circumstances, so we visited other areas infested by goldenrod within the territory of the national park in order to be able to provide suggestions based on more detailed observations.

We carried out interviews with the owner of the hayfield in order to reveal how the study sites were used in the past.

Experiences gained

Our experiment shows that after 8 years of treatment, giant goldenrod spread or thinned to different extents depending on the treatments used (Fig. 2). The chart represents the level of goldenrod cover in 8 sampling units per treatment types for both areas and both surveyed years. The most visible spread happened in the two unmowed areas: goldenrod became dominant in all but one abandoned sampling units. Experience shows that goldenrod prefers mesic grasslands in valleys that are not marshy. Without treatment, it can create stable, homogeneous populations in these areas, and it also hinders the growth of trees.

In general, we can conclude that a single early mowing is unable to stop the spread of goldenrod. The average cover increased in this type of treatment in both experimental areas. Although goldenrod does not able to bloom after early mowing, it starts a vigorous vegetative spread, displacing many native species. After mowing in May–June it has enough time to spread remaining in the growing season. Rangers of the area reported that sites mowed only once in June are in bad condition, and goldenrod is continuously spreading on them.

Single late mowing was, however, able to control or sometimes reduce the cover of goldenrod. This is not the case in the unit close to the road in Area No. 1. The reason is probably the high level of disturbance due to the maintenance works of the road and its ditch, or to the fact that the soil water conditions are the most balanced here. In September-mown plots stands of *S. gigantea* grow thinner, although remain permanent. These results suggest that it is more sensitive to mowing during the flowering period when most energy invested in sprout and florescence. Late mowing therefore weakens polycormons more efficiently. In addition, late mowing favours to the spread of native competitor species as well, which are more resistant to the colonisation of goldenrod.

It can be seen in both areas that approaching the stream – regardless of treatment – the cover of goldenrod decreased, and its populations are sparser, scattered in small patches (Fig. 3). This is because of the deep stream bed drains water from the area, thus creating unfavourable conditions for goldenrod. Under these circumstances, the species is more vulnerable to mechanical treatment. In case of treatment units close to the stream, there are smaller patches of goldenrod populations even in units of single early mowing. The reduced vitality level is also represented by their smaller size (Fig. 4).

Outstanding results were only achieved with twice mowing. This effectively prevented the spread of goldenrod, and it managed to eradicate it almost completely from areas that were severely infested in 2008. It has to be added, however, that goldenrod cover was not above 20% in any sample unit assigned for double mowing in 2008. Sometimes double mowing also has mixed results. In a visit near the village of Szőce, we found a small (200–300 m²) hayfield – with mesic site characteristics – surrounded by forests that had been covered by a dense population of gold-

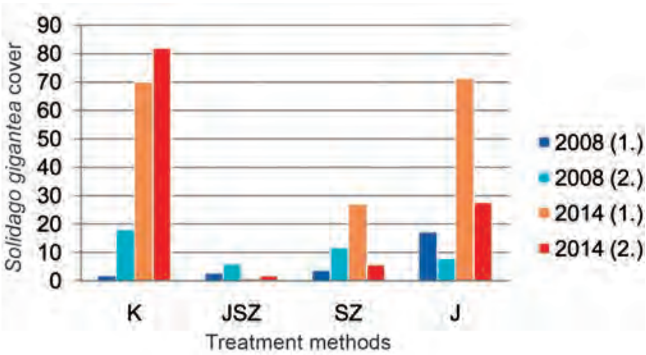

Fig. 2. Average cover of *Solidago gigantea* in pilot area No. 1 and 2 in 2008 and August 2014, based on the average of the 2 x 2 quadrants (U = untreated; JS = mowed in both early June and early September; S = mowed in early September; J = mowed in early June).

Fig. 3. In drier areas close to the stream, goldenrod populations are sparser, even in the untreated sampling units. (Photo: M. Szépligeti)

Fig. 4. In unfavourable conditions, giant goldenrod can be curbed with a single early mowing. (Photo: M. Szépligeti)

enrod before its treatment begun. It turned out that after 10 years of twice mowing, the invasive species is still dominant in the area (Fig. 5). Although there is a grassland patch with a good species composition less than 100 m away, it takes a lot of time for grassland species to appear on meadows surrounded by forests. Under wet and humid circumstances, exhausting the stolons of goldenrod is a very slow process. Again, the area close to the Szőce stream is less infested.

Regarding the most important protected species of the study sites, we can conclude that lemon day-lily, marsh gentian and sneezeweed spreads faster in wet areas that are mowed late. In treatment units mowed early or twice, these species are smaller, and they bloom rarely or not at all. Other researches revealed that ant species host to *Maculinea* larvae as well as corncrakes also prefer unmowed or late-mowed areas. The lack of treatment, however, quickly results in featureless vegetation and spreading weeds or trees. The hay mowed at the end of summer cannot be used as feed, thus its economic value is very low. In order to effectively control goldenrod and to restore the species pool of wet meadows, two times mowing per year should be considered.

There are no patterns for control planning, however. The first task in every case is to set the most important conservation goals. For this, the current state, the level of infestation and the distance of other potential seed sources has to be considered. For example, if we do not intend to utilise a bog meadow economically, and goldenrod is only sporadically present on it, a once, late mowing could be enough. In areas free of goldenrod it is not even necessary in every year. In other lands under agricultural use – and where the land is big enough –, it is suggested to leave a 5–20% patch of the area unmowed, but it has to be ensured that the rest of the land is free of goldenrod. In severely infested areas, significant results can only be achieved if the site is mowed twice (or even three times) per year. Cut material has to be disposed of immediately! Regeneration is slower in areas isolated from seed sources, but if the required resources are available and the area is important from the conservation aspect, small-scale mowing should be carried out several times a year in order to eliminate small goldenrod patches. In case of drying fen-meadows and mesic hayfields on hillsides, where there are no specially protected species, once early mowing is sufficient, but the spread of goldenrod has to be constantly monitored. Another mowing should be carried out if needed, at least in the infested patch.

It is advisable to change the timing and frequency of mowing from time to time, with leaving unmowed refuge areas. If goldenrod starts spreading in the habitat of valuable, protected species, twice mowing per year should be done for the next 3–4 years. If it is necessary, goldenrod-free refuge areas should be assigned for protected species.

Issues raised

We have no relevant experience of how goldenrod responds to grazing. This should be examined in the future.

So far, we only know that cattle, the most dominant grazing animals of the national park, do not eat old goldenrod individuals. However, they do eat young plants – especially when there is nothing else.

Cattle also cause damage to the plant as they trample on the stolons. There was a young, homogeneous goldenrod population covering a large area near the livestock farm of the national park directorate close to Őriszentpéter. When the animals were grazing the population for years, goldenrod completely disappeared in a short time. Based on this information, we consider grazing a viable temporal solution against homogeneous goldenrod populations on degraded sites, but in case of meadows in good condition (especially wet meadows), we recommend repeated mowing, as excessive grazing pressure can lead to infestation of other meadow-weeds.

Fig. 5. The area was previously covered by a homogeneous goldenrod population. However, after 10 years of mowing two times per year, the condition is still not satisfactory. (Photo: M. Szépligeti)

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Control of tree of heaven in the Mecsek Park Forest

István Szidonya

Natural characteristics of the area

The project area belongs to the almost 5000-hectare territory of the Mecsek Park Forest. The area is bordered by Gyükés to the east, the Misina-Tubes crest road to the north, the Remeterét–Albaliget road to the west and the city of Pécs to the south. There are protected forests, forests for tourism as well as productive forests in the Mecsek Park Forest. The area is frequently visited because of its diverse geological, botanical and zoological values. Its highest point is Tubes at 611 m altitude which continues with steep slopes to the Misina summit to the east. The mountain consists of Triassic Anisian limestone which is covered with skeletal and rendzina soil. The Misina–Tubes area is one of the richest parts of the Mecsek Hills regarding plant communities and protected natural assets. The most characteristic communities are deciduous rock thickets, calcareous rocky steppes, Tilio-Acerion forests of slopes, mixed relic oak forests on rocky soils (top forests with anthora), *Quercus pubescens* scrubs (with *Inula spiraeifolia*). The protected and specially protected species are as follows: Russian spiraea (*Spiraea media*), monkey orchid (*Orchis simia*), dwarf morning glory (*Convolvulus cantabrica*), *Inula spiraeifolia*, *Plantago argentea*, leopard's bane (*Doronicum orientale*), pink woodruff (*Asperula taurina*), mouse thorn (*Ruscus hypoglossum*), yellow monkshood (*Aconitum anthora*), wolfsbane (*Aconitum vulparia*), grape hyacinth (*Muscari botryoides*), martagon lily (*Lilium martagon*), bastard-agrimony (*Aremonia agrimonoides*), *Himantoglossum caprinum*, violet limodore (*Limodorum abortivum*) and Hungarian iris (*Iris variegata*).

Initial conditions

Regarding invasive alien plant species in the territory of Mecsek Park Forest, the biggest problem is caused by tree of heaven (*Ailanthus altissima*), as it is able to survive in areas with a very thin layer of topsoil, it spreads rapidly using generative and vegetative methods, creating completely homogeneous populations and at the same time shrinking the area available for valuable communities.

Fig. 1. Application of a chemical on tree of heaven sprouts. (Photo: I. Szidonya)

Due to its reproductive and regenerative abilities, tree of heaven is one of the most uncontrollable invasive plants. It can only be controlled if resprouting is prevented. According to Hungarian conservation experience, the most effective control method is injecting easily absorbable herbicide in vascular tissues, hence reaching its roots. Tree of heaven control includes at least three treatments (treatment and two post-treatments) using injection and/or wiping of sprouts (Fig. 1) or spot spraying.*

In accordance with the relevant authorisation, first treatments begin in autumn, the first post-treatment is carried out in the following spring, while the second post-treatment is done in the following autumn.

*Attention! Experimental chemical control methods described in this chapter are subject to authorisation! Their practical application requires an emergency permit issued by the pesticide control authorities for the given area and period!

The first treatments are usually effective, but after several weeks, some individuals may start regenerating (i.e. they simply survive or they grow root sprouts). This is why after the first treatment post-treatments are needed, at least twice. Tree of heaven is an invasive alien plant species well-known in Hungary, so a number of chemicals and methods have been used to control it. If the control treatment is carried out in a vulnerable area, special attention has to be paid to prevent chemicals dripping or spilling on other plants, and vulnerable species should not be disturbed in any form.

The most widely accepted period for chemical control of invasive alien wood species starts in the middle of summer, and it lasts until the onset of the autumn leaf fall (before the first frost). The sap flow from the foliage to the roots is the most intensive during this period. This is extremely important in the case of tree of heaven, because if the chemicals do not reach every root in full length, the plant responds with massive sprouting. During our experimental and technological development activities carried out in the past ten years, we arrived at the conclusion that chemicals containing glyphosate (Medallon Premium) and its combinations tend to trigger the lowest rate of sprouting. (The more widespread (and cheaper) glyphosate isopropylamine salt reaches the roots less effectively. It still kills the parent individual at the same rate, but it results in more severe sprouting.)

Methods used

The method and technology of applying the chemicals depends on the size of the plant.

Injection

It is a method used in case of populations including bigger trees (above 8 cm in trunk diameter). With a drill head of at least size 6, every trunk between 5-15 cm in diameter is drilled at a comfortable height at an angle of 45°. Using an automatic self-filling syringe, we inject 1 ml of the solution (containing glyphosate) into the hole. The use of silicone to seal the holes after the treatment is obligatory in order to prevent the evaporation of the solution. The treatment was carried out in September 2013.

Basal bark treatment

A method used in populations that contain individuals thinner than 8 cm in diameter. We prepared a Medallon Premium in oil emulsion (containing glyphosate) and painted parallel, 10-15 cm wide stripes on the surface of trunks using a radiator brush. In heterogeneous areas, we combined basal bark treatment with injection. We sprayed the same emulsion on the leaves of short sprouts.

To make our work more effective, we added slowly fading, bright-coloured paint to the solution used for painting or spraying, as this made it easier to identify individuals that had already been treated.

It is also very important to indicate the borders of the working area around playgrounds and frequented footpaths with clearly visible tapes, and to place signs that inform people about the fact that chemicals are being used in the treatment, including the possible dangers. Dead trees collapse and decay within a few years, but since the Park Forest is frequently visited, these are the source of dangers and they litter the landscape, so they have to be felled and removed from the area. Removing the trees turned out to be challenging in some areas densely populated by native species. The felling of the trees is carefully planned, and sometimes they are pulled with ropes in order to protect the crown of other species.

After felling, we mostly brought the cut material to the nearest road accessible by car in December 2013.

Fig. 2. Tettye dog park before the treatments. (Photo: I. Szidonya)

Fig. 3. Tettye dog park after the treatments (autumn of 2014). (Photo: I. Szidonya)

In December 2013 we inspected the results of the chemical treatments: the project manager revealed that the sprouts died. As the stabilising root system and rootlets died, sprouts were easy to pull out from the soil. The mycelium of decomposer fungi was already visible on the roots. Since we visited the field in winter, there were no leaves on the trees, so it was difficult to tell how successful the treatment was (manually pulling out every sprout was not included in our task), so the first detailed evaluation of the results and the identification of surviving individuals was done in May 2014. The 2013 tree of heaven control was successful, there was no sign of resprouting at the time of the field inspection.

Due to the density and difficult terrain, many individuals were left untreated or were partially treated (there was a big difference in altitude sometimes, so the team members only managed to inject one side of the trunk – in this case, branches on the untreated side survive) in the Tettye dog park in 2013, so we decided to treat these individuals again, using the same technology (Figs 2 & 3).

In September 2014, we carried out the second post-treatment. The number of individuals of sprout origin was insignificant, but in areas previously covered with dense populations, where the soil was rich and there was enough sunshine, tree of heaven seedlings of 5–40 cm in diameter appeared. These individuals were sprayed.

Experiences gained

The applied technology and the experience gained by the team that executed the task enables almost perfect eradication of tree of heaven in the project site if the required treatments are carried out at least three times. The project also showed that the eradication task extends beyond the scope of a 1.5–2 years long project. Densely covered areas become more open after the treatments, which leads to massive spreading of seedlings, hence follow-up treatments are required to control these. This is possible using herbicides that are absorbed from the soil (our experience shows that metsulfuron-methyl effectively kills tree of heaven seedlings) and/or painting/spraying herbicides containing glyphosate. The use of these herbicides is easier due to an amendment of the relevant plant protection legislation that was enacted in 2013, as this enables chemicals of Category III to be used by workers without previously participating in an 80-hour training.

Controlling invasive tree species on Szabadság-sziget using traditional and dense row forest regeneration technology as well as individual eradication

Endre Sztellik

Introduction

One of the objectives of the project involving the 47-hectare Szabadság-sziget was to increase the naturalness of the forests by transforming the non-indigenous plantations. As well as that, we planned to eradicate sporadically appearing species. Our goal was to facilitate the dynamic development of the softwood gallery forest of the floodplain by using the developing shading to control and diminish the rate of invasive tree species to an acceptable level. We primarily concentrated our efforts to the stand-like parts and to the sporadically appearing seed-dispersing specimen.

Natural characteristics of the area

Szabadság-sziget is a 47-hectare island situated on the lower Hungarian section of the Danube near Mohács on the right bank of the river. It was formed in the early 1900s and the soil of its still developing territory is sandy, with poor water retention capacity. The differences in the microrelief are significant, in accordance with the characteristics of the surrounding area, which are mostly manifested in the expanse of the water-covered areas during a flood. Its vegetation developed according to the succession of the islands up until the emergence of forest management. Following the first management plan in the 1950s, tree utilization was carried out in compliance with the relevant plans.

The territory is a strictly protected nature conservation area and part of the Duna–Dráva National Park and the Natura 2000 network (also according to the Bird and Habitat Directives).

From a phytogeographic point of view, the area belongs to the Southern Great Plains (Titelicum) floristic zone of the Great Hungarian Plain (Eupannonicum) floristic district, its vegetation containing certain subalpine species, e.g. snowdrops (*Galanthus nivalis*).

The island and the banks are dominated by softwood floodplain gallery forests that mainly consist of white willow (*Salix alba*) and black poplar (*Populus nigra*), while on the higher reliefs we can find patches of smaller hardwood gallery forests containing European white elm (*Ulmus laevis*) and Hungarian ash (*Fraxinus angustifolia* subsp. *danubialis*).

Under the leadership of WWF Hungary the LIFE+ nature project, co-financed by the EU, the inner section of the island was made permeable for the river (by opening the former riverbed block). At the same time, forestry measures were implemented in order to restore the habitat.

The objective of the project was to achieve continuous water flow on the side-arm of the Danube almost all year round. To that end, the rock-fill dam that connected the bank to the island had to be opened, the plumbing in the dam repositioned by controlled drilling and the sediment-charged side-arm dredged.

Initial conditions

The decrease of forest communities consisting of natural species and the spread of invasive alien species can be traced back to two main causes. One is the establishment of non-native plantations mainly consisting of *Populus* × *euramericana*, in which intensive forest management was carried out and it formed a homogeneous unit. The other reason is the spontaneous propagation of woody invasive alien species on the project area such as the box elder (*Acer negundo*), the green ash (*Fraxinus pennsylvanica*), a certain number of black locust (*Robinia pseudoacacia*) and the false indigo (*Amorpha fruticosa*). These species can be found in the plantations and sporadically in the indigenous forest stands that are in a bad natural condition, where they are severe rivals to the young indigenous seedlings. Invasive species can spread from neighboring territories (in this particular case from the left bank of the river) or may come from even farther away, carried by the river flow to the protected areas.

During the course of the project we implemented management actions in the following areas.

We carried out full re-forestation (leaving behind a couple of remnant trees) on two 2.5-hectare plantations of 27-meter tall *Populus × euramericana* in bad condition with severe green ash and ash-leaved maple infestation.

We carried out reforestation with underplanting method over a 4-hectare area in similar condition, while leaving behind certain indigenous species ensuring 50% canopy coverage.

On the remaining 36-hectare territory of the island, the specimens of invasive alien species were removed individually and manually.

Management concepts prior to the implementation of the project

1. Replacing the non-indigenous populations with native species. The plan for this part of the project was to transform the stands containing non-native species or with not adequate species composition for the site into forests with the best species composition suited for the site.

In the higher altitude parts of the island with shallow tilth, we wished to carry out the reconstruction of the natural forest stands by removing the *Populus × euramericana* (*Populus marilandica*) plantations in one step and by ensuring the spread of native hardwood species that appear through artificial regeneration or by natural means. In these territories we expected the rate of *Populus × euramericana* to be reduced to zero and the rate of native species to grow.

We were also planning to install a fence in order to protect the sections undergoing artificial regeneration and the natural regrowth appearing under the native stands against large game. Given the characteristics of the territory, the most easily supervised way (from a conservational point of view) to reduce pressure on the forest caused by game is to build a fence expelling the game from the area, which will facilitate the conservation and the rehabilitation of the vegetation in the given section.

2. Control of invasive species and decerelation of their spread. One of our tasks was to transform the stands consisting of invasive species into natural forest communities. We managed to suppress box elder, green ash and tree of heaven, which did not grow in stands but occurred sporadically, in patches or were found in large areas in the second storey of *Populus × euramericana* stands.

We wanted to facilitate the expansion of native tree species by mechanical removal of invasive species, which results in natural seeding and appearance of root-shoots and the acceleration of natural succession processes.

In addition, it was our goal to sustainably increase and strengthen the population of protected or specially protected species that are potentially present in the community and represent a conservation value of their own.

Another objective was to decelerate the spread of invasive species, the fragmentation of native communities and thus the degradation of environmental values.

Methods used

Subsequent to clear cutting (with a divergent number of remaining trees) a game fence was installed. The partial (strip) soil preparation was carried out by a winged subsoiler mounted on an agricultural tractor. The species used for regeneration: grey poplar, European white elm, green ash and European wild pear. The eradication of invasive species was done manually and mechanically (brush scythe, machete, clearing saw Stihl FS 400). 10–50-mm stem diameter specimens of invasive species were cut in this manner in the shrub and regrowth layers. Post-treatments were carried out 3 times during the year (May, July and August/early September), of which the last one was timed so that the new sprouts would be frostbitten once winter comes.

Before the logging operations (late winter/spring) the sporadic and island-like 10–50-mm stem diameter specimens of invasive species were cut manually and mechanically (brush scythe, machete, undergrowth clearing Stihl FS 400) in the shrub and regrowth layers. In the autumn-winter period of 2011 manual-mechanic treatments were carried out (brush scythe, machete, undergrowth clearing Stihl FS 400) on a further 5.5-hectare area in the shrub and regrowth layers (infestation: 5–20 pieces/m^2). The proportion of invasive specimens in the shrub layer was high in this area (20–50-mm diameter, 4–7-m height). Post-treatments were carried out 3 times during the year in this forest subcompartment as well (May, July and August/early September), of which the last one was timed so that the new sprouts would be frostbitten once winter comes.

Table 1. Forest regeneration technology applied in the Mohács 75 B forest subcompartment.

	Area 1	Area 2	Area 3
Area (ha)	2.5	2.5	4
Logging	Clear cutting while leaving native trees behind (a few specimens)	Clear cutting while leaving native trees behind (several specimens, approx. 20% coverage)	Clear cutting while leaving native trees behind (approx. 50% coverage)
Exclusion of game	Game fence construction		
Groundwork	Strip subsoil loosening (70-cm deep winged subsoiler)		
Species planted	70% grey poplar (*Populus* x *canescens*), 20% European white elm (*Ulmus laevis*), 8% green ash (*Fraxinus pennsylvanica*) and 2% European wild pear (*Pyrus pyraster*)		
Seedling number (piece/ha)	12500	8000	10000
Propagule	30 cm open-rooted seedling		
Spacing (m)	1.5	3	variable (in the spaces between remaining trees)
Technology	“dense regeneration”	Normal density regeneration	underplanting regeneration
Clearing of invasive species			
2011	Manual and mechanic [infestation: 10–35 piece/m^2)]	Manual and mechanic [infestation: 10–35 piece/m^2)]	Manual and mechanic [infestation: 5–15 piece/m^2)]
2012	Manual and mechanic	Manual and mechanic	Manual and mechanic
2013	Manual and mechanic	Manual and mechanic	Manual and mechanic
Nursing period and frequency	3 times a year		

Table 2. Technology applied in the Mohács 75 B forest subcompartment to eliminate invasive species.

2011	End of winter–spring: manual and mechanic [infestation: 10–35 pieces/m^2]
	Autumn–winter: manual and mechanic [infestation: 5–20 pieces/m^2]
2012	Manual and mechanic
2013	Manual and mechanic
Nursing period and frequency	3 times a year

Experiences gained

In the forests regeneration areas

The objectives laid down at the beginning of the project were met; the proportion of non-native species was reduced to the set level. The proportion of invasive specimens was reduced to below 20% of the starting point over the total project area. Continuous post-treatment needs to be carried out – according to the After-LIFE Conservation Plan for a minimum of 5 years – until the natural forest dynamic processes take over.

Fig. 1. Winged subsoiler. (Photo: E. Sztellik)

Fig. 2. The dense-row area after subsoil loosening. (Photo: E. Sztellik)

Monitoring is crucial so that in case of potential rate shift the necessary measures can be taken. Forestry monitoring – over the 9 sample areas chosen prior to the project – follow the changes in the species pool of the vegetation and document the efficiency of the management action and the succession processes taking place over the island. It was significant that the seed-dispersing specimens, which play a key role in spreading, were almost completely removed. However, these results can only be viewed as temporary, as the shoots of woody non-native species will reappear and the propagules are regularly carried over here by the river from the upper areas. We consider it important that the eradication of invasive species was not confined to the actual cutting out of the plants but we were trying to simultaneously develop a natural forest landscape consisting of native species that create an unfavorable environment (shade) for the non-native species.

Through the forest habitat restoration activity we carried out forest regeneration on two 2.5-hectare areas, where we replaced *Populus × euramericana* plantations with native species (domestic poplars, European white elm, green ash and European wild pear). This was done using different methods on the two subcompartments. After clearing the site, partial (strip) soil preparation was carried out by winged subsoiler (Fig. 1) mounted on an agricultural tractor. The spacing between the rows and the plants was 1 × 0.3 m and 3 × 0.5 m respectively. The area regenerated by dense-row technology (Fig. 2) was exclusively treated manually, while mechanical row spacing treatment – with chained forestry crusher – was carried out on the areas planted with larger spacing until the riverbed-blocking paving was dismantled during two vegetation cycles. Several times the usual amount of propagules was placed on the areas with dense row regeneration.

This resembles the natural self-renewal processes of the forest, when significant regrowth appears from the large number of propagules that enter the soil or appear on the ground. Another consequence of this is that due to the natural mortality rate and the seedlings that die because of biotic and abiotic effects there is no replacement responsibility and the afforestation process may be accelerated. The area regenerated in such a way achieved closure sooner, thus hindering the settlement of invasive species.

Seedling destruction for any reason, if surpasses a certain rate, causes costly replacement requirements on the areas planted with larger spacing and usual amount of propagules. Moreover, invasive species will be more likely to strive.

The removal of sporadic specimens and isolated patches

There was no fence constructed in the subcompartment that would hinder the movement of game. Primarily seedlings of invasive species sprouted in the gaps resulting from cutting down individual trees, which could be effectively eradicated by successive mowing over a period of a few years. This is made difficult by the accessibility and mobility conditions on the island; only manual mowing is possible. We have no experience to report in this respect but this option seems to be necessitated.

Eradication of invasive alien plants under operating and experimental conditions in the sandy grasslands near Győr

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Nikolett Endrődyné Király, Ferenc Kele,
Melinda Király, Roland Peszlen and Péter Szőke

Natural characteristics of the area

The Hungarian Little Plain Life+ project (LIFE08 NAT/H/000289) is realised on the calcic sand steppe used for army purposes around Győr. Geographically the project area is part of the Komárom–Esztergom Plain lying on the bench area of Győr–Tata on 247 ha (Fig. 1). Its climate is moderately warm and moderately dry with an annual precipitation of about 580–620 mm, out of which 330–360 mm falls in the vegetation period. The duration of annual sunshine in the area can reach 2000 hours with an average of 780 hours in the summer and 185 hours in the winter. The surface of the shooting range is characterised by wet bogs and relatively flat, short and wide dune ridges of around 112–122 metres in height. Due to the anthropogenic effect (military activity) the micro-terrain shows only a slight topographic diversity. The area and its surroundings are covered with chernozem-type sandy soils. The permanent watercourse is the Danube, and the project area is characterised by small temporary lakes developing in artificial holes. Typical habitats include open sandy grasslands, sand steppe grasslands and habitats transitioning into shrubs and forests to different extents. Secondary habitats are represented by black locust and black pine forests, patches of common milkweed as well as secondary or degraded grasslands.

The project area has been used as a military practice and shooting range where apart from military activities, forest management and wildlife management activities also regularly take place. The breeding of grazing livestock, which used to be typical even a few decades ago, has practically vanished by now.

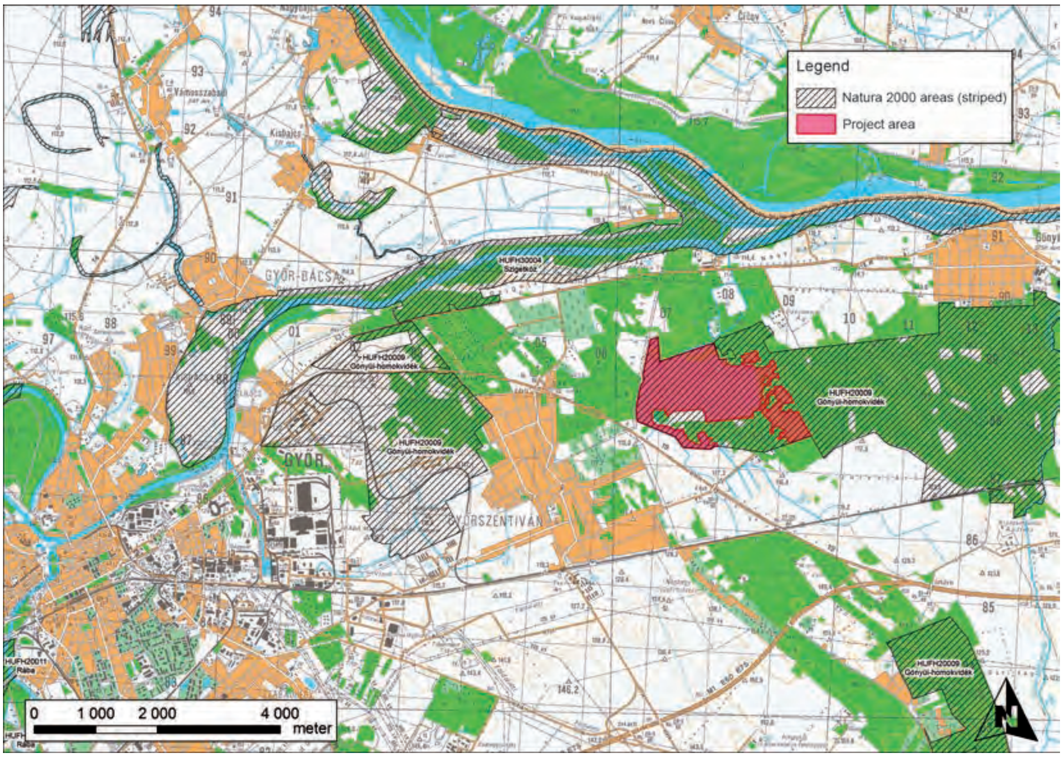

Fig. 1. The geographical location of the Hungarian Little Plain Life+ project site.

Initial conditions

Besides the five main invasive species originally included in the project (*Ailanthus altissima*, *Asclepias syriaca*, *Elaeagnus angustifolia*, *Robinia pseudoacacia*, *Solidago gigantea*), five additional invasive plant species (*Ambrosia artemisiifolia*, *Amorpha fruticosa*, *Celtis occidentalis*, *Conyza canadensis*, *Prunus serotina*) have been identified which pose a serious threat at other parts of the country.

Out of the five main species, the most serious issues are caused by the presence and spread of black locust (*Robinia pseudoacacia*) which occurs in almost every habitat patch – there were only 53 ha of area found where it is not present at all. The size of slightly infested (1–5% coverage) areas is 112.1 ha while the size of areas belonging to the "low infestation level" category is 219 ha, representing 8.8% of the whole area.

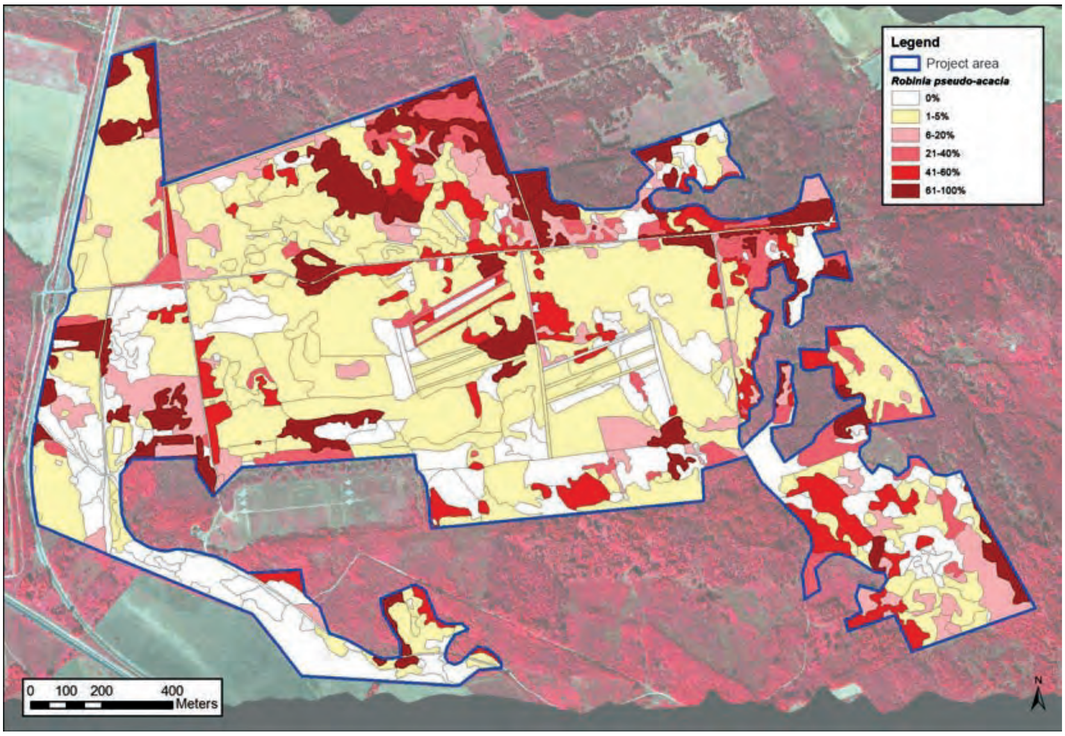

Fig. 2. Black locust coverage (%) in the project area.

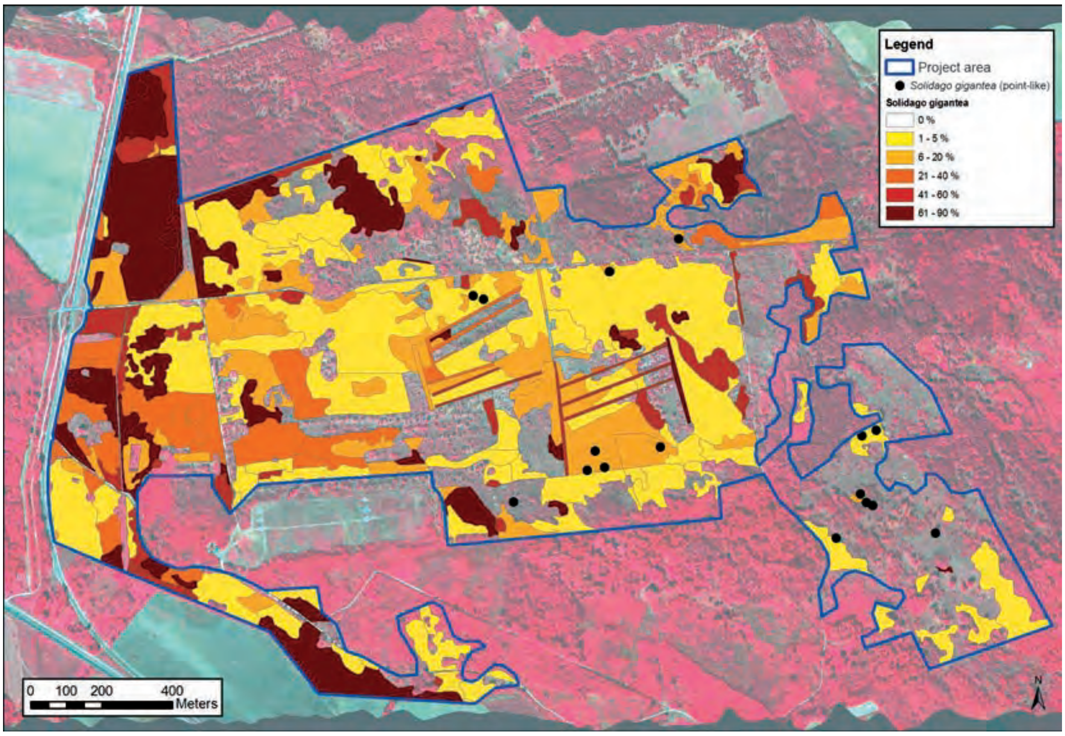

Fig. 3. Giant goldenrod coverage (%) in the project area.

The overall size of moderately frequent and strongly infested areas is 60.7 ha which represents almost one fourth (24.5%) of the project area. Black locust, due to its spreading- and habitat transforming capacity might pose the most severe threat to sandy habitats to be protected (Fig. 2).

Giant goldenrod (*Solidago gigantea*) is the second most common invasive plant of the area after black locust, however, the rate of strongly infested areas is quite low and its occurrence is limited to former sand dunes and the banks of watercourses. Similarly to other species appearing in larger quantities in the area, the coverage indicators were categorised for the giant goldenrod as well. In the project area the species is not present or occurs only in spots on 87.1 ha (35.2%). 29.7% (73.6 ha) of the area belongs to the "sporadic" category. In such areas giant goldenrod can be found in smaller groups, or sporadically but in smaller quantities. 11.6% (28.7 ha) of the area belongs to the "low infestation level" category.

Typical habitat patches belonging to the above category are severely degraded sandy grasslands often

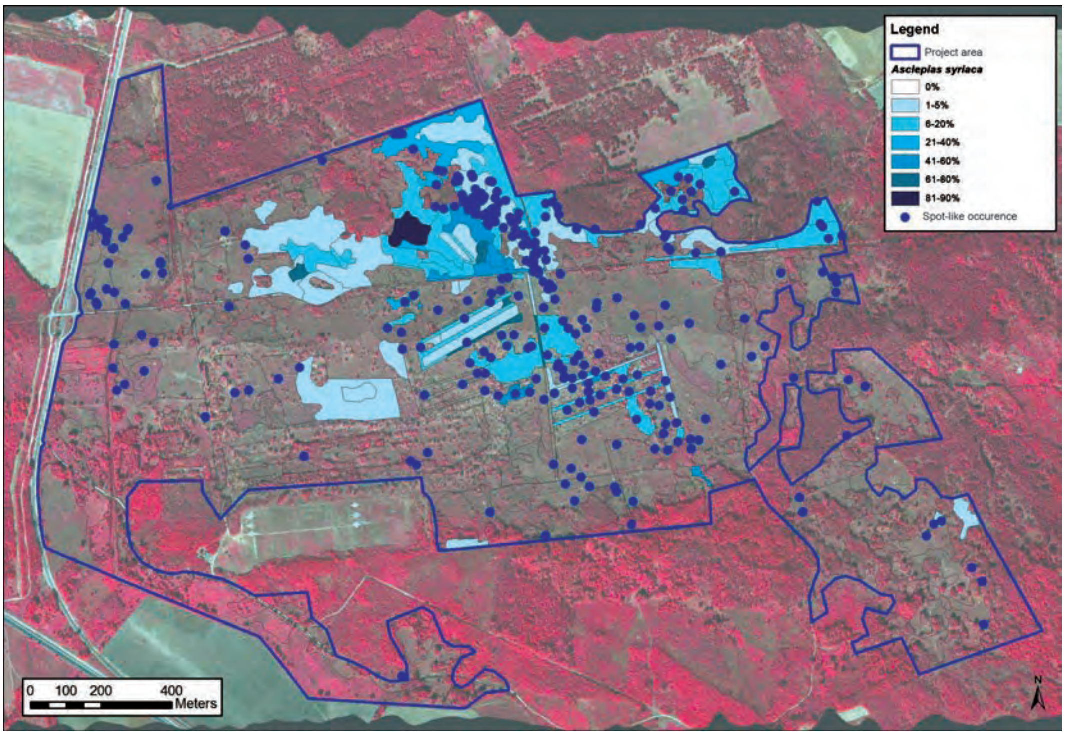

Fig. 4. Common milkweed coverage (%) in the project area.

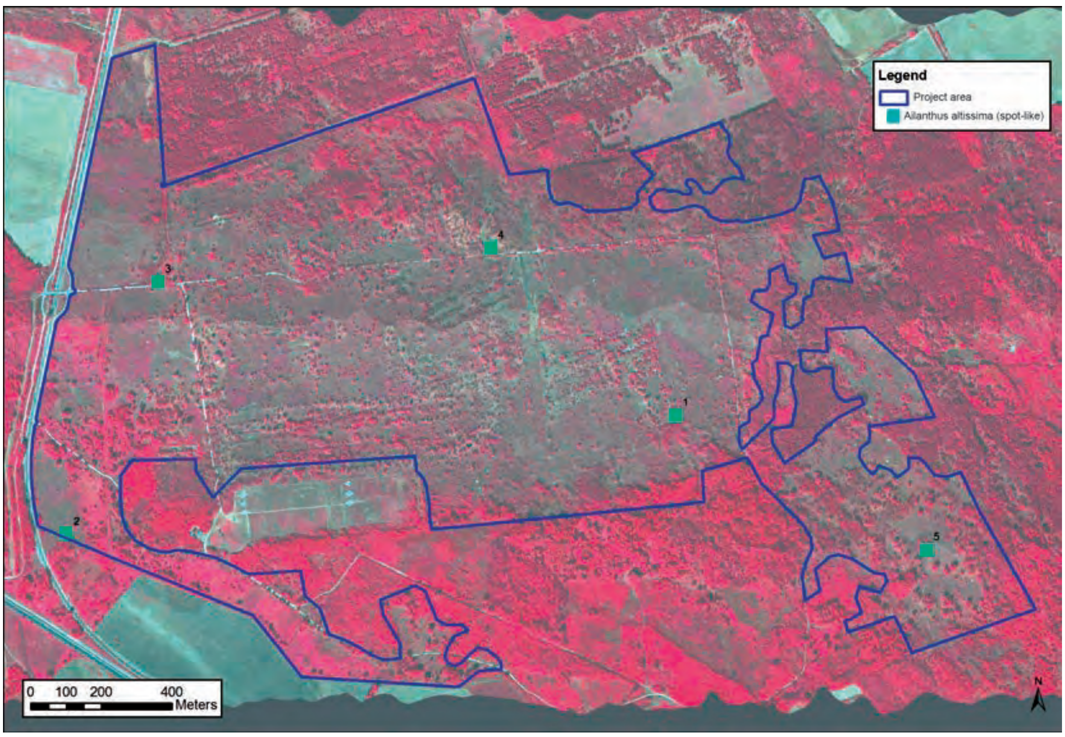

Fig. 5. Occurrence of tree of heaven in the project area.

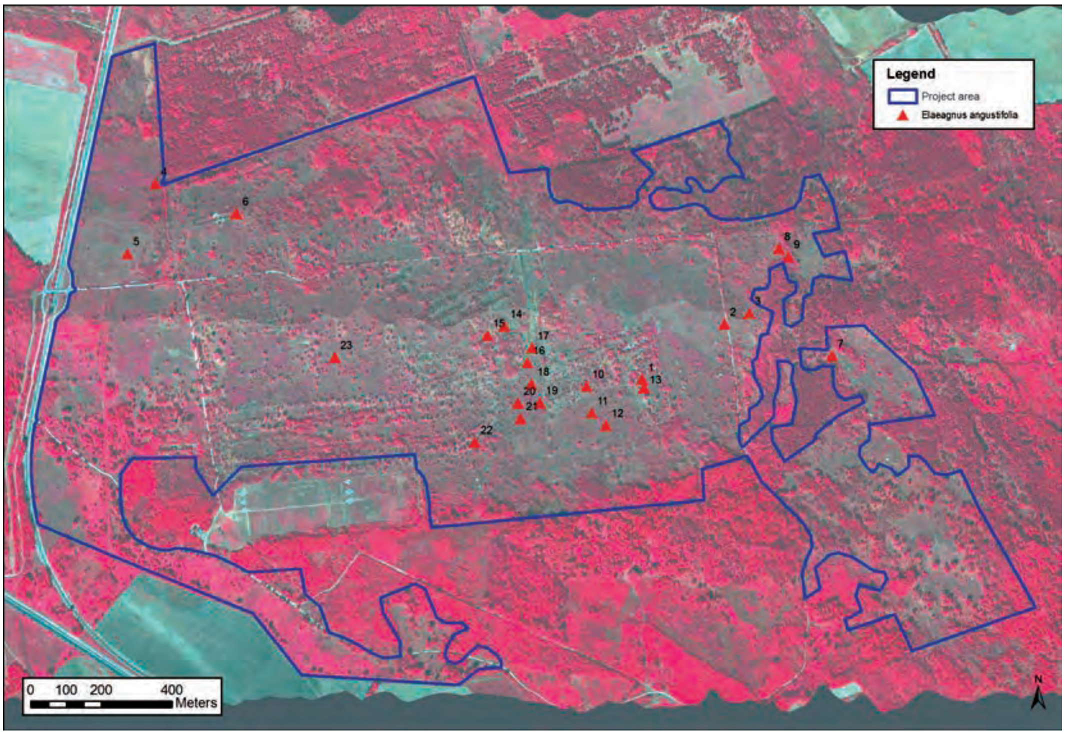

Fig. 6. Occurrence of Russian olive in the project area.

with a considerable coverage of small reed, habitats with spontaneous afforestation or less frequently black locust stands (Fig. 3).

Common milkweed (*Asclepias syriaca*) is not the most widespread throughout the project area, however, it might be considered as the most dangerous invasive species for natural sand steppe habitats. Patchy occurences of milkweed are typical mainly on the northern parts of the project area, which is where it had probably established first. As the typical wind direction is north/northwest, the species spreads toward the south. Its occurence is "frequent" on 0.9% (2.2 ha) of the project area, mainly at certain sections of the military rampart systems and on one of the northern clearings. We only categorised one patch as "forming a stand" with a size of 1.6 ha. The "low infestation level" and "moderately frequent" categories are present in 18.5 ha (7.5%) of the project area. The size of the area belonging to the "sporadic" category is 19.4 ha (7.8%). These primarily include areas where common milkweed is only present in a few places in a point-like manner and therefore cannot be easily mapped. Common milkweed does not form larger patches on 83.2% (206 ha) of the area, however, it does occur individually, or forming patches of a few plants or a few square metres. In order to avoid further spreading, the fast eradication of these has become one of the major objectives of the project (Fig. 4).

Tree of heaven (*Ailanthus altissima*) has only five known occurences in the project area. Out of five occurrences three can be regarded as more significant, however, compared to the neighboring forests these still count as insignificant infestations, even though the patches are clearly growing with a high number of young sprouts (Fig. 5).

Russian olive (*Elaeagnus angustifolia*) was found at 23 places within the project area exlusively as point-like occurrences, within circles of up to 20–25 metres. Larger, closed stands were not found in the area (Fig. 6).

Methods used

We began the control of invasive plants in the area with the presumption that within a short time frame (2–3 yrs) the eradication of these species (except for giant goldenrod) is not possible without the use of chemicals. Eradication by merely mechanical means is deemed possible for every species only if we have unlimited time and workforce at our disposal. In practice, however, this is never provided in operating conditions since projects usually span just a few years, and wages are considered as one of the most important factors when selecting treatments.

Under operating conditions

In ideal cases, experiments are carried out before operational use. Given the short time frame of our project (4 years), however, the project work had to be carried out simultaneously, therefore we started working on controlling the invasive species right away under operating conditions, with methods accepted in forestry and nature conservation.

The treatment of invasive plants was carried out according to the permit issued by the North Transdanubian Environmental Protection and Water Management Inspectorate with the issue number 7807-6/2012.*

Black locust

Injection: Trunk injection was performed in grasslands in good condition on plants with a trunk diameter larger than 5 cm, in a 45 degree angle using a wood drill with a bit size of least 6 (chemical: Medallon Premium 50%). This was followed by cutting a year later.

Cut stump method: Following the cutting of black locust within 10 minutes, the cut surface was wiped with an oily emulsion of glyphosate reagent with colourants (marker dye) added to the solution, using a long paintbrush. Stump sprouts possibly appearing were allowed to grow to a height of about 1.0 metre in order for them to become easily manageable and to enable optimal usage of the chemicals. Once they reached this height, the leaf rosette growing from the top of the offshoot – or in the case of branching plants, the top leaf rosette of the side shoots – was wiped with an oily emulsion containing glyphosate reagent and surface tension reducer called Silwet L-77 mixed with marker dye, using a long paintbrush. This method was used for closed black locust stands as well as severely degraded grasslands. If there were grassland patches to be protected under the black locust shoots, or (turkey) oak seedlings as associate plant species, then the application of the reagent (wiping or spot-spraying) was carried out with a Lontrel 300 0.7 litre/ha dose.

Tree of heaven

Injection: Injection to a drilled hole into the trunk of plants with 10 cm or larger trunk diameter, by first drilling a hole in a 45 degree angle with a wood drill bit of at least size 6. The holes are injected with an oily emulsion with glyphosate reagent by using a veterinary mass vaccination syringe. Following the treatment the holes are sealed with an ointment for tree injuries or silicone in order to avoid evaporation. The treatment should be carried out in the July–October period. Simultaneously, we performed spot spraying and wiped the shoots growing next to the older plants.

Basal bark treatment without cuts: The thin bark of the tree of heaven facilitates this treatment technique: plants with diameters smaller than 10 cm were wiped with an oily emulsion of glyphosate reagent coloured by marker dye, with high levels of effectiveness.

Common milkweed

Spraying: In order to control patches, we carried out the treatment with an engine-powered backpack sprayer and a spraying adapter fitted on a quad with 80 litres/ha of herbicide. The herbicide used was a mixture of Tomigan 250 EC 1 litre / ha and Banvel 480 S 1.5 litre/ ha with Silwet L-77 added to reduce surface tension. In case there were valuable grassland patches near the common milkweed stands, we used a diluted solution of Garlon 4E for spraying.

Wiping: Wiping isolated common milkweed individuals with a 30% water solution of the Medallon Premium herbicide. The reagent was applied using a radiator brush (Medallon Premium 30%, Silwet L-77, N-fertiliser).

Russian olive and common hackberry

For plants appearing in isolated patches we applied the partial bark stripping technique using an oily emulsion with glyphosate reagent coloured with marker dye. The treatment was repeated the following year if required. No felling was performed.

Under experimental conditions

In the course of control treatments carried out under experimental conditions we were mainly trying to find out whether there were any other methods more effective and more succesful in protecting natural habitats than the ones used under operational conditions. The following variables were examined for specific species:

- method of application;
- treatment period;
- combination of reagents;
- amount of herbicide used;
- time requirements of the treatment;
- ratio of surviving, damaged and destroyed plants;
- damage caused to the surrounding vegetation;
- diameter of treated plants (in the case of woody species).

Fig. 7. Partial bark stripping treatment. (Photo: G. Takács)

* Attention! Experimental chemical control methods described in this chapter are subject to authorisation! Their practical application requires an emergency permit issued by the pesticide control authorities for the given area and period!

Table 1. Data concerning experimental treatments of black locust.

Code	Composition of the mixture used (in 1 litre)		Concentration (%)	Application	Time period	Treated circumference (cm)
MAY 1	750 ml Medallon Premium + 15 g fertiliser		75	injection	May	1824.34
MAY 2	500 ml Medallon Premium + 15 g fertiliser		50	injection	May	1161.80
MAY 3	750 ml Medallon Premium + 0.5 ml Nonit + 15 g fertiliser		75	partial bark stripping treatment	May	822.68
MAY 4	500 ml Medallon Premium + 3.5 ml Nonit + 15 g fertiliser		50	partial bark stripping treatment	May	
MAY 5	750 ml Medallon Premium + 3.5 ml Silwet Star + 15 g fertiliser		75	partial bark stripping treatment	May	1070.74
MAY 6	500 ml Medallon Premium + 3.5 ml Silwet Star + 15 g fertiliser		50	partial bark stripping treatment	May	1221.46
JUNE 1	1. treatment: + 330 ml Taifun + 3.5 ml Nonit + 15 g fertiliser	2. treatment: + 35 ml Taifun + 3.5 ml Nonit + 15 g fertiliser	33	cut stump treatment, spraying of sprouts	June	1786.66
JUNE 2	1. treatment: + 500 ml Taifun + 3.5 ml Nonit + 15 g fertiliser	2. treatment: + 35 ml Taifun + 3.5 ml Nonit + 15 g fertiliser	50	cut stump treatment, sprout spraying	June	1862.02
JUNE 3	1. treatment: + 330 ml Medallon Premi- um + 3.5 ml Nonit + 15 g fertiliser	2. treatment: + 35 ml Medallon Premi- um + 3.5 ml Nonit + 15 g fertiliser	33	cut stump treatment, spraying of sprouts	June	1500.92
JUNE 4	1. treatment: + 500 ml Medallon Pre- mium + 3.5ml Nonit + 15g fertiliser	2. treatment: + 35 ml Medallon Premi- um + 3.5 ml Nonit + 15g fertiliser	50	cut stump treatment, spraying of sprouts	June	2012.74
JUNE 5	1. treatment: + 330 ml Taifun 360 + 3.5 ml Silwet L-77 + 15 g fertiliser	2. treatment: + 35 ml Taifun 360 + 3.5 ml Nonit + 15 g fertiliser	33	cut stump treatment, spraying of sprouts	June	872.92
JUNE 6	1. treatment: + 500 ml Taifun 360 + 3.5 ml Silwet L-77 + 15 g fertiliser	2. treatment: + 35 ml Taifun 360 + 3.5 ml Silwet L-77 + 15 g fertiliser	50	cut stump treatment, spraying of sprouts	June	1425.56
JUNE 7	1. treatment: + 330 ml Medallon Premium + 3.5 ml Silwet L-77 + 15 g fertiliser	2. treatment: + 35 ml Medallon Premium + 3.5 ml Silwet L-77 + 15 g fertiliser	33	cut stump treatment, spraying of sprouts	June	1453.82
JUNE 8	1. treatment: + 500 ml Medallon Premium + 3.5 ml Silwet L-77 + 15 g fertiliser	2. treatment: + 35 ml Medallon Premium + 3.5 ml Silwet L-77 + 15 g fertiliser	50	cut stump treatment, spraying of sprouts	June	1403.58
JUNE 9	750 ml Medallon Premium + 15 g fertiliser		75	injection	June	1425.56
JUNE 10	500 ml Medallon Premium + 15 g fertiliser		50	injection	June	1029.92
JUNE 11	750 ml Medallon Premium + 0.5 ml Nonit + 15 g fertiliser		75	partial bark stripping treatment	June	1287.40
JUNE 12	500 ml Medallon Premium + 0.5 ml Nonit + 15 g fertiliser		50	partial bark stripping treatment	June	1824.34
JUNE 13	750 ml Medallon Premium + 0.5 ml Silwet Star + 15 g fertiliser		75	partial bark stripping treatment	June	1259.14
JUNE 14	500 ml Medallon Premium + 0.5 ml Silwet Star + 15 g fertiliser		50	partial bark stripping treatment	June	1111.56
SEPT 1	1. treatment: + 330 ml Taifun 360 + 3.5 ml Nonit + 15g fertiliser	2. treatment: + 35 ml Taifun 360 + 3.5 ml Nonit + 15g fertiliser	33	cut stump treatment, spraying of sprouts	September	690.80
SEPT 2	1. treatment: + 500 ml Taifun 360 + 3.5 ml Nonit + 15 g fertiliser	2. treatment: + 35 ml Taifun 360 + 3.5 ml Nonit + 15 g fertiliser	50	cut stump treatment, spraying of sprouts	September	668.82

Code	Composition of the mixture used (in 1 litre)		Concen-tration (%)	Application	Time period	Treated circumfer-ence (cm)
SEPT 3	1. treatment: 330 ml Medallon Pre-mium 3.5 ml Nonit 15 g fertiliser	2. treatment: + 35 ml Medallon Premium 3.5 ml Nonit 15 g fertiliser	33	cut stump treatment, spraying of sprouts	September	907.46
SEPT 4	1. treatment: + 500 ml Medallon Premium + 3.5 ml Nonit + 15 g fertiliser	2. treatment: + 35 ml Medallon Premi- um + 3.5 ml Nonit + 15 g fertiliser	50	cut stump treatment, spraying of sprouts	September	750.46
SEPT 5	1. treatment: + 330 ml Taifun 360 + 3.5 ml Silwet L-77 + 15 g fertiliser	2. treatment: + 35 ml Taifun 360 + 3.5 ml Silwet L-77 + 15 g fertiliser	33	cut stump treatment, spraying of sprouts	September	835.24
SEPT 6	1. treatment: + 500 ml Taifun 360 + 3.5 ml Silwet L-77 + 15 g fertiliser	2. treatment: + 35 ml Taifun 360 + 3.5 ml Silwet L-77 + 15 g fertiliser	50	cut stump treatment, spraying of sprouts	September	753.60
SEPT 7	1. treatment: + 330 ml Medallon Premium + 3.5 ml Silwet L-77 + 15 g fertiliser	2. treatment: + 35 ml Medallon Premium + 3.5 ml Silwet L-77 + 15 g fertiliser	33	cut stump treatment, spraying of sprouts	September	549.50
SEPT 8	1. treatment: + 500 ml Medallon Premium + 3.5 ml Silwet L-77 + 15 g fertiliser	2. treatment: + 35 ml Medallon Premium + 3.5 ml Silwet L-77 + 15 g fertiliser	50	cut stump treatment, spraying of sprouts	September	869.78
SEPT 9	750 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser		75	injection	September	1026.78
SEPT 10	500 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser		50	injection	September	1168.08
SEPT 11	750 ml Medallon + 3.5 ml Nonit + 15 g fertiliser		75	partial bark stripping treatment	September	998.52
SEPT 12	500 ml Medallon Premium + 3.5 ml Nonit + 15 g fertiliser		50	partial bark stripping treatment	September	806.98
SEPT 13	750 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser		75	partial bark stripping treatment	September	904.32
SEPT 14	500 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser		50	partial bark stripping treatment	September	838.38
OCT 1	750 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser		75	injection	October	916.88
OCT 2	500 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser		50	injection	October	1036.20
OCT 3	750 ml Medallon + 3.5 ml Nonit + 15 g fertiliser		75	partial bark stripping treatment	October	546.36
OCT 4	500 ml Medallon Premium + 3.5 ml Nonit + 15 g fertiliser		50	partial bark stripping treatment	October	584.04
OCT 5	750 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser		75	partial bark stripping treatment	October	995.38
OCT 6	500 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser		50	partial bark stripping treatment	October	1064.46

Experiments were carried out according to the No. 8255-4/2012 permit issued by the North Transdanubian Environmental Protection and Water Management Inspectorate as conservation authority and the no. 04.2/1810-2/2013. permit for the experiments issued by the Plant, Soil and Agricultural Environment Directorate.

Black locust

In the case of black locust we exclusively examined Category III reagents (Medallon Premium – glyphosate diammonium salt, Taifun 360 glyphosate-isopropylamine salt so that the method could be used without the supervision of a plant protection professional) with three types of application (injection, partial bark stripping treatment and cut stump method) carried out in four different periods (May, June, September, October) (Table 1). In the case of injection and partial bark stripping the treatments were monitored until the treated plants died or until root suckers appeared. Partial bark stripping was performed on 50% of the circumference at 30–50 cm vertical length (Fig. 7). When designating the test areas we tried to find places where all possible diameter categories (0–5 cm, 6–10 cm, 11–15 cm, 16–20 cm, >20 cm) were found and represented by at least five plants.

Table 2. Data concerning experimental treatments of tree of heaven.

Code	Composition of the mixture used (in 1 litre)	Application	Treatment period	Number of plants	Circumference treated (cm)
MAY 7	750 ml Taifun + 3.5 ml Silwet Star + 15 g fertiliser	injection	May	118	2471.18
MAY 8	750 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser	injection	May	197	3011.26
MAY 9	750 ml Medallon + 4 g Mezzo + 3.5 ml Silwet + 15 g fertiliser	injection	May	156	3582.74
MAY 10	8 g Titus Plus + 3.5 ml Silwet Star + 15 g fertiliser	injection	May	202	2948.46
MAY 11	750 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser	partial bark stripping method	May.	110	1887.14
MAY 12	500 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser	partial bark stripping method	May	119	2176.02
MAY 13	8 g Titus Plus + 3.5 ml Silwet Star + 15 g fertiliser	partial bark stripping method	May.	157	2292.20
MAY 14	6 g Titus Plus + 3.5 ml Silwet Star + 15 g fertiliser	partial bark stripping method	May	158	2345.58
JUNE 15	1. treatment: + 500 ml Taifun + 15 g fertiliser; 2. treatment: + 35 ml Taifun + 15g fertiliser	cut stump method, spraying of sprouts with 2 x 3.5% Taifun	June	99	1714.44
JUNE 16	1. treatment: + 6 g Titus Plus + 15 g fertiliser; 2. treatment: + 35 ml Banvel 480 S + 15g fertiliser	cut stump method, spraying of sprouts with 2 x 3.5% Principal Plus/Titus Plus/Banvel 480 S	June	98	1723.86
JUNE 17	750 ml Taifun + 3.5 ml Silwet Star + 15 g fertiliser	injection	June	100	1391.02
JUNE 18	750 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser	injection	June	119	1808.64
JUNE 19	750 ml Medallon + 4 g Mezzo + 3.5 ml Silwet + 15 g fertiliser	injection	June	115	1692.46
JUNE 20	8 g Titus Plus + 3.5 ml Silwet Star + 15 g fertiliser	injection	June	98	1962.50
JUNE 21	750 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser	partial bark stripping method	June	90	1372.18
JUNE 22	500 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser	partial bark stripping method	June	50	1011.08
JUNE 23	8 g Titus Plus + 3.5 ml Silwet Star + 15 g fertiliser	partial bark stripping method	June	37	706.50
JUNE 24	6 g Titus Plus + 3.5 ml Silwet Star + 15 g fertiliser	partial bark stripping method	June	40	788.14
AUG 1	750 ml Medallon Premium + 4 g Mezzo + 3.5 ml Silwet + 15 g fertiliser	injection	August	170	2251.38
AUG 2	8 g Principal Plus + 3.5 ml Silwet Star + 15 g fertiliser	injection	August	142	1774.10
AUG 3	500 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser	partial bark stripping method	August	151	2081.82
AUG 4	8 g Principal Plus + 3.5 ml Silwet Star + 15 g fertiliser	partial bark stripping method	August	185	1921.68
AUG 5	6 g Principal Plus + 3.5 ml Silwet Star + 15 g fertiliser	partial bark stripping method	August	187	1918.54
SEPT 15	500 ml Taifun + 15 g fertiliser	cut stump method, spraying of sprouts with 2 x 3.5% Taifun	September	87	863.50
SEPT 16	600 ml Medallon + 150 ml Banvel 480 S + 15 g fertiliser	injection	September	108	1180.64
SEPT 17	750 ml Taifun + 3.5 ml Silwet Star + 15 g fertiliser	injection	September	168	1635.94
SEPT 18	750 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser	injection	September	161	1720.72
SEPT 19	750 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser	partial bark stripping method	September	90	935.72
OCT 7	750 ml Taifun + 3.5 ml Silwet Star + 15 g fertiliser	injection	October	16	401.92
OCT 8	750 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser	injection	October	32	728.48
OCT 9	20 g Mezzo + 200 ml Banvel 480 S + 15 g fertiliser	injection	October	22	687.66
OCT 10	750 ml Medallon Premium + 4 g Mezzo + 3.5 ml Silwet + 15 g fertiliser	injection	October	30	847.80
OCT 11	750 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser	partial bark stripping method	October	16	442.74
OCT 12	500 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser	partial bark stripping method	October	12	282.60

Table 3. Data concerning experimental treatments of common milkweed.

Code	Composition of the mixture used (in 1 litre)	Concentration (% or dose)	Application	Period
MAY 15	100 ml Medallon + 3.5 ml Silwet Star+ 15 g fertiliser	10	wiping	May
MAY 16	330 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser	33	wiping	May
MAY 17	500 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser	50	wiping	May
MAY 18	100 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser	10	semi-mechanical wiping	May
MAY 19	330 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser	33	semi-mechanical wiping	May
MAY 20	500 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser	50	semi-mechanical wiping	May
MAY 21	100 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser	10	mechanical wiping	May
MAY 22	200 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser	33	mechanical wiping	May
MAY 23	330 ml Medallon + 3.5 ml Silwet Star + 15 g fertiliser	50	mechanical wiping	May
MAY 24	0.2 g Granstar + 3.5 ml Silwet Star + 15 g fertiliser	1st dose	spot spraying	May
MAY 25	0.4 g Granstar + 3.5 ml Silwet Star + 15 g fertiliser	2nd dose	spot spraying	May
MAY 26	0.8 g Granstar + 3.5 ml Silwet Star + 15 g fertiliser	3rd dose	spot spraying	May
MAY 27	0.3 g Mezzo + 3.5 ml Silwet Star + 15 g fertiliser	1st dose	spot spraying	May
MAY 28	0.6 g Mezzo + 3.5 ml Silwet Star + 15 g fertiliser	2nd dose	spot spraying	May
MAY 29	1.2 g Mezzo + 3.5 ml Silwet Star + 15 g fertiliser	3rd dose	spot spraying	May
MAY 30	0.3 g Titus Plus + 3.5 ml Silwet Star + 15 g fertiliser	1st dose	spot spraying	May
MAY 31	0.6 g Titus Plus + 3.5 ml Silwet Star + 15 g fertiliser	2nd dose	spot spraying	May
MAY 32	1.2 g Titus Plus + 3.5 ml Silwet Star + 15 g fertiliser	3rd dose	spot spraying	May
MAY 33	0.2 g Granstar + 3.33 ml Tomigan 250 EC + 3.5 ml Silwet Star + 15 g fertiliser	1st dose	spot spraying	May
MAY 34	0.4 g Granstar + 6.66 ml Tomigan 250 EC + 3.5 ml Silwet Star + 15 g fertiliser	2nd dose	spot spraying	May
MAY 35	0.8 g Granstar + 13.32 ml Tomigan 250 EC + 3.5 ml Silwet Star + 15 g fertiliser	3rd dose	spot spraying	May
MAY 36	0.33 g Titus Plus + 3.33 ml Tomigan 250 EC + 3.5 ml Silwet Star + 15 g fertiliser	1st dose	spot spraying	May
MAY 37	0.66 g Titus Plus + 6.66 ml Tomigan 250 EC + 3.5 ml Silwet Star + 15 g fertiliser	2nd dose	spot spraying	May
MAY 38	1.32 g Titus Plus + 13.32 ml Tomigan 250 EC + 3.5 ml Silwet Star + 15 g fertiliser	3rd dose	spot spraying	May
MAY 42	2 g Casper + 3.33 ml Tomigan 250 EC + 3.5 ml Silwet Star + 15 g fertiliser	1st dose	spot spraying	May
MAY 43	4 g Casper + 6.66 ml Tomigan 250 EC + 3.5 ml Silwet Star + 15 g fertiliser	2nd dose	spot spraying	May
MAY 44	8 g Casper + 13.32 ml Tomigan 250 EC + 3.5 ml Silwet Star + 15 g fertiliser	3rd dose	spot spraying	May

Tree of heaven

In the case of the tree of heaven we designated closed stands as sample areas, where all possible trunk diameters (0–5 cm, 6–10 cm, 11–15 cm, 16–20 cm, >20 cm) were represented by at least 5 plants. Similarly to black locust, we examined the effectiveness of trunk injection, partial bark stripping treatment as well as cut stump method (Table 2). In this case, however, besides the Category III reagent glyphosate we also studied the effects of 1st category reagents such

Table 4. Average amounts of herbicide used and average time frame in the case of black locust.

Application method	Time needed for treatment	Amount of chemical used	Time needed for treatment (for treated circumference unit)	Amount of herbicide needed for treatment (for treated circumference unit)
Injection	26 minutes (min. 14 minutes, max. 45 minutes)	171.25 ml (min. 100 ml, max. 220 ml	2.31 minutes	15.43 ml
Partial bark stripping method	18.5 minutes (min. 14 minutes,max. 23 minutes)	241.87 ml (min. 130 ml, max. 320 ml	1.94 minutes	24.47 ml
Cut stump method	34.7 minutes (min. 22 minutes,max. 55 minutes)	390.6 ml (min. 120 ml, max. 850 ml	3.28 minutes	31.87 ml

Table 5. Average amounts of herbicide used and average time frame in the case of tree of heaven.

Application method	Time required for treatment	Amount of chemical used	Time required for treatment (for treated circumference unit)	Amount of herbicide reuired for treatment (for treated circumference unit)
Injection	33.9 minutes (min. 17 minutes, max. 60 minutes)	411 ml (min. 200 ml, max. 1000 ml	2.24 minutes	25.58 ml
Partial bark stripping method	20.2 minutes (min. 8 minutes, max. 30 minutes)	275 ml (min. 70 ml, max. 460 ml	1.67 minutes	18.72 ml
Cut stump method	65 minutes (min. 37 minutes, max. 80 minutes)	390 ml (min. 270 ml, max.500 ml	4.49 minutes	27.87 ml

as metsulfuron-methyl (Mezzo) and rimsulfuron-dicamba (Titus Plus) as well. The herbicide called Banvel 480S previously deemed effective was not tested since it had turned out to be ineffective during previous experiments (KAEG Ltd.) (treated and seemingly dead plants re-sprouted again within the following 2–3 years).

Common milkweed

In the case of common milkweed we studied the effects of the first treatment in May (during and after blooming) with different application methods and herbicide mixtures (Table 3). Wiping and spot-spraying do not require detailed explanation. The “semi-mechanical” wiping was carried out with a tool called Microwipe (Fig. 8) while mechanical wiping was performed with the help of a wiping machine fitted onto a quad (Fig. 9). The experiment areas were 10 × 10 quadrants, in these we counted all individuals in 3, 1 m × 1 m micro-quadrants in order to measure the effectiveness of the treatment. During our study we tried to differentiate between surviving plants and those shooting from a seed; however, since it was not always possible to determine which was which, we ended up evaluating all plants found in the micro-quadrant together. The damage in the surrounding flora was measured on a 3-point scale (1: no effect of the herbicide can be detected on the surrounding flora; 2: the effect of the herbicide on surrounding vegetation is discernible; 3: the surrounding flora is mostly destroyed) and also added a written, detailed evaluation if needed.

Giant goldenrod

For giant goldenrod only mechanical treatments (mowing) were examined in sandy habitats. We measured the effectiveness of one mowing/ year (May) for 1–3 years, mowing two times/ year (May, June) and three times/ year (May, June, September) by monitoring the thinning of the coverage. Mowed plants were removed from the area in order to reduce nutrition input. As we only have partial results (results of the first year of treatments), no detailed presentation should follow here.

Experiences gained

We examined the effectiveness (ratio of destroyed plants) of the control treatments and the associated damage done to surrounding vegetation under both operating and experimental conditions. However, as the most effective treatment is not necessarily the best one we also assessed the amount of herbicide

Fig. 8. Microwipe tool for wiping (source: http://www.marvipak.fi).

Fig. 9. Mechanical wiping tool fitted onto a quad. (Photo: G. Takács)

Fig. 10. Result of black locust treatment (OCT1 – Medallon Premium 75% injection) a year later. (Photo: G. Takács)

and time required for each method, based on which expected costs can be estimated.

Evaluation of application methods

The methods of applying herbicide were mostly examined under experimental conditions.

During our survey we estimated the time and the amount of herbicide required for the treatment as well as its effectiveness and collateral damage.

Tree of heaven and black locust

In the case of black locust and tree of heaven we examined the effects of the trunk injection method, the partial bark stripping method as well as the method of felling followed by cut stump treatment, which is quite widely used in practice (Tables 4 & 5). Regarding black locust, it was stem injection that required the smallest amount of chemicals per circumference unit, unlike in the case of tree of heaven where higher amounts were needed as plants with a circumference smaller than 10 cm were more frequent. For both species the method requiring the largest amount of chemicals was cut stump treatment (taking into account the follow up spraying of regrowth).

The amount of time needed for the first treatment was the lowest in case of the partial bark stripping method and highest in case of the cut stump method, as it needs to be preceded by felling (treatment time does not include chopping and cleaning up). Considering that trees also have to be felled in the subsequent year after using partial bark stripping or injection, the most favourable method as far as time requirements are concerned is clearly the cut stump method.

Considering all factors, the cut stump method can be considered as the most favourable time-wise, but it also requires the highest amount of chemicals (including follow-up treatments).

A disadvantage of the technology is that it can only be carried out during a limited period of time, as in protected areas it cannot be performed during the vegetation period (disturbance, nesting) and the effectiveness of the reagent wiped on the stump is low. Another disadvantage of this method is that the evaporation of the reagent applied to the plant has a considerable effect on the surrounding vegetation (in a 1–3 metre circle). Partial bark stripping treatment can be performed rather fast with an amount of herbicide lower than in the case of the cut stump method but usually higher than in the case of injection. As for tree of heaven, plants with smaller circumference (1–3 cm) can only be treated effectively by wiping, which requires even less time. In the case of the partial bark stripping treatment the evaporation of the reagent has to be taken into consideration, especially in the June–August period. Injection requires the smallest amount of herbicide and comes with the fewest side effects (practically no evaporation); however, this is the most time-consuming method regarding the first treatment.

Based on the measured data, there can be no obvious order among the three methods of application as all of them are capable of eradicating black locust and tree of heaven. The choice has to be made by considering the advantages and disadvantages of each technology, as well as the features of the area to be treated; based on which sometimes the best choice can be a combination of methods.

Fig. 11. 16 MAY (common milkweed – Medallon Premium 33% wiping) experimental lot No. 2 sample area before treatment. (Photo: G. Takács)

Common milkweed

In the case of common milkweed, the so-called semi-mechanical wiping (Micro-wipe) did not achieve any positive results, the tool (Fig. 8) is not suitable for performing the treatment since the cohesion enhancer almost immediately gets bound into the cloth used to perform the wiping, and the reagent never reaches the plants. The wiping device fitted onto a quad is suitable for performing the treatment to common milkweed only to a certain extent. We experienced two severe flaws in the technology, due to which we do not recommend its application in grasslands yet. Feather grass and a number of other taller grass species typical of sandy grassland bloom in this period, and are affected by the chemical even if the wiping table is set to a high position (Fig. 9), in most cases causing them to die or suffer damage.

A significant problem with this technology is that if the wiping surface too wet, there is a considerable amount of dripping; while if it is not wet enough, there will not be a sufficient amount of herbicide on the plants. Wiping and spot-spraying are suitable methods for the control of common milkweed stands when implemented correctly. Wiping is more time-consuming as it requires twice as much time on average than spot spraying. If performed appropriately, wiping comes with a lot less dripping and the surrounding vegetation is barely damaged; while in the case of spot spraying the chemical inevitably reaches the surrounding vegetation. Regarding the amount of herbicide used there is no significant difference between the two technologies.

Evaluation of treatment periods and reagent combinations used

Black locust

In the case of black locust it can be stated that in general, injection (Fig. 10) proved more effective than partial bark stripping. When using the latter technique, the treated plant often partly survived. However, this technology is not completely ineffective and can be successfully used for plants with thin stems (the ones that can not be injected).

There was no significant difference found between the 50% and 70% solutions used for the injection, therefore it is advised to use the lower concentration.

The autumn period is clearly the most favourable of all periods for both injection and partial bark stripping. In case the treatments need to be performed in the spring or early summer, their effectiveness will be reduced by about 20%, which means that the number of necessary repeated treatments will grow. Due to strong evaporation, summer (June–August) treatments are not recommended. The traditional cut stump method was effective in every case. Nonetheless, September treatments are more effective than the ones in the summer.

Fig. 12. 16 MAY (Common milkweed – Medallon Premium 33% wiping) experimental lot no.2. Sample area after 1 year of the treatment. (Photo: G. Takács)

Following treatments in June sprouts always had to be sprayed in the autumn (10–50 stump or root suckers depending on the number of treated plants). The following year about 1–8 suckers were found in these areas. In the case of treatments in September, no sprout spraying had to be carried out in the year of the treatment and there were no more than 1–7 suckers found (mostly growing from the root). Therefore, in the case of autumn treatments, one less sprout spraying had to be performed.

Regarding the reagent used no significant difference was observed, both Medallon Premium and

Fig. 13. Shoots with phytotoxic symptoms on tree of heaven (MAY 9). (Photo: G. Takács)

Taifun 360 proved to be effective. When performing cut stump treatment with solutions of 33% and 50% concentration, the higher concentration was not apparently more effective. Considering that in protected areas one should always prefer the method with the least possible amount of chemicals, we suggest using lower concentration solutions for cut stump treatments, despite the fact that in some cases this means that more suckers will have to be treated.

Summarising the results of the experiment, we can conclude that after considering effectiveness, costs and damage to the surrounding vegetation, the recommended control method for black locust is the following:

Closed stands of black locust without natural values to be protected: Autumn (September–October) cutting followed by stump wiping within 10–20 mins (Medallon Premium or Tai fun 360 33% + cohesion enhancer 3.5 ml/l + fertiliser 15 g/l), followed by a treatment of the suckers by spot spraying (Medallon Premium or Taifun 360 3.5%). Time required for the treatment is 1–3 years.

Smaller patches of black locust in grasslands, or isolated trees (with diameters wider than 5 cm): Late summer or autumn injection if possible (Medallon Premium or Taifun 360 50% + cohesion enhancer 3.5 ml/l + fertiliser 15 g/l, drill bit of min. 5–6 mm in diameter, in a 45 degree angle with 1–2 cm reagent per hole injected with the help of a veterinary mass vaccination syringe. The hole must be sealed with e.g. plasticine, silicone sealing, ointment etc.). Should be repeated the following year if necessary. Dead trees can be felled the second winter following treatment, but if it is possible, waiting one additional year is even more favourable. Removal of the cut material has to be performed on dry or frozen soil. Time needed for the treatment: 2–3 years. Stump and root suckers might appear following cutting, these should be sprayed with a 3.5% solution of Medallon Premium or Taifun 360.

Thin stemmed trees on grasslands (with diameters smaller than 5 cm): Partial (around ⅓ of the circumference in a length of 40–50 cm) stripping of the plants' bark, followed by wiping with a 50% Medallon Premium or Taifun 360 (+ cohesion enhancer 3.5 ml/l + fertiliser 15 g/l) solution, performed in the autumn. The treatment should be repeated the following year if needed. Snags can be cut down the second winter following treatment and if possible, waiting one extra year is even more favourable. Removal of the cut material has to be performed on dry or frozen soil. Time needed for the treatment: 2–3 years.

Tree of heaven

Injection proved to be more effective in the case of tree of heaven as well, yet more time-consuming and expensive than the partial bark stripping treatment. The latter is better for plants of a smaller diameter. The first results of cut stump method were favourable since barely any suckers appeared the following spring. In the summer, however, a mass of suckers appeared, so further follow-up treatments were needed.

As far as treatment periods are concerned, no significant difference was found in the case of injection; the treatment can practically be applied at any point between May and October. Regarding the partial bark stripping method, it can be concluded that autumn treatments achieved good results while in the case of spring and summer treatments, many treated plants showed signs of life a year later (Fig. 13).

Out of the reagent combinations used, glyphosate and glyphosate + metsulfuron-methyl proved to be effective. In the case of May–June glyphosate treatments, offshoots with severe phytotoxic symptoms appeared, but these mostly froze during the following year. In the case of glyphosate + metsulfuron-methyl treatments, this phenomenon could only be observed sporadically. Both combinations caused absorption through the root, which resulted in the appearance of root suckers with severe phytotoxic symptoms a few meters away from the trunk. Treatments with herbicides containing rimsulfuron and dicamba reagents resulted in fast canopy loss, and some of the treated plants showed phytotoxic symptoms – however, only a small portion of the treated plants was destroyed. Herbicides with such reagents are not recommended for the eradication of tree of heaven.

Summarising the results of the experiment, we can conclude that after considering effectiveness, costs and damage to the surrounding vegetation, the recommended control method for tree of heaven is the following:

Older plants (diameter larger than 5 cm): Injection at any time within vegetation period (Medallon Premium 75% + Mezzo (4 g/l) + cohesion enhancer 3.5 ml/l + fertiliser 15 g/l, min. 5–6 mm diameter drill bit, in a 45 degree angle with 1–2 cm reagent per hole injected with the help of a veterinary mass vaccination syringe. The hole must be sealed (plasticine, silicone sealing, ointment). Should be repeated the following year if necessary.

Snags can be cut the third winter following the first treatment. Removal of the cut material has to be performed on dry or frozen soil. Stump and root suckers might appear following cutting which must be sprayed with the 3.5% concentration solution of Medallon Premium or Taifun 360. Time needed for the treatment: a minimum of 3 years.

Young plants (with diameters smaller than 5 cm): Following partial bark stripping (around ⅓ the circumference in the length of 40–50 cm) apply 50% Medallon Premium of Taifun 360 solution. The treatment must be repeated the following year if necessary.

Snags can be cut the third winter following the first treatment. In case it is possible, waiting one extra year is even more favourable. Removal of the cut

Table 6. Offshoot ratio of common milkweed after treatment.

Concentration	The number of treated plants in the microquadrants (piece)	Plants alive a year later (piece)	Offshoot ratio (%)	Damage to surrounding vegetation*
10%	48	7	14.5	1
33%	60	13	21.6	2–3
50%	84	7	8.33	2–3

* 1: no effect of the herbicide can be detected on the surrounding flora; 2: the effect of the herbicide on the surrounding flora is discernible; 3: most of the surrounding flora has been destroyed

material has to be performed on dry or frozen soil. Stump and root suckers often appear following cutting which must be sprayed with the 3.5% concentration solution of Medallon Premium or Taifun 360 late in the summer. Time needed for the treatment: a minimum of 3 years.

Parallel with the experiment we also tested an experimental Medallon Premium-based oily emulsion under operational conditions (the Environment and Energy Operational Programme (EEOP) project of the KAEG Ltd. won for controlling tree of heaven) which can be wiped on older plants with larger than 10 cm trunk diameter without cutting the bark, and the success rate was quite high.

It has to be noted that in the case of closed stands of trees of heaven we need to take into account the seed banks in the soil which start to germinate in large numbers and right away as a reaction to increased light conditions. There could be as many as 4000–5000 seedlings per m^2 (based on the verbal account of the forester Gábor Pozsgai as well as our own experience) therefore treatments should not be stopped for as long as 3 years.

Common milkweed

In the case of common milkweed, the only successful reagents were the Medallon Premium-based mixtures. In the case of wiping and spot spraying the most effective ones were those used in 50% solutions. However, as these cost five times more than other herbicides, and cause significant damage to the surrounding vegetation, this is not necessarily the most favourable solution (Tables 6 & 7, Figs 11 & 12).

In the case of other reagent combinations the effect is still discernible on surrounding plants, but the number of plants destroyed is insignificant.

Treatments with a mixture with the highest dose of Casper successfully eradicated a few target plants but since the surrounding vegetation was also almost completely destroyed, its application in protected areas is not advisable. Within the framework of the project, common milkweed was treated once in the whole area during 2012 and 2013. As a result of the treatments under operating conditions common milkweed was effectively controlled, however, it is still present in the area even if not in uninterrupted stands. During samplings in 2014, sporadic plants or smaller groups of the species were found in almost all previously identified habitats. However, the effects of the herbicide were discernible in most cases, as the plants found rarely had any flowers or fruits.

There were also a high number of plants growing from seeds in the area, which had not received chemical treatment before. These plants were treated in 2014 (only in the form of wiping), but it became clear that their appearance prolongs the complete eradication of the species with a few more years.

Summarising the results of the experiment we can conclude that after considering effectiveness, costs and damage to the surrounding vegetation, the recommended control method for common milkweed is the following:

Closed, continuous stands as well as patches in degraded grasslands: Spraying with a 33% solution of Medallon Premium (+ cohesion enhancer 3,5 ml/l + fertiliser 15 g/l) at the end of May or beginning of June. Repeated a month later if needed. In the following years: only wiping. Time required for the treatment is 3 years; however, the area must be surveyed every two years and newly appearing plants must be treated.

Stands of sporadic plants in grasslands in good condition: Wiping with a 10% solution of Medallon

Table 7. Offshoot ratio of common milkweed after spot-spraying.

Concentration	The number of treated plants in the micro- quadrants (piece)	Plants alive a year later (piece)	Offshoot ratio (%)	Damage in the surrounding vegetation*
10%	30	6	20	2
33%	103	1	0.9	1
50%	71	0	0	2

* 1: no effect of the herbicide can be detected on the surrounding flora; 2: the effect of the herbicide on the surrounding flora is discernible; 3: most of the surrounding flora has been destroyed

Premium (+ cohesion enhancer 3.5 ml/l + fertiliser 15 g/l) at the end of May or beginning of June. Time required for treatment is a minimum of 3 years, however, the area must be surveyed every two years and newly appearing plants must be treated.

Issues raised and observations made during treatments

Both under experimental and operating conditions the weakest link was the staff carrying out the treatments. According to our experiences, even the best group of people needs a trained professional supervisor (with experience in nature conservation and in plant protection) who continuously oversees their work. The following mistakes were the most common during implementation.

- Stump wiping is performed later than within the compulsory 10–20 minutes. In the case of black locust we experienced mass sucker growth after treatments performed under operating conditions while the amount of stump suckers was minimal under experimental conditions.
- A general problem in wiping is the phenomenon of "sprinkling holy water". After a few hours of quite monotonous work the workers just sprinkle the herbicide, which then does not reach the plant in sufficient amounts, while the inaccurate method application (dripping) increases the damage to the surrounding vegetation.
- In case of spot spraying of closed stands, whole strips are often missed. The problem can be solved by continuous supervision and by adding a right colourant.
- In case of injection there are always a few plants that are missed. The number of untreated plants can be reduced by continuous supervision.
- In case of injections drilling a hole too deep or too shallow may lead to only partial success. The problem can be prevented by using the right drill bit size.

In the course of common milkweed control treatments, under operating conditions we observed that treatments are more effective if target plants are shaded by tree stands. However, due to evaporation both black locusts and grey poplars were destroyed in masses which means that if our aim is to keep preserve these tree stands then this technology can only be used to a limited extent.

The damage to shading tree stands can be reduced by using a lower reagent concentration as well as by performing the treatment under colder weather conditions. However, there were no experiments dedicated to this issue.

Summary

Within the framework of the Hungarian Little Plain Life+ project we examined the efficiency of invasive plant control treatments under experimental and operational conditions, and we managed to find a technology for all target species (black locust, tree of heaven, common milkweed) which can successfully control them in sandy habitats. Tests carried out under experimental conditions showed that there is no exclusive application technology, but methods need to be applied in certain combinations. Based on our observations, the treatment needs to last at least 3 years under operating conditions for each species examined. In the case of common milkweed and tree of heaven, however, a 5-year treatment is more favourable. Following the "first" treatment the treated areas should be monitored at least once every two years, and all newly appearing or suriving plants should be eradicated.

Tree of heaven in the Fóti-Somlyó Nature Conservation Area – a brief history of a successful treatment procedure

Mária Tóth

Natural characteristics of the area

The lithological structure of the Somlyó mountain near Fót is dominated by lime (both saltwater limestone and travertine) and calcareous sand, but loess and pyroxene andesite tuff also appears in small patches. The soil chiefly consists of rendzina and brown forest soil at the foot of the mountain. The surface is various, there are chasms, sloping plateaus, rocky outcrops. The areas at the foot used to be wetlands created by the Sződrákos and Márton streams. The area is characterised by continental climate, and thanks to its micromosaic structure, there are habitat patches of sub-Mediterranean and subalpine nature. The Somlyó mountain is part of the range at the edge of the Great Hungarian Plain. Due to its unique positon and its geological and climatic mosaicism, it represents an intermediate stage between mountain range and lowland vegetation communities. Despite the size of the area, its flora and fauna is very diverse. The small but biogeographically very significant mountain is often referred to as the "mecca" of butterfly experts, botanists and geologists.

The area was designated as protected in 1953 as a result of a recommendation made by Bálint Zólyomi, Gábor Fekete, Pál Jakucs and József Papp. The first (and for a long time only) population of *Plebejus sephirus* was discovered here, so this butterfly species, as well as the main food of its caterpillar, the *Astragalus exscapus* became symbol of the mountain.

The protection was extended to all forests of the mountain in 1971, and later to the areas of the foot in 1989. The Nature Conservation Area is located in the territory of the Duna–Ipoly National Park Directorate, it covers 282 hectares, out of which a core area of 105 ha is specially protected, and its highest point is at 288.5 m.

The area is characterised by continental steppic woods, Pannonic, Pontic, Ponto-Mediterranean, Euro-Siberian and sub-Mediterranean elements.

The most frequent communities are closed termophilus oak forests, steppe woodlands with Tatarian maple, karst scrub forest, Turkey oak woodlands, rock steppes, slope steppes, perennial sand grasslands and sand meadows (Seregélyes 1990). The area is well-known for its relict botanical values, butterfly fauna and the protected geological section from the Miocene epoch. During our sampling, we recorded the presence of about 376 butterfly species, 90 bug species, 37 ant, 84 spider, 5 amphibious, 6 reptile, 54 bird and 23 mammal species. Some protected species include *Rileyana fovea*, *Carabus hungaricus*, juniper skink (*Ablepharus kitaibelii*) and forest dormouse (*Dryomys nitedula*).

Since the fact that it is a protected area does not protect it from human disturbance, anthropogenic impacts are nothing new here: the area is surrounded by houses, arable lands and a frequented road from the west – there are no remaining buffer zones.

Motocross and quad riders intruded the area for years, causing serious damage. Common ragweed spread quickly along wheel tracks in grasslands, and at road and forest edges. Without effective treatment, common ragweed is still present, often in large populations. The accelerating degradation and isolation of the protected area seems to be irreversible.

Previous history of the area

In the 19th century, when the area belonged to the territory of the Counts of Károlyi, Turkey oaks, black locust and black pines were planted. Moderate forest and wildlife management, grazing and mowing might have slowed succession processes and sometimes contributed to the survival of valuable and characteristic grassland communities. It was an important factor that the area was not isolated from the natural habitats of the Hills of Gödöllő.

During World War II Russian forces caused permanent damage to the landscape, bomb craters, trenches, tank parks created holes and pits that are still visible today. First the sources of the Great Lake near Fót went dry, then due to an ill-considered initiative to artificially recharge water and imperfect water management, wetlands (fen-meadows, bog meadows with great burnet) surrounding the foot were lost. The succession of grasslands was further accelerated when grazing and mowing was stopped in the area in the 1960s.

This facilitated shrub encroachment, while land use triggered the aggressive spread of alien and adventive plant species.

Some natural vegetation species, such as common hawthorn and blackthorn also spread rapidly, leading to shrubby grasslands. In order to overcome this issue in 1997–2001, the WWF organised action days in order to control common hawthorn, and goats and sheep were grazing in the area for some months in 2001. No impact assessment has been conducted regarding the grazing, but goats and small herds of cattle have been grazing in the area ever since.

Initial conditions

There were assessments on the Fóti-Somlyó hill between 1996 and 2010, conducted within the framework of my special course of lectures at ELTE University. The tree of heaven programme lasted from 2003 until 2006, but the area has been continuously monitored ever since. The aim of the course of lectures was mainly to collect faunistic and zoocenological data, while acquiring the knowledge of biological field survey sampling methods. The samples were used to assess and compare the vertebrate and invertebrate species, as well as the fauna composition of habitat patches in the protected area. Before this, no similar research had been conducted on the hill, but basic faunistic data is essential during habitat protection, conservation biology or nature conservation related activities.

We also examined the seasonal changes of the vegetation, as it influences the growth and dynamics of the fauna. This was however a race against unfavourable impacts that keep enhancing each other. It was expected that the vegetation and the fauna would change significantly. Sand and loess grasslands, forest edges, frequented roads and trails tend to degrade most severely. In these areas, the number of common hawthorn is increasing rapidly, while damaged grasslands are closing, opening up the opportunity for invasive plant species, such as black locust (*Robinia pseudoacacia*), Russian olive (*Elaeagnus angustifolia*), hackberry (*Celtis* sp.), common milkweed (*Asclepias syriaca*) and tree of heaven (*Ailanthus altissima*) to spread. The first tree of heaven was recorded by Petrányi in 1955. Fekete and Kovács in 1982 mentioned a number of invasive species and their dangers (Fekete and Kovács 1982). In 1990, Seregélyes marked only two small patches and some lonely individuals on his vegetation map, but Udvardy found larger populations in 1997 (Udvardy and Zagyvai 2012). Late studies (within the framework of META Programme – a map database for Hungarian habitats) based on land, aerial and satellite images all arrived at the conclusion that invasive species are gradually spreading. The number and size of tree of heaven populations is constantly on the rise.

In 2003, we chose two small but compact tree of heaven populations for long-term analysis. Monitoring activity was only performed in these patches. We also examined some other populations along the ridge, where we thinned the plants or removed the bark from the trees. In order to assess the zoological impacts of the treatment, we set up traps to capture small mammals, but the results were not reliable, as the traps often got damaged, or they simply disappeared.

Methods used

The area is protected but severely disturbed. After considering the characteristics of the area, nature conservation aspects, our budget and other resources (time, energy), we tried to complete the treatment with the slightest possible disturbance and using as little equipment as possible. We simply wanted to "help" the grassland patches to regain their natural resistance.

We wanted to eradicate tree of heaven using chiefly mechanical and occasionally chemical treatment. In the spring of 2003, we conducted faunistic and botanical survey of the area at its pre-treatment stage. We selected two populations of tree of heaven close to each other. These were located at the north-western side of the mountain, on a closing, sand steppe with an increasing number of common hawthorn. The two tree of heaven patches were 150 metres away from each other, but their structure was completely different (Fig. 1).

Population "A" was located after I. András Street that leads from Fót to Csomád and after the railway crossing, near the dirt road leading to Somlyó, immediately behind the protected area traffic sign, at the edge of a closing, degrading sand steppe. The age composition of the population was homogeneous, its density was high, and it consisted only of male

Fig. 1. Treatment areas "A" and "B" were about 150 m away from each other. (Photomontage: M. Tóth, 2014, based on Google Earth)

Fig. 2. Population "A" consisted only of male individuals, and apart from some weak elder sprouts, the closed population was completely homogeneous. The herb layer was very sparse with only few species in small patches. (Photo: M. Tóth)

individuals: the patch was about 1200 m² large, and there were 698 thin (4–8 cm trunk diameter) trees of heaven in the population. The estimated individual density was about 35–40 individuals per square metre (Figs 2 & 3).

Population "B" was located on the western side of the mountain, where a large thermophilous oak forest and a sand steppe grassland meets. It was a mixed population with an approx. 50 years old bisexual individual with high seed yield in the centre. Directly next to this, there was an old hybrid poplar (*Populus ×euramericana*) – which died in the meantime – and some hackberry (*Celtis* spp.) individuals. The size of this patch was 800 m², and we recorded 220 trunks in it with a trunk diameter of about 4–35 cm. The estimated individual density was 25–30 individuals/m² (Fig. 4).

The workflow of the treatment

Chemical treatments were carried out only in 2003, with a permit and in cooperation with the experts of the Duna–Ipoly National Park Directorate. Mechanical control was continuous. The coenological surveys were carried out in 2004 and 2005. In chronological order: Population "A" and "B" was partially cleared (10%) and treated with Medallon.* The chemical treatment consisted of painting the stumps with a 1:2 mixture of water and Medallon Premium (containing glyphosate ammonium). In December, we felled 70% of the population, and then we dripped Garlon (1:2 mixture of water and Garlon 4E containing triclopyr) on the top of the stumps. This work was assisted by the Directorate of the National Park. Stumps of population "B" (earlier treated with Medallon) were also treated with Garlon.

There were coenological surveys in the selected 1 × 1 meter quadrants in 2004 and 2005. Sprouts outside these quadrants were continuously cleared (using mechanical methods, i.e. uprooting) between 2004 and 2006. In December 2004, we felled every tree of heaven in population "A" using branch cutters or hand-saws, and we uprooted the young sprouts manually (Fig. 5). In population "B", we chiefly cleared sprouts, but we also removed the bark from some thick trunks in both populations.

In 2005, we selected 10 sample squares of a size of 1 m² in area "A", where four were part of the area treated with chemicals, and four belonged to the mechanical control only area. The remaining 2 squares per population were control areas, where no sprout control was applied. Sprout control was carried out about every 10 days. In some parts of population "B", we assessed the impacts of the Medallon Premium treatment done in the spring of 2003. Due to the different population structure, we decided to mark the quadrants in four different directions along transects,

*Attention! Experimental chemical control methods described in this chapter are subject to authorisation! Their practical application requires an emergency permit issued by the pesticide control authorities for the given area and period!

Fig. 3. In 2003, it was difficult to move among trunks in population "A". (Photo: R. Kalotai)

Fig. 4. Population “B” was more open and mixed (in 2005) with a diversified herb layer and some shrub species along the border. (Photo: M. Tóth)

Fig. 5. Completely clearing population “A”. (Photo: M. Tóth)

where transects originated from the central, oldest tree. We marked quadrants up to the point where we could still find tree of heaven sprouts. Within the quadrants, we recorded the height and number of the sprouts as well as the vegetation composition and percent cover. In October, we cleared population “B” and removed the bark from several thick stumps.

In 2006, new sprouts and seedlings were manually uprooted on a monthly basis (between April and November).

By 2007, tree of heaven completely disappeared from the two test areas, and it has not reappeared ever since (Fig. 8).

Cut trunks and sprouts were collected at a trail next to the test areas until they withered. The Duna–Ipoly National Park Directorate (DINPD) later disposed of the withered plant residues. Thick trunks were presumably collected by the residents of the surrounding settlements, and used as firewood.

Control methods

Chemical treatment

Using a dropper – very carefully, avoiding chemicals to drop on the ground or surrounding plants – we applied Garlon 4E and Medallon Premium on the top of freshly cut stumps.

Mechanical control

Clearing: Thick trees were felled using chainsaws provided by the DINPD, while thin trunks were cut using our own equipment, with hand-saws and branch cutters. Trunks were cut at a height of about 30–50 cm to enable us to find and identify them, and to monitor their vitality and sprouting abilities (Fig. 6).

Uprooting: We uprooted the sprouts in gardening gloves. The participants formed a chain leaving 2–3 m space between each other, and they went through the entire area, uprooting tree of heaven sprouts (Fig. 7). Bark removal: The bark of remaining stumps was completely removed, to accelerate their withering.

Experiences gained

Instead of sharing detailed analysis and lists of botanical species (Szöllősi and Tóth 2007), I would like to summarise (point by point) our extensive experience, as it may prove useful for further treatments.

The two areas controlled were different from each other, but our strategies turned out to be successful in both patches. Due to a single chemical treatment on the surface of freshly cut stumps, then continuous mechanical control, the individuals lost their vitality and chemical communication ability. It is important to underline that we tried to remove the entire root system where it was possible.

Despite the fact that the Somlyó hill and its surroundings are infested, there has been no sign of reinfestation, even though there are populations nearby from which seeds could reach the area.

It is important to note that the increasing number of shrubs in the surrounding grasslands may also affect the now cleared areas in the long run. In place of population “A”, we can already see that common hawthorn and restharrow (*Ononis spinosa*) is spreading quickly, so the series of treatments cannot be stopped after tree of heaven has been eradicated from the area.

After the successful control treatments of tree of heaven, the number of species increased in both test patches. In 2003, there were only 18 species, but in 2006, already 73 species (including woody and her-

Fig. 6. Population "B": stumps with their bark removed. (Photo: M. Tóth)

Fig. 7. Uprooting sprouts was done on a monthly basis. Participants formed a chain to be more effective. (Photo: M. Tóth)

baceous plants) were registered. The first new species to arrive were nitrophilous and other weeds that are not vulnerable to disturbance, but later other species characteristic of sand grasslands appeared gradually.

Regarding arthropods, we could only examine the bug fauna and only for two years because our traps were disturbed on a regular basis, as the area is very frequented. The number of species and diversity value (based on the Rényi scale) was average compared to the other 15 faunistic measuring points of the zone. Presumably due to the "springboard" theory, the fast colonisation strategy of R strategists and the role of propagules in secondary succession, this value was greater than expected. This situation might have changed later, as the grassland gradually closed, but we were unable to monitor that.

Populations of the Fóti-Somlyó Hill are not too old, the only old (the oldest) tree of population "B" was estimated to be about 50 years old, based on its growth rings. According to the trunk diameter of the trees, individuals were between 2 and 30 years of age. The clones, i.e. isolated, undisturbed tree of heaven populations were about the same age, but disturbance triggers an increase in the number of trees of the same age. During a rainy period, new sprouts often reach a height of 1–1.5 m within a month (with a very mixed size composition).

Fig. 8. By 2008, the grass layer of population "A" regenerated and turned into a closed sandy grassland which prevented tree of heaven from recolonizing the area. (Photo: M. Tóth)

Disturbance triggers massive sprouting (and presumably higher seed yield), and if this happens, the treatment must not be stopped, as this would result in rapid spread and sharp increase in the number of individuals.

Tree of heaven sprouts were only rarely chewed by cows or goats grazing in the area. There was no significant difference between the spread of male and bisexual populations. Seeds of bisexual individuals mean no advantage, as both populations spread with root sprouts. Seeds may only help to infest areas that are located further away. Bisexual individuals often do not start sprouting for years.

Tree of heaven has unpredictable "lifestyle strategies". Almost any disturbance may trigger aggressive spread, rendering its surroundings homogeneous. This spread sometimes also happens spontaneously (or due to unknown reasons). In small patches, we managed to eradicate tree of heaven. This was very time-consuming, required lots of energy, but the costs were minimal (the work was done by volunteers!) and the applied methods were environmentally friendly.

Using the help of volunteers in conservation activities greatly improves efficiency. If it is linked with academic education, i.e. students can take part in these projects to complete their professional practice, the projects are beneficial for both students and nature.

Issues raised

Unfortunately, there is little information available for the professional planning of biological treatments. There is only little scientific evidence published, but according to this, only a surprisingly small number of animal species tend to consume tree of heaven. In case of invertebrates, some moths, such as Ailanthus silkmoth (*Samia cynthia*) and ermine moths specialized for tree of heaven (*Atteva* spp., Yponomeutidae) could assist biological control. Sadly, there is always a chance that monophagous and oligophagous species, when introduced to a new habitat, find new plants to eat, hence becoming polyphagous. This is why introducing the aforementioned species requires careful and exhaustive background research.

Mushrooms on the wounded trunks, such as *Schizophyllum commune* clearly indicated that the roots withered. This was further underlined by the fact that there were no root sprouts. Injecting chemicals could have been more effective than painting the stump tops, as it results in faster and easier absorption, but we did not have the opportunity to do that.

It is an interesting question whether the manure of grazing animals triggers changes in the chemical structure of the soil. The first plants to appear after clearing the tree of heaven populations were nitrophilous species, but today species characteristic of sand grasslands also appear frequently. Under controlled circumstances, the manure of grazing animals can help to overcome the high level of nitrogen in the soil, which was triggered by the tree of heaven population.

It may be advisable in the future to support the control of invasive or adventive populations and related research with zoological research, as these could help better understand the natural processes started by these interventions. The changes of the fauna are also very significant indicators and measures regarding conservative treatments.

Acknowledgements

The tree of heaven programme required regular and sometimes very exhausting work, which also had a team building effect. Within the framework of the lectures, students of the ELTE and SZIE universities and other volunteers took part in it.

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Experience gained from control efforts aiming to eradicate common lilac in Sas-hegy Nature Conservation Area

Zoltán Tóth, András Dániel and László Papp

Introduction

There is a significant number of non-native plants on Sas-hegy in Buda, which has been a nature conservation area since 1957. A part of them has been present in the region for 50–100 years but their spread was initially ignored and no sufficient attention was paid to it until the last decades of the previous century. Intervention, however, has become unavoidable for conservational reasons. This paper will present a short account of this intervention, the treatments realised but most importantly the experiences gathered through the process. Control was first attempted mostly by mechanical methods, but as they proved ineffective, chemical treatments became inevitable. We can learn from both the positive and the negative results as they offer numerous generalised elements that one can encounter in one form or another during habitat conservation management.

In this article we will focus on the eradication of the common lilac (*Syringa vulgaris*). However, there are approximately 45–50 woody neophytes on Sas-hegy, of which 15–20 are significant as they appear in large numbers/extensive patches or stronger populations. We can find plants that are nationwide known as invasive species, about which numerous and diverse experiences have been published. The common lilac, however, is the most significant habitat-transforming species that has spread while harming the natural habitats (in the present case the spread is observed over protected natural areas and grasslands of highly significant natural value) and form patches to exclude all other herbaceous species (as well as most of the woody species). The common lilac has therefore become the local enemy number one on Sas-hegy. The methodology of control has been largely based on this species and to simplify, we dubbed it "lilac control". However, the technology and chemicals applied proved effective for other woody, non-native species too, while in exceptional cases (e.g. *Ailanthus altissima*) other specific-use herbicides were also applied. Overall, it needs to be noted that the generalised experiences and results of "lilac control" can be interpreted as the experiences of "invasive plant control".

Natural characteristics of the area

Due to the significant amount of literature published regarding Sas-hegy and the fact that it is relatively well known, we will refrain from the geomorphological, geographical, pedological and botanic–zoological description as well as the importance of conservation and anthropogenic danger. Among the recommended literature, one can find such descriptions and summaries in a number of studies in Volume 8 of the Rosalia series.

However, we would like to draw attention to the uneven evolution of the protected area and the originality of the vegetation. These must be taken into account when analysing the present conditions.

(1) The most valuable sections of the Buda Sas-hegy Nature Conservation Area (as well as the key factor for gaining protected status) are the open and closed rock grasslands appearing on the dolomite cliffs and surrounding furrows, as well as the northern and southern slopes. The vegetation here has been able to retain its ancient state, while the diversity of dolomite grasslands, the dolomite phenomenon relicts and the native taxons have also been preserved as this section is less disturbed by anthropogenic influences. Since cultivation is mostly not feasible in this area, these parts have become less disturbed. It must be added that the dolomite cliffs have been continually surrounded by the forests (thermophilous oak forest presumably closed in previous centuries and/or partially open xero-thermophilous oak forests) that could not invade the cliffs for edaphic reasons. The grass-covered cliffs emerge from these forests in patches, while the forests containing different plant and animal species isolate the nearest dolomite cliffs

from each other, which hinders the migration of plant taxa.

(2) This isolation was barely changed by the fact that the forests of Sas-hegy (as well as the entire Buda Hills close to the Danube) were felled starting in the 12th and 13th centuries and replaced by vineyards and, in certain parts, mixed orchards. The isolation prevailed even after the phyloxera scare at the end of the 19th century when the vineyards were not able to be repatriated onto the foothills of the Buda Hills, which is partly also due to the dramatic spread of urbanisation at the beginning of the 20th century. Therefore, the dolomite cliffs have always been isolated, although in recent centuries it is increasingly due to the anthropogenic vineyards and the strain caused by the suburbs.

Moreover, the areas previously covered by forests have very different bedrock compared to the dolomite of the cliffs. In other words, the bedrock of these areas was more conducive to the forests in terms of soil formation processes than the dolomite. This bedrock includes the Eocenic marl of Buda, the Oligocenic clay of Kiscell, the slope sediment and washed-out sediment from later epochs (the Upper Pleistocene or the Holocene) accumulated in larger valleys or at foothills after the degradation of the previous bedrock, as well as the loess deposited north of Sas-hegy.

Regarding the potential (natural) vegetation of the protected area in its present state, it is not at all homogeneous. The expected (or unexpected) succession processes are completely different over a less disturbed rock grassland than over a foothill region that has most probably lost all its previous native forests and topsoil.

Initial conditions

This duality characterised the newly proclaimed nature conservation area from the second half of the 20th century, where the secondary succession processes started to lead, gradually and exponentially, in a negative direction. On the one hand, it is naturally in the foothill regions where we could find the largest abandoned areas and it is precisely these areas that were the most neglected by the then growing nature conservation, the attention of which was mainly directed at the dolomite cliffs. Moreover, human intervention started to have more and more of an influence on the secondary succession processes. The large abandoned areas, the nearby gardens and the proximity of the non-native woody species of the town allowed homogenous and species-poor shrubs and then forest patched (growing into trees from certain species) to spread. On the other hand, due to the pressure from nearby gardens, these shrubs collectively reached the rock grasslands from all directions and caused the spreading of shrubs, starting from furrows and more protected ravines with detrital soil, then eventually led to the shrinking and isolation of grasslands with the closing in of smaller shrub patches.

It was announced several times during a less active period of nature conservation that invasive species do not cause severe problems, as there are few species and they only recently appeared on the area. We took on the challenge to try and disprove these statements. We finally had an opportunity to do so during the management actions in recent years when trees and presumably the oldest shrubs were eliminated. When counting the growth rings on the smoothed stumps of the thickest trees, it turned out that the species considered the most significant had been present since before the area was proclaimed a nature conservation area. Among the oldest specimen, *Syringa vulgaris* was 63, *Robinia pseudoacacia* 45, *Ailanthus altissima* 52, *Laburnum anagyroides* 57, *Thuja orientalis* 56, *Ptelea trifoliata* 55 and *Aesculus hippocastanum* was 55 years old (Fig. 1).

In spite of the efforts to underrate the danger citing a shortage of resources, some initiatives were started in the last decades of the 20th century to control certain species. The most notable was the attempt to control common lilac with mechanical means close to the entrances and on the areas more and more infested by shrubs along the pedestrian passageways. Treatments were undocumented in this period and any possible records have been lost. As these might have been singular interventions with no follow-up

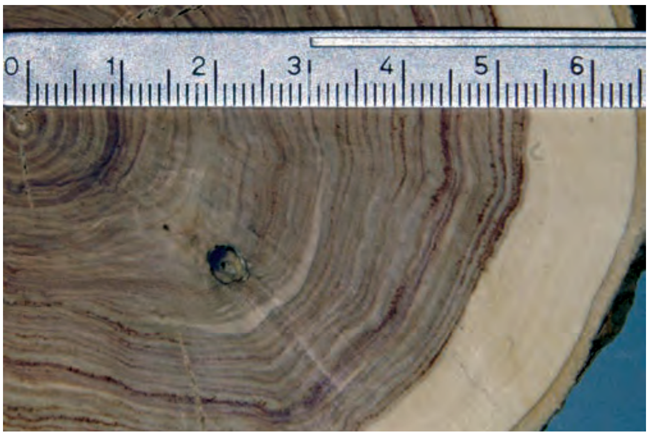

Fig. 1. Smoothed cross-section of the trunk of a common lilac. (Photo: Z. Tóth)

treatments, the shrub patches quickly regenerated and recovered from the treatments. Due to significant sprouting in the following year, the efforts proved counterproductive and the treatment achieved the opposite of the desired result.

As a consequence of the unfavourable results of the mechanical treatments (which seemed to be an increasingly national phenomenon), environmentalists started to shed their former objections and turned towards chemical control. In lieu of sufficient experience, however, they did not have adequate knowledge base on the effect mechanisms of the available herbicides, their dosage and selectivity. Not surprisingly, this led to initial reluctance, isolated treatment efforts and a lack of information sharing.

The initiative of the Duna–Ipoly National Park Directorate was revolutionary, both on a national level and on Sas-hegy, in the framework of which controlled experiments were conducted in 2003 on the control of several species (including the common lilac) to compare optimal treatment periods, possible chemicals and application technologies. These surveys then provided the foundation of the subsequent treatment plans.

Methods used

For treatments covering larger areas, we had to wait until the tenders for subsidies were awarded. We were then able to implement two projects not too long apart in time. The gradually extending target area included 1 hectare of treated land in the first project (total area was larger due to untreated patches), while the second project targeted 13.4 hectares of land.

The first treatment cycle started in the autumn of 2007 within the framework of the INTERREG III/a "Development of ecotourism along the Danube" (HUSKUA/0502391), when the clumps of shoots (in theory of all the non-native shrubs but in practice mostly those of common lilac (*Syringa vulgaris*) and forsythia (*Forsythia* spp.)) were removed from 1 hectare of land.

This chemical treatment of such a large area was preceded by the development of an environmentally friendly herbicide technology during the series of experiments conducted in 2003, when they surveyed the applicable chemicals, their times of application and dosage.* However, the developed optimal treatment time and method (autumn canopy spraying) could not be applied due to a delay in the start of the treatment. Instead, a less effective chemical and method had to be used (cut stump method). The trunks of the common lilac and forsythia shrubs were cut by chain saw and the resulting stumps were painted over with chemical compounds. As opposed to the previously planned removal, the cut shrubs were reportedly incinerated on site, on all of the 19 sites.

The second treatment cycle more significant in volume did not start until a few years after the initial attempt. After summarising previous experiences, the treatment covering the largest area was carried out in 2011–2012 financed by a KMOP-3.2.1/A-09-2009-0005 tender, over an area of 13.4 hectares (approximately over the open and closed rock grasslands of Sas-hegy). Several chemicals were used at varying times. The treatment included felling the standing dead trees (snags) previously destroyed by the chemicals. The initial treatment was followed by two waves of subsequent follow-up treatments (primarily spot spraying of sprouts). Moreover, the entire black pine stock was cut during the winter period.

Regarding the chemicals applied, we can only report the use of chemicals witnessed by us on site or that we were informed about: Medallon Premium was used primarily and in the largest amounts, Garlon 4E and Tomigan 250 EC in smaller amounts and Banvel 480 S to eradicate *Ailanthus*, but the contractor might have used other chemicals as well. The chemicals were used in varying concentrations, which to the best of our knowledge depended primarily on the distribution technology applied. The adhesive used was Silwet L-77. We are not in the possession of more detailed information, which we were not provided in spite of successive attempts to obtain them.

Four application methods were distinguished during the application of the chemicals. The experiences gained with each are discussed below:

(1) internal combustion engine backpack sprayer;
(2) shoulder-borne 3–5-litre manual pump sprayer;
(3) manual 0.2–1-litre spray flask;
(4) stump painting with brush.

* Attention! Experimental chemical control methods described in this chapter are subject to authorisation! Their practical application requires an emergency permit issued by the pesticide control authorities for the given area and period!

Experiences gained

It must be noted concerning the experiences of the first treatment cycle that the “slight” modifications in the methods predetermined the success of the results and the effectiveness of the treatment. If 5–10–15-centimetre stumps were left behind, all subsequent post-treatments were rendered more difficult and the removal of such trunks has not been completed to this day. On the one hand, late mowing was made impossible by the dried out stumps; on the other hand, it took years for even a certain proportion of the dried and partially decayed stumps to be removed. Removal by a machine or a three-blade brush cutter (which would have been the only feasible option) would have meant unnecessary mechanical disruption and would have put too much pressure on the individual patches.

Apart from the fact that post-treatment was difficult on this area, it also proved a hotspot for initial resprouting. This negative effect is due to the fact that the chain saw, however carefully handled, cannot handle the thin twigs close to the ground or barely showing, which in the case of the common lilac appear in large numbers as sprouts at the base of thick branches. A portion of these twig sprouts is left intact by the chain saw, while they also remain untreated by the chemical painting of the stumps of cut branches. Moreover, they are left unnoticed even during the first year of survey of clumps of sprouts. However, from the second year onwards, it is specifically these twigs that sprout, gain ground and lead to the regeneration of the whole shrub if left untreated (Figs 2 & 3).

Another observation is that weeds were much more likely to appear on the bare grounds surrounding grasslands during the settling of their perennial and more valuable species. One chemical post-treatment was carried out and late mowing was sporadic, as a result of which we can establish that the regeneration of grasslands during spontaneous succession procedures took an unfavourable direction and was slower than desired. The majority of the weed species were herbaceous, but unfortunately we did find some woody seedlings as well (Fig. 4), the windborne seeds of which might have come here from further propagule sources (tree of heaven, box elder).

After the treatments, the monitoring of the settlement of new vegetation was carried out for several years (3 times thus far) by coverage estimations based on classical coenological methodology in 1 m × 1 m quadrants along transects. The regeneration of the grasslands and the settlement of vegetation was monitored along two transect lines, one on the southern, one on the northern exposure. Regular monitoring

Fig. 2. Sprouting lilac a few months after the treatments (14 October 2014). (Photo: A. Dániel)

Fig. 3. Sprouting golden rain a few months after the treatments (31 August 2011). (Photo: Z. Tóth)

Fig. 4. Established tree of heaven seedling in the treated patches. (Photo: Z. Tóth)

Fig. 5. Spraying herbicide with an engine sprayer on the first day of the project (25 May 2011). (Photo: A. Dániel)

Fig. 6. Herbicides with blue colourant before drying, sprayed by a pump sprayer over the leaves of the common lilac. (Photo: A. Dániel)

was carried out in 28 adjoining 1 m × 1 m quadrants of each transect line.

The most significant difficulties encountered during the second treatment cycle can be divided into two categories. On the one hand, the "skilled workers" were unable to maintain awareness to differentiate between targeted and non-targeted species throughout the whole day, which meant that on occasion they overlooked some specimens that should have been sprayed or accidentally sprayed specimens that were not to be sprayed. Contrary to prior agreement, apart from the first couple of days, paint signals were not used to track the progress of the work, which would have in turn made the contractor's job easier, too. The conclusion to draw is that it is advisable for the client to delegate an expert to monitor the works throughout the entire day.

The experiences concerning the four treatment technologies listed under "methods" are the following.

(1) The high-power internal combustion engine backpack sprayer is the most suitable to treat large areas (Fig. 5). Its advantage lies in its performance; however, its handling requires experience to make sure that the vaporised and far-reaching solution is sprayed evenly. On the other hand, the effectiveness of the spray also depends on the dose of the agent diluted. Even with consistent spraying, the amount of the distributed chemical might be too low, or conversely, we might overdose the environment. The application of this device is only advisable on patches infested in a cohesive and homogenous way. It is indispensible to be aware of the degree of infestation as well as the terrain and the vegetation of the area when planning the application of this machine. Since the chemical used in this method is not selective, particular attention must be paid to the herbaceous species below the shrub patches, drifting (due to wind) and evaporation (due to temperature), as the chemical can reach large areas where its effect can only be detected after days.

On areas where the homogeneous patches are interspersed with occasional specimens to be protected, it might be covered with plastic foil or a larger plastic barrel. The preparation of this method is labour-intensive, the execution uncertain. Moreover, the workers entering the sprayed territory to remove the coverage of protected plants are excessively exposed to contact with the chemical. However, it must be admitted that in spite of efforts to isolate and protect certain plants, there has been some (involuntary) environmental damage caused on Sas-hegy too. This damage can be detected by a thorough knowledge of the area and regular surveys after the treatment (it might take days for visible effects of the chemical to be seen) and by looking up the specimens and populations of rare, priority species. Unfortunately, however, often in hindsight there is nothing to be done.

Fig. 7. A few remaining specimens (bottom left corner) over the treated area (14 October 2011) even after removal. (Photo: A. Dániel)

(2) Individual or sporadically appearing plants can be effectively treated with 3–5-litre, manual pump backpack sprayer tanks and short but flexible manual sprayer heads. In this case, the chemical is typically directed at the shoot tips (partly herbaceous) and the leaves (Fig. 6). By adjusting the sprayer head, the particles can in theory be distributed selectively; on the other hand, lower-level plants can also come into contact with the chemical dripping off the leaves or the branches. The use of a funnel fitted on the front of the sprayer head is often recommended or required, which is supposed to facilitate selective distribution. Based on our experiences, however, the chemical accumulating and dripping off the funnel contributes to the above-mentioned dripping effect. Continuously cleaning the funnel and wiping off accumulated chemicals is difficult to manage under rough terrain conditions as it necessitates the use of large amounts of paper towel, wiper and rubber gloves, which might be difficult to handle, collect, store and carry during the execution of the treatment, not to mention the concerns that its waste disposal might cause.

A further negative consequence of this method lies in the skills and diligence of the workers implementing the treatment (Fig. 7). Unfortunately, we observed several instances where in spite of our best efforts to train the staff in advance, not all of them could be trusted to recognise what plants can be sprayed (or have to be sprayed, as they are the targeted species) and what plants are to be avoided. As fatigue set in and their attention wavered, even the more experienced handlers made mistakes. The chemical, once sprayed, cannot be removed from a plant that should have been spared, and in all likelihood it will die.

It is not enough, however, to be able to differentiate between targeted and non-targeted plants, but they must also pay attention to where they tread when roaming the territory. For easier traceability, it is a good idea to mix paint into the spray fluid. This way, we can trace where the plants have been sprayed. Good quality, long-lasting marker dyes with high marking quality are expensive and difficult to obtain in Hungary. It can be substituted with cheaper paint (powder in methylene blue or carmine red) or even simple food colorants. From the latter group, blue hues proved the most effective. It is worth trying out the food colorants first as some of them barely leave a discernible mark while others are stronger. Attention must be paid to the concentration, too (how much colorant can/must be added to a 5-litre tank), as it might impact costs as well.

In order to compensate for the above-mentioned shortcomings, we made sure during the post-treatments that somebody should be in charge of the spraying staff and assist their work by determining the route and pointing out the targeted plants.

(3) The methodology of sprout wiping is similar to that of the use of manual 0.2–1-litre spray flasks. The chemical in both cases is applied to the shoot tips of plants with smaller sprouts. Sprouts were wiped with sponges or brushes, while spraying is done with a manual flask from a distance of several centimetres. Since the chemical is distributed in small amounts (as opposed to pressurised sprayers, where the particles are being vaporised as long as the valve is open), this method has acceptable selectivity and a far lower risk ratio. We preferred the manual sprayer during our volunteer work as the distribution of the chemical is more easily feasible with a sprayer. In the case of application with brushes or sponges, the plant must be supported (in order to wipe it with a sufficient amount of chemical). The rubber glove comes into contact with the substance and consequently needs to be wiped or changed frequently (see previous paragraph). Expert supervision and the use of marker dye are also needed, as described in (2). The effectiveness of the intervention can be enhanced by adding adhesives or absorption facilitators to the herbicide.

When an expert is used to facilitate the work of the staff, the processes can also be documented. The accuracy of the method we applied is in proportion with the accuracy of the GPS used, i.e. we registered sites about 3–5–7 metres apart, where we documented e.g. the number of cut shrubs, at times even classified then based on size (1–5-cm diameter shrubs, 5–10-cm older shrubs or smaller trees, trees above 10 cm diameter) in a 3–4-metre radius of the given location. This way the location and the treated stumps can be retraced even years later to monitor the effectiveness of the work, which helps us draw conclusions and leaves records of the treatments carried out over the area (and shows where treatments have not been applied).

Fig. 8. The stumps can be treated without dripping and with the use of marker paint with the application of the "sponge pom-pom". (Photo: D. Mersich)

Fig. 9. Real-image map of Sas-hegy Nature Conservation Area in Buda. The red line marks the border of the protected area, the orange line signals the area targeted by the most significant habitat-treatment project, the black line shows the borders of the 11th district of Budapest, while the grey line (with the values given) corresponds to the 100-metre Unified National Projection grid.

Fig. 10. This real-image map (with the same scale as the previous one) shows only the borders of the targeted area and within it the yellow lines mark the polygons for monitoring the changes in the vegetation.

(4) The cut stump method can be carried out on sprouts trimmed with pruners as well as on trees and shrubs which are cut with a handsaw or a chain saw. An important requirement in both cases, provided that the cutting and wiping are not carried out by the same person, is that the handlers should synchronise their work, i.e. cutting should not be done at a faster pace than what the wiper can keep up with. Colourants are also applicable to trace the progress, although there are certain tree and shrub species on the stumps of which the marker dye is barely visible, while others are much more conducive to it. The distribution of the chemical is selective, the risk of dripping is minimal. The best way to prevent dripping is the use of a re-closable, half-litre plastic bottle with a wider than average mouth (possibly jar) and a piece of sponge (dubbed "the pom-pom" by our students) fitted onto the end of an approximately 25–30-cm long small twig (that can be easily cut on site during the eradication process) (Fig. 8). The excess liquid can be removed from the sponge by pressing it against the inner wall of the bottle, thus the stumps can be easily wiped without dripping by pressing the sponge onto their surface.

Treating thinner and densely grown shrubs is much more difficult and requires particular patience (and is more time-consuming). It is also more labour-intensive compared to spraying as it necessitates the use of extra staff for cutting out the shrubs. Moreover, if the loppings cannot be left on site, they must be collected and deposited at the designated spot. With sufficient experience and in the case of thinner shrubs, a single person might be able to cut the shrubs with one hand and wipe the stumps with the other (making sure that the sponge is sufficiently damp with chemicals).

Post-treatment is also indispensable in this case, as sprouting is nearly unavoidable.

Over scrublands and woody areas this method is not only applicable for the elimination of targeted species but for the development of target habitat (e.g. shrub forest–grassland mosaics at the foothills of Sas-hegy). With adequate planning, retaining shrub patches around larger trees, chemical elimination of non-native species and cutting out native shrubs between the patches, we can easily create a habitat mosaic where swarding can start within a few years depending on the amount of propagules spreading from surrounding grasslands. Late mowing of growing shrubs must be carried out annually (preferably during the winter). This practice has been followed for years on Sas-hegy to open up and extend orchid habitats suppressed by shrubs.

For the monitoring process following the chemical treatment of larger areas, the treated area was divided into smaller sections (uneven polygons), and each section was surveyed before and during the treatments, as well as at the end of the follow-up treatment. The spread of the priority, native and removed non-native species were measured in proportion to the area within the given polygon, while the effective-

Fig. 11. Strong regeneration of the lilac after one or two years, over the areas with no post-treatment. (Photo: Z. Tóth)

Fig. 12. The extent of non-native tree and shrub coverage in the individual polygons in April–May 2011, based on the pre-treatment survey. The shading of the polygons shows the degree of infestation, while the numbers indicate the percentage of the coverage in proportion of the area of the given polygon.

Fig. 13. The extent of non-native tree and shrub coverage in the individual polygons changed (was reduced) in March 2012 as a result of successive post-treatments. The shading of the polygons shows the degree of infestation, while the numbers indicate the percentage of the coverage in proportion of the area of the given polygon.

Fig. 14. The extent of non-native tree and shrub coverage in the individual polygons changed (mostly increased) in June 2012 due to the initial resprouting after the post-treatments. The shading of the polygons shows the degree of infestation, while the numbers indicate the percentage of the coverage in proportion of the area of the given polygon.

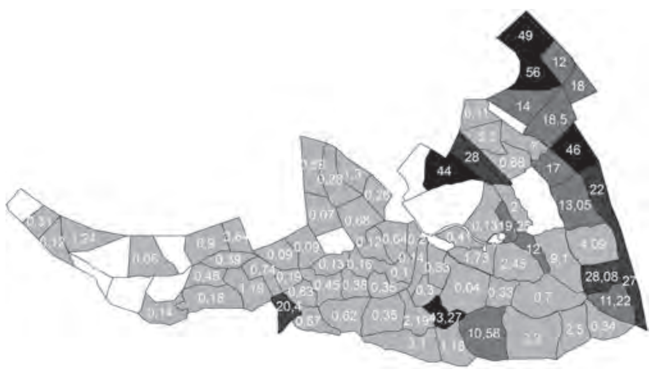

Fig. 15. The extent of non-native tree and shrub coverage in the individual polygons is significant in September 2014, two years after the project. In spite of partial post-treatments, the degree of resprouting is also significant in certain sections. The shading of the polygons shows the degree of infestation, while the numbers indicate the percentage of the coverage in proportion of the area of the given polygon.

ness of the intervention was measured through the estimation of resprouting (Figs 9 & 10).

After analysing the polygons, two major conclusions were drawn. On the one hand, due to technological negligence on such a large area (see above); on the other hand, due to the strong regenerative tendencies of the targeted species, regeneration started as early as the following year (more or less intensely). This regeneration could only be partially moderated by post-treatments (Fig. 11). These tendencies are illustrated on the maps showing data recorded in 4 subsequent periods. Although the surveys involving the most significant non-native taxons have been completed, this paper only presents the total non-native coverage (Figs 12–15) and the spread of the common lilac (Figs 16–19). The data is presented in proportion with the area of the polygons and given in percentages.

The following important observations can be made concerning the post-treatments. It must be noted that no treatment can be 100 per cent successful for the first try, not only on Sas-hegy (which can be safely concluded based on our other activities on different areas).

The frequency and the methodology of the post-treatments do not necessarily have to match those of the original interventions. On the one hand, treatments are often done at less than optimal times, and on the other hand the technology might be modified as the post-treatment targets sprouts instead of larger plants. Provided that prior planning is possible, post-treatments should be done at optimal times (e.g. chemical treatment before the autumn leaf fall). However, depending on capacity, other periods of the vegetation cycle might be appropriate as the efficiency and accuracy of the follow-up treatment is directly proportional to the time invested and how thoroughly the treatment is applied.

It is advisable to repeat the post-treatment processes for a period of several years with decreasing frequency. The experiences on Sas-hegy called our attention to the fact that the shrubs that remain un-

Fig. 16. The extent of lilac percental coverage before the 2011 treatments. The shading of the polygons shows the degree of infestation, while the numbers indicate the percentage of the coverage in proportion of the area of the given polygon.

Fig. 17. The extent of lilac percental coverage before in the spring of 2012 after the elimination of the shrubs. The shading of the polygons shows the degree of infestation, while the numbers indicate the percentage of the coverage in proportion of the area of the given polygon.

Fig. 18. The extent of lilac percental coverage in the summer of 2012 during sprouting. The shading of the polygons shows the degree of infestation, while the numbers indicate the percentage of the coverage in proportion of the area of the given polygon.

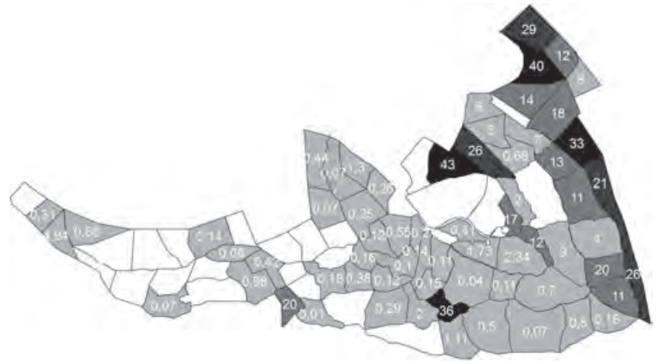

Fig. 19. The extent of lilac percental coverage in the autumn of 2014 during the end of the vegetation period. The shading of the polygons shows the degree of infestation, while the numbers indicate the percentage of the coverage in proportion of the area of the given polygon.

sprouted (presumed dead) until the end of the last year of the treatment unfortunately tend to sprout the following year or even years later. This is why the results presented in the final report of the project should not be considered as facts, as they merely contain the data gathered during the most recent survey.

Further post-treatment processes have been carried out in the protected natural area of Sas-hegy in Buda since the completion of the project. A part of these are organised by the National Park Directorate, but they are primarily executed and supervised by Sas-hegy Visitors' Centre with the help of volunteers (e.g. students majoring in landscaping can do their annual 3-week apprenticeships). These activities are carried out depending on the current capacity and other conditions and the progress is documented in the polygons devised by us during our surveys. Biology and ecology majors of ELTE University also frequent the area. Their work is supervised and planned by us through the Visitors' Centre and with the cooperation of the national park.

According to the collected documentation, landscaping students participated in the post-treatments of the following polygons (Fig. 20):

– 23 polygons between 2–20 September 2013 (1, 4, 10, 11, 14, 18, 20, 24, 25, 26, 27, 43, 44, 45, 46, 59, 60, 61, 62, 63, 74, 79, 88) and over the orchid protection area.

Fig. 20. The polygons treated by landscaping students during follow-up treatments after the completion of the project in the autumns of 2013 and 2014. The light grey shading illustrates the polygons that were treated in any of the two years, while the darker shading shows the sections treated in both years. (The unshaded polygons did not go through post-treatment throughout the apprenticeship of the students).

Fig. 21. The unremoved loppings left behind in each polygon at the completion of the project in the summer of 2012, shown in percentages in proportion to the area of the shrub patches.

– 34 polygons between 3–21 September 2014 (1, 2, 3, 4, 5, 6, 7, 9, 10, 12, 13, 15, 18, 21, 22, 23, 24, 25, 26, 27, 28/B, 29, 32, 37, 38, 39, 43, 45, 59, 60, 61, 62, 74, 81), the orchid protection area and on the area registered under the number 2638/2 (scrubland next to a garden plot belt).

After the completion of Sas-hegy project there still remained a number of responsibilities besides post-treatment. We would like to call attention to two of these responsibilities to promote a broader interpretation of post-treatment (follow-up activities). It is important that direct treatments should be complemented by activities that help improve the general conditions of the area.

The last and most significant project on Sas-hegy did not have the necessary funds to take care of the collection, deposit and removal of the shrubs and trees that had been eliminated by the chemical treatment then severed. This task was only partially completed during the project: in some cases, the branches and twigs were left uncollected, while in other cases they were deposited but not removed due to shortage of time and/or manpower. The areas typically affected by this problem are the furthest or steepest parts of the hill that are therefore difficult to access. The geographic location of these areas, based on the concluding survey of the project, can be seen on figure 21 together with the amount of loppings left behind in each polygon.

Fig. 23. Woodchipping the loppings of the black pine in the winter of 2011–2012. (Photo: Z. Tóth)

Fig. 22. Strong regeneration of the lilac after one or two years, over the areas with no post-treatment. (Photo: Z. Tóth)

This situation has improved somewhat with the inclusion of volunteers, but total removal has still not been accomplished over all of the polygons. The most dramatic change can be seen on the eastern part of the area, where the majority of the loppings has been gradually removed, mostly by volunteers.

The unremoved dried shrub piles (covering large patches) hinder access to the area and, even more importantly, make post-treatments impossible and facilitate unwanted shrub regeneration (Fig. 22) as well as the survival of shrub patches, not to mention the fire hazard these large volume, dry, flammable twigs pose on the habitat.

The utilisation of the resulting phytomass is conducted in an environmentally conscious way, showing a good example not just to local residents but to visitors as well. The dry wood chips and twigs has been used for years to heat the Visitors' Centre, which has been renovated and extended with an extra floor (Fig. 23).

The volume of weeding over the bare ground left after the elimination of large patches of shrubs is significant in the first years after the treatment. Another important and beneficial activity is the acceleration of habitat regeneration, which might necessitate the enhancement of swarding, strictly by sowing locally collected seeds. We carried out experimental sowing with a seed mixture, followed by the sowing of seeds of known taxons in 1 × 1 metre identifiable subsections of the experimental parcel.

Acknowledgements

The interventions undertaken on protected areas of national significance were initiated and the resourced provided by the Duna–Ipoly National Park Directorate.

Special thanks to János Kremincsán, the director of the Visitors' Centre and his staff, who provided us with the documentation of volunteer projects and gave their full support to the surveys, experiments and volunteer projects conducted by us.

Apart from outside experts involved in the surveys, civilian participation and volunteer work was also significant during treatments and post-treatments, the awareness raising aspect of which was of particular importance to us.

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Experience of invasive plant species control in the Turjánvidék area of the Upper Kiskunság region

Csaba Vadász

Natural characteristics of the area

The area presented in this study belongs to the administrative territory of Kunpeszér and partially of Kunadacs and Tatárszentgyörgy, covers the northern half 'Felső-kiskunsági turjánvidék' Natura 2000 area that encompasses the northern part of the Peszéradacs meadows of the Kinkunság National Park, numerous ex lege protected natural reserves and non-protected natural areas (Fig. 1).

The three most important characteristics of the territory are low fertility, unfavourable environmental conditions and high environmental value. The area is typically characterised by low fertility (AK fertility index 3–8) sand (partly silt), as well as meadows and bogs. These soil types are situated mosaic-like, where the lower altitude matrix exposed to regular excess water and higher altitude dunes and ridges alternate. The seasonal surface waters appearing over the lower altitude areas are mostly not due to the local precipitation (annual average 520 mm), but rather originate from rainwater, arriving below ground level from the sand ridges of the area between the Danube and the Tisza rivers. The areas covered by groundwater floods and the period of flooding shows significant difference year by year. Due to low fertility and the stochastically fluctuating ground water level, numerous grasslands had not been ploughed up before until the last years of the former socialist cooperatives. These grasslands were used in a traditional way for grazing. Although cooperatives ploughed up some of these primary grasslands in the last few years of their operation, they still exist today in relatively large areas, albeit sporadically.

Partly due to the presence of primary grasslands, partly because of the variety of soil conditions, this is one of the richest areas in Hungary in protected and unprotected vascular plant species. Some of Hungary's most significant populations of several animal and plant species can be found here, for example the great bustard (*Otis tarda*), the Hungarian meadow viper (*Vipera ursinii* subsp. *rakosiensis*), ground-squirrel, (*Spermophilus citellus*), the spider orchid (*Ophrys sphegodes*), the woodcock orchid (*Ophrys oestrifera*), the giant plantain (*Plantago maxima*), a milkvetch species (*Astragalus dasyanthus*), as well as the pannonian bush-cricket (*Isophya costata*). The environmental value of the area in Hungarian terms is exceptionally high (Fig. 2).

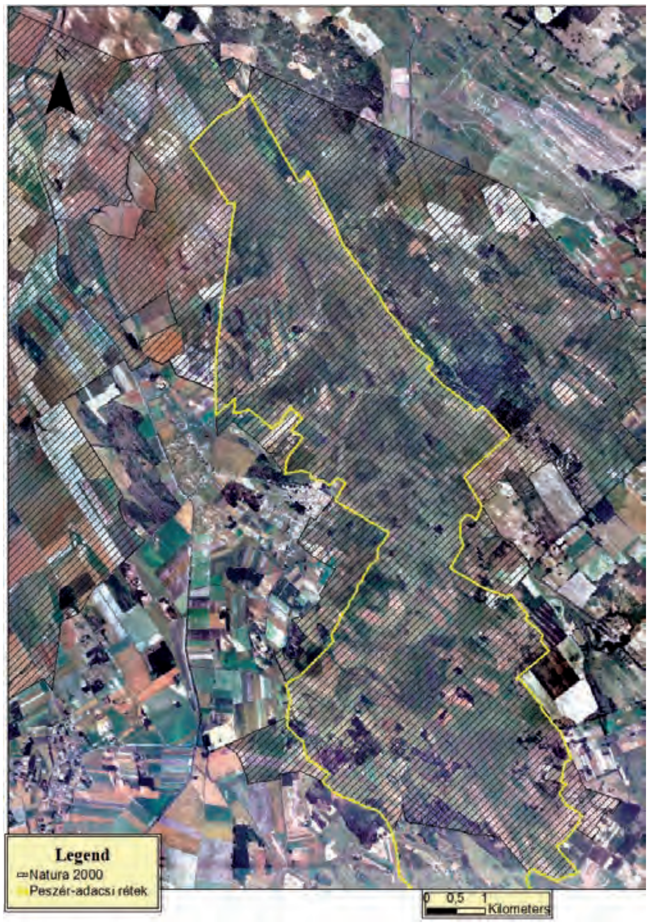

Fig. 1. Map overview of the treated areas.

Initial conditions

Land use

Most of the territory is by now classified and utilised as grassland (pasture or meadow). Environmental protection started to gain ground in the supervision of land management in 1997, and controlling invasive species also dates back to that time. Given that nearly 2000 hectares of arable land has been converted back to grassland in the past decade and a half (although a significant percentage of these converted spontaneously after abandonment), the conditions became favourable for the settling and potential spread of herbaceous (common milkweed (*Asclepias syriaca*), giant goldenrod (*Solidago gigantea*)) and woody invasive species (Russian olive (*Elaeagnus angustifolia*)). In addition, the condition of the areas classified as forests (that were exploited by cutting in accordance with several decades of tradition) proved favourable for further woody invasive species (tree of heaven, box elder (*Acer negundo*), common hackberry (*Celtis occidentalis*), black cherry (*Prunus serotina*)). Apart from the above listed strictly speaking invasive plant species often mentioned in environmental literature, technological descriptions and scientific publications, we also observed the spread of so-called 'internal' invasive species in the fresh converted fallow lands (native flora elements capable of creating monodominant populations, e.g. common reed (*Phragmites australis*), bushgrass (*Calamagrostis epigeios*) and yellow bluestem (*Bothriochloa ischaemum*)).

Land ownership

The Kiskunság National Park Directorate uses the state owned lands and areas under their property management (except for forests) by leasing them out, typically as extensive cattle pastures. In addition, a prominent user/forest manager of the territory is the Budapest Forestry Company of the Ministry of Defence and KEFAG Ltd. Privately owned areas in the territory presented are not significant these days.

Fig. 2. Typical habitat mosaic with rich biodiversity in Upper Kiskunság. (Photo: Cs. Vadász)

Stages of controlling invasive species

Given that controlling invasive species in the areas under the protection of the Kiskunság National Park Directorate (coordinated by local rangers) started in due time around the abandonment of arable lands and the conversion to grasslands (i.e. in the second half of the 1990s), invasive species only appeared sporadically, their spread and the appearance of large populations were successfully prevented by the early 2000s. Outside business partners were also involved in the various projects of the control efforts, e.g. chemical treatments or in some cases by mechanical means. Moreover, land users were instructed to comply with the obligations regarding the control of invasive species and such activities were continually monitored.*

By the mid-2000s the presence of invasive species on protected natural areas had been reduced to below the detectable threshold (only smaller populations prevailed on protected territories that were not observable). The size of the populations has approximately maintained those levels since then, no spread has been observed. On the contrary, they are tending towards total eradication.

Significant control of invasive plants in forests and non-protected grasslands started in the early 2010s. These areas surround the protected grasslands, which means that in lieu of invasive species control, these surrounding areas posed a constant source of propagules towards the protected areas. By today the populations of invasive species have been successfully reduced to below the detectable threshold on even larger non-protected areas and forests. As these areas are typically privately owned, the appearance of EU subsidies provided a significant incentive for landowners and users to take considerable measures to eradicate invasive plants. In addition, the Directorate called farmers' attention to the fact that the "appropriate agricultural and environmental condition" that is cited as a criterion for the subsidies can only be maintained by adequate control of invasive species. We also shared our technological experiences with the farmers so that their eradication efforts could prove proficient and effective.

To sum up the current situation, invasive species on the northern section of the Peszéradacs meadows have been reduced to below the detectable threshold. Some herbaceous species that are still present are

*Attention! Experimental chemical control methods described in this chapter are subject to authorisation! Their practical application requires an emergency permit issued by the pesticide control authorities for the given area and period!

common milkweed and goldenrod, as well as invasive cocklebur species (*Xanthium* spp.), while woody species include (in descending order of significance in terms of the severity of the represented problem) tree of heaven, box elder, common hackberry, black cherry and common lilac (*Syringa vulgaris*) around abandoned farmyards. On the protected grasslands of the Peszéradacs meadows, black locust (*Robinia pseudoacacia*) does not typically show invasive characteristics, while in the ex lege protected forests (e.g. the "native birch woods" of the Peszér forest), where it could potentially spread, it is easily controlled (contrary to the other species listed above).

The following study includes an account of practical experiences gained in the control of invasive species over the past 15 years. The description is not confined to explanations of the technologies used, since in our view controlling invasive species as one of the elements of land management and use can only be effective if realised in a systematic, professional and efficient way and not as an arbitrary, self-serving act. Therefore, apart from a specific description of the technologies applied, we will discuss other important factors such as the effectiveness of the treatments (as well as the factors influencing effectiveness), the necessary amount of time and chemicals.

Methods used

Now we will turn to describing the controlling technologies currently used and considered most effective by the Directorate.

As regards woody invasive species, we have gained experience in the eradication of black locust, common hackberry, box elder, black cherry, tree of heaven, Russian olive and common lilac. Mechanical eradication techniques can be used in the case of Russian olive, and partly the common lilac and black locust. We were not able to find productive (effective) chemical-free methods for controlling the other species mentioned.

The mechanical eradication of the Russian olive was carried out in two ways: reaching below with a front-end loader and turning the trunk out together with the entire shallow root structure, or by fixing a cable on the tree and extracting it. The first method is only applicable up until a certain trunk diameter and is strongly dependent on the power and resilience of the power tools and machines used (Fig. 3). As a general observation, under appropriate soil conditions (i.e. when the tractor does not cut into the lawn but the soil is not so dry either that the roots get torn), an overwhelming majority (70–80%) of the trunks can be extracted by both methods in a way that no root shoots appear the next year. Both methods require that the extracted trunk be taken care of as soon as possible. Although the trunks and spikey branches lying on the ground provide excellent shelter for several animal species, they significantly impede the appropriate use of the land (e.g. late mowing of grasslands where necessary) as well as the potential post-treatments of Russian olive (controlling new shoots) and other invasive plants. One of the unfavourable characteristics of the Russian olive is that it makes a very poor fuel when it is fresh (due to its high water content), while at the same time it is difficult to cut when dry. That is why it is advisable to process the trunks and branches to be used for fuel immediately after extraction so that it is less labour-intensive and does not hinder land management in the following year. Woodchipping and transportation of the thinner twigs is usually taken care free of charge by the local contractors if they are sufficient in quantity.

A well-known feature of black locust, which is also exploited during natural regeneration, is its high regenerative capacity and its ability to grow root, base and trunk shoots shortly after the trunk has been severed. We observed on several sites that shoots appeared on the trunks of previously cut trees – with annual flail mowing – even after 7–8 years (which means that post-treatment in this case is particularly costly). What makes non-chemical control still possible is grazing animals' preference for black locust. If the fresh shoots of black locust are regularly grazed (several times a year so that it is not too long for the animals to graze), the underground reserves become depleted within 1–2 years and the specimen die, not being able to grow new shoots. At the same time, if it is only possible to have the black locust sprouts grazed once a year for a short period of time, it is inevitably going to grow too big for the animals to graze, and at that point control can only be successful through chemical treatment. This method is obviously not feasible in forest areas as forest grazing is illegal.

The grazing sheep also showed a preference for common lilac, chewing off the shoots of the stumps and with regular grazing, the common lilac trunks died completely within 1–2 years.

It can be deduced from the above that non-chemical technologies for control and eradication only proved feasible for certain species, and even in those cases we had to meet strict requirements (e.g. the black locust or common lilac shoots had to be cut back with adequate frequency and the Russian olive had to be extracted under optimal soil conditions). However, we still believe that wherever it is feasible, we will strive to attempt non-chemical control of in-

Fig. 3. Front-end loader tractor extracting a Russian olive with the root structure. (Photo: Cs. Vadász)

vasive species and the eradication of their specimen by all means.

Where it is not possible to apply non-chemical methods, then the following methods should be used, which are successful and effective for all woody species (i.e. the black locust, the common hackberry, the box elder, the black cherry, the tree of heaven, the Russian olive and the common lilac).

The application method of the chemicals into the trunks selected for treatment is determined by the thickness of the trunk.

In the case of specimen with a chest height diameter smaller than 8 cm, after partial bark stripping (with billhook, knife and two-handed saw), the chemical is applied over the debarked area of the tree with a brush. The bark is never stripped in a full ring but is done above the base of the tree by removing approximately 40 cm of the bark over about 60% of the entire cylinder wall on one side (about 3–5 drags of the knife), then this is repeated on the other side, making sure that approximately 10 cm of intact bark is left on the cylinder wall. That way the first cut starts above the base of the tree and ends about 40 cm above that on one side, while the other cut starts at a height of about 50 cm and ends at around 90 cm on the other side. Viewed from above, there is an approximately 5–5% overlap between the two cuts. The cuts follow the above pattern because it has been observed with several species that in the case of a single-sided cut, the canopy only partially dries out (and the trunk survives the chemical treatment), while if the bark is peeled in a full ring (especially in the case of the tree of heaven), the circulation of the treated trunk is completely cut off and the chemicals do not reach the root structure (which generally results in an overwhelming number of new shoots) (Fig. 4).

In the case of specimen that reach the 8 cm chest height diameter, the chemicals are applied with a veterinary automatic syringe, distilled water flask or plastic injector (Figs 5 & 6) into a 8–10 mm diameter hole drilled into the centre of the heartwood in a 45 degree downward angle with manual, electric or internal combustion drill. The number of holes depends on the diameter of the trunk: as a general rule, there should be at least one hole in every 5 cm of the circumference of the tree, i.e. a tree with a 10 cm diameter will have to have about 6 holes. After the injection of the chemicals the holes are closed. We used to apply putty for this purpose, which is, however, rather costly (currently around 300–400 HUF/kg), so we decided to change to the most inexpensive adhesive, tile adhesive without antifreeze. Although a disadvantage of this material is that is dries quickly (which means we should only create enough mix to be used up within 30–40 minutes), the advantage is that a 25-kg bag costs only 700–800 HUF (which means that one plaster costs around 25 HUF). The plaster is usually applied at the opening of the hole with a spatula.

The chemical applied for both the wiping of the debarked surface or the injection into drilled holes is a concentrated glyphosate containing herbicide in free circulation used for total control (Medallon Premium, Fozát 480, Figaro, Clinic 480 SL, NASA, etc.). In these cases, other substances are not mixed in, e.g. absorptive or adhesive materials.

It is important that the treatmnet should be carried out between 1 August and 31 October (but no later than the first frost). A single treatment is sufficient for an overwhelming percentage of specimens. However, treatment needs to be repeated for those specimens whose canopies do not dry out completely. The effects of the treatment generally become visible within a couple of days.

Correction with an appropriately timed second treatment (when the effects of the first treatment have already become visible) can increase the rate of treated trees to almost 100%.

Fig. 4. Applying the chemical by brush after stripping the bark. (Photo: Cs. Vadász)

Fig. 5. Drilling a hole into a larger trunk before injection. (Photo: Cs. Vadász)

We experimented with distribution in other periods, but due to the high rate of trunks surviving chemical treatment, the control of woody invasive plants is now exclusively carried out in the above-mentioned time frame. We are not aware of the specific physiological explanations but presume that the trunks pump nutrition back to the roots in the late summer and autumn period, while prior to that, circulation of nutrients typically follow an upward trajectory. In the latter case, even though the sprouts are destroyed, the root survives to grow new shoots.

The above-described distribution methods are 100% selective. In order to prevent accidental dripping, the chemical rolls need to be placed on a plastic sheet until application.

Chemical spraying had previously been used for the eradication of woody invasive species. However, that method has a far lower selectivity rate and a much higher chemical requirement, while the necessary amount of time is not lower (compared to backpack spraying).

In our experience, among the perennial herbaceous invasive species (Canadian and giant goldenrod (*Solidago canadensis*, *S. gigantea*, common milkweed), the goldenrod species can be effectively controlled through mechanical means, while only chemical treatments proved effective for milkweed.

Cattle graze on goldenrod relatively gladly (until the phenophase before blooming). We are unable to provide data on other grazing species such as sheep, buffalo, horses or donkeys. Goldenrod is not resilient against regular grazing and the stems die quickly. In grazing systems where animals graze on the areas infested with goldenrod for only short periods of time, grazing is not efficient for controlling the goldenrod species. From this point of view, the mass presence of goldenrod can be seen as an indicator of the underuse of pastures. Larger goldenrod populations cannot survive on pastures proficiently managed with appropriate rotation and grazing pressure. In the cases where goldenrod has achieved blooming, depending on the size of the patch, manual uprooting, manual and mechanical mowing or flail mowing is applied. The preference of cattle for goldenrod depends on several factors (not only the phenophase of plants). The most interesting data were gathered when a cattle herd was transported from a floodplain of the Danube due to high water to the Peszér territory, where the cattle fed on goldenrod almost exclusively. The cattle appeared to specifically seek out the species and were only willing to graze on other plants where no more goldenrod could be found.

In the chemical treatment against perennial herbaceous invasive plants, the following method proved the most effective. The chemicals were applied by spot spraying with a manual pump under low or medium pressure and with drop-like dispersion. This way spraying can be done selectively. Under high pressure, the chemicals bounce off the leaves, while with overvaporised dispersion most of the chemical is not dispersed on the targeted species. 5–6-liter manual sprayers proved the most efficient, which weigh less than the 16–18-litre backpack sprayers so they are less exhausting to use all day long.

The chemical applied here was also a total control, free circulation, glyphosate containing herbicide (Medallon Premium, Fozát 480, Figaro, Clinic 480 SL, etc.), from which we created a 2.5% dilution spray. It is advisable to add a walnut-size amount of Nitrogen chemical fertilizer for every 20 litre of the solution (most commonly CAN) as well as 2–3 ml adhesive (e.g. Nonit). The adhesive should always be added at the end of the mixing process (we first pour the concentrated chemical in the can, then add the fertilizer,

Fig. 6. Filling the hole with chemicals. (Photo: Cs. Vadász)

Fig. 7. Controlling common milkweed by spraying. (Photo: Cs. Vadász)

then the water and finally the adhesive), because if the adhesive is added before the water, the water will make the solution foam and run over.

In our experience treatment of milkweed should be carried out between 1 May and 31 October (but no later than the first frost), while the optimal time for the goldenrod species is between 1 June and 31 October (but no later than the first frost). Chemical treatment must be carried out exclusively on non-blooming plants. In the case of blooming specimens, they must be mowed and chemical treatment can be applied after the sprouts have strengthened (have reached the 4–8-leaf stage). If the entire leaf structure does not dry off on a certain specimen, they must be treated repeatedly (correction, i.e. treatment of overlooked or not properly treated specimen, is usually done 10 days after the initial treatment). With this treatment, i.e. chemical treatment of stems before blooming and mowing of blooming stems, can be carried out on both milkweed and goldenrod throughout the entire vegetation period. This is a significant advantage compared to the control of woody species, as the available time frame in their case is very narrow.

The effectiveness of the eradication of herbaceous invasive plants is not primarily determined by the season, but the choice of time of day. We have observed that the effectiveness of the treatment dramatically decreases due to heat or sun exposure. Therefore, in the summer heat only early morning hours (only without significant dew) or late afternoon hours are appropriate for the application of the treatment.

Spot spraying is a highly selective method (Fig. 7). The milkweed populations mixing with steppe or sand spear grass could be eradicated (due to their large leaves) without damaging protected species (or other plants not targeted for control).

The cocklebur species, which are herbaceous invasive species, are relative newcomers in the area. They are controlled by mechanical methods (manual uprooting) regularly from the appearance of seedlings. We are not able at this point to provide quantitative data on the control of these species but it is estimated that the spread of these species will cause severe problems in the future.

Experiences gained

The effectiveness of the treatment

It is important to stress that the effectiveness of a treatment in any given year can actually only be evaluated in the following year, as it is possible both for woody and herbaceous species that the chemical burns off the shoots above ground but does not completely destroy the root structure, which will result in new root shoots the following year. With the above-described technology, if the treatment is applied in the appropriate period, with the proper method, with the appropriate amount of chemicals and with well-timed corrective treatments, the stem rate can be reduced by 90% by the following year. This means that the density of invasive species can be reduced to 1/1000 of the original population in a given area within 3 years (total eradication is only impeded by detectability). It is also important to note that there were significant disparities in the effectiveness of the treatments between the different years. In the years when the plants were in a good physiological state (i.e. received sufficient amounts of precipitation in the vegetation period), chemical treatments were approximately 20–30% less effective in general. However, in the years when plants were in physiological stress, e.g. due to prolonged droughts, the effectiveness of the treatment came close to 100%.

Resource requirements of the treatment

Given that the methods described here are severely labour-intensive, the highest expense ratio is accounted for by wages and personal expenses, not so much chemical and other material costs. We did not apply less selective, mechanical methods, e.g. weed wiper, thus we have no experiences to report.

Here we must stress the significance of community work in the control of invasive species. The Kiskunság National Park Directorate employed an average of 8–10 workers in the community work programme in the Peszéradacs meadows in recent years, the most important task of whom was to control invasive species. A fundamental factor to ensure the efficiency of the work was to employ people who are disciplined, can follow instructions, can execute their tasks conscientiously, give a consistent performance as well as meet the legal conditions detailed below.

A fundamental legal condition of chemical plant control is that the employees have had the necessary plant protection training (have acquired a green certificate). Therefore, the workers who showed proper work morale were enrolled in a plant protection training course organised within the framework of the community work programme. After successfully completing the course, they received a licence that enables them to carry out plant protection tasks (in this case, invasive species control) as employees. Another obligatory legal requirement is the employment of a plant protection professional with a degree in higher education. Finally, as our tasks were carried out on a protected natural area, our Directorate had to obtain the legal permission of the local environment protection authority to carry out chemical treatments. In previous years this permission was requested for a long list of registered lands, which was later exchanged for a general permission valid for all areas under the property management of the Directorate, which was duly granted by the authorities. The advantage of this is that if invasive species were detected on new territories, a new permission did not have to be requested. This general permission is only valid for the above-described selective methods. The Kiskunság National Park Directorate also applied other techniques on different areas (e.g. weed wipers), which are not used in the Peszéradacs meadows. As those methods are far less selective than the technology presented in this paper, they required individual permissions.

Our overall experience is that under proper professional guidance and supervision – and with community workers who have an appropriate work morale – the community work programme can open up several opportunities in terms of controlling invasive species. To give a random example, we eradicated the herbaceous invasive species over a 72-hectare moderately, at parts heavily infested forest with the help of the community work programme in 2 consecutive years (by the 3rd year the density of invasive species had become marginal). Moreover, the woody invasive species, which caused the most severe problem locally, (in descending order of severity: tree of heaven, box elder, common hackberry, black cherry) were almost completely controlled over a total of 115 hectares of forest. If the work had been done by a contractor, it would have cost an estimated 20–25 million HUF. However, with the community work programme, the total cost of the project to the Hungarian government, including personal expenses, training fees, expert consultancy, tools and chemicals, was 10 million HUF.

Specific time commitment associated with the different species

The average stem density of the tree of heaven populations of different ages grown from seed (including current year and previously sprung specimens) in the assigned sample area of the Kunadacs 1B forest section was 3.31 (±1.11) stem/m^2. The net treatment time for one stem was 14.06 seconds (±5.08) taking into account the accessibility of the stem within the stand, but ignoring the time needed to access the stock itself and the break allocated to the workers. We can thus calculate the net treatment time for 1 hectare of seedling tree of heaven stand, which is 129.31 hours (±43.32). Taking into consideration workers' time off pro rata temporis, the breaks, the time needed for the maintenance of tools and to access the stands, one worker needs approximately 6 weeks to complete control of 1 hectare of tree of heaven stand, provided that no other hindering factors occur, e.g. unfavourable weather conditions. This indicator is only valid with the proper work morale and at least average workload.

For the tree of heaven stand of coppice regeneration, the net treatment time for one stem was 17.47 (±3.09), i.e. there was no significant difference. However, the trunk density of the tree of heaven coppice forest (resprouting after the exploitation of a former, almost homogenous tree of heaven forest) can be several times that of the trunk density of seedling tree of heaven forest. Consequently, the cutting of live tree of heaven will later result in a much more time consuming chemical treatment, which is why the most effective method is to start with chemical treatment and then apply cutting, not the reverse. Therefore, wood exploitation in the tree of heaven-infested forests in the Peszéradacs meadows is only carried out after the chemical treatment of tree of heaven. This practice has unfortunately not become common in non-protected areas, which forecasts a much higher eventual cost of tree of heaven control treatment compared to applying chemical control prior to exploitation.

The average density of giant goldenrod (controlled by manual extraction) in the moderately infested sample area along the Danube-valley Main Canal was 34.78 (± 16.01) stem/m^2. The average treatment time for 1 m^2 was 49.56 seconds (±18.29). On the highly infested sample area in the Kudacs Long meadow the average stem density was 176.89 (±58.16) stem/m^2, while the average treatment time was 211.33 seconds (±37.94).

Based on this, it takes one worker a net amount of 410–550 work hours (i.e. 5 months) to control the giant goldenrod stand over 1 hectare of highly infested land with the above-described method (involving 3–4 treatments a year). It can be deduced that it is much more efficient to apply regular mowing in order to control the goldenrod (except in cases where other species are present that could be endangered by mowing, or if there are technical obstacles). With mowing, depending on the experience of the handler and the type of mower used, the productivity can be increased tenfold or even more with mechanical mowing, provided there are no environmental factors that might exclude it. In the case of highly infested homogenous goldenrod stocks, the stem density is much higher and the treatment time is far longer.

The average stem density of the milkweed on the ex lege protected sample area belonging to the Peszéradacs meadows was 3.24 (±1.23) stem/m^2. The average treatment time for 1 m^2 was 14.69 seconds (±5.64). Based on this, it takes one worker 40.81 work hours net (i.e. approx. 2 weeks) to treat 1 hectare of moderately infested land. In our experience one corrective post-treatment is sufficient after the initial treatment. There are no highly infested sections in the protected natural areas, which is why we can provide no data on the treatment needs of such areas.

Generalisation of experiences

During our efforts to control the invasive species, we devised a technology for each individual species that can be deemed sufficiently effective under the local environmental circumstances and opportunities. We also experienced significant discrepancies in efficiency between the different years. We cannot claim, however, that these methods can be applied with the same rate of effectiveness on other areas with different edaphic and hydrological conditions. Moreover, we are not saying that these methods cannot be further improved as we are striving to increase their efficiency while decreasing their potential negative effects (due to the use of chemicals) on ecosystems. We can, however, conclude that we have been able to achieve promising results on the presented area with these methods as an integral element of the treatment system: we are able to keep the rate of invasive species consistently around the detectable threshold and can even control these plants with similar effectiveness on a considerable part of the surrounding non-protected areas as well. In addition, regarding the sustainability of these results, we can conclude that compared to other expenses associated with land use the populations of invasive species can be kept on a low level close to the detectable threshold with minimal financial investment.

As an explanation of the results achieved in the control of invasive species in the Peszéradacs meadows, it is important to mention that we succeeded in sustaining the extensive grazing of the land (as it had been done previously, for centuries) taking into account the characteristics of the poor fertility soil. One of Hungary's most significant beef cattle stock can be found here, which cannot be extended any further as the stock has achieved the maximum level the area can sustain from an conservational protection point of view, therefore it can be considered optimal. There is real agricultural activity on this area (i.e. it is not the open-air museum type of national park). Through the selection of appropriate species and subspecies, as well as the selection of optimal grazing pressure, we have developed a diversifying treatment system that is fundamentally unfavourable to the spread of invasive plants (as opposed to the regularly overgrazed or underused domestic grasslands), at the same time not only conducive but necessary to the protection of species with conservational importance. Consequently, not only do the classically speaking invasive species pose a less severe problem over these grasslands in question compared to other regions of the country, but this treatment and land use system also solves other problems (e.g. the so-called internal invasive species like the common reed, bushgrass and lemongrass). We consider the efforts to control invasive plants only one element of the treatment system. In other words, controlling invasive species is not the goal, but the means to sustain the biodiversity of the local natural system, which is unique at a national level.

Mechanical eradication of common milkweed: can it serve as a possible alternative to chemical methods?

Zoltán Vajda

Natural characteristics of the area

The "Fülöpházi sand dunes" region of Kiskunság National Park is located on the sand plateau of the Danube–Tisza Interfluve. The materials of this plateau were carried here by the primeval Danube over hundreds of thousands of years. The vast sand mass was formed into the present sand dunes by the prevailing NW–SE winds. The soil of these dunes consists of sand rich in lime. The easily warming surface of the dunes is predominantly covered by open sand grassland. The core species of these sand dunes are red fescue (*Festuca vaginata*) and *Stipa borysthenica*. The most valuable plants of this area are *Iris arenaria*, *Sedum urvillei* subsp. *hillebrandtii*, *Dianthus serotinus*, yellow everlasting daisy (*Helichrysum arenarium*) and *Dianthus diutinus*.

As open sand grasslands are not fully closed and their soil erodes easily, these areas are very fragile and vulnerable to disturbance. Prolonged disturbance, such as constant grazing, or sporadic but serious disturbance (e.g. motorbikes) causes the grasslands to degrade, hence providing a chance for the alien species to spread.

Initial conditions

The Fülöpházi sand dunes and the entire plateau in general is heavily infested by common milkweed (*Asclepias syriaca*). In 2010, Katalin Szitár conducted the habitat mapping of a 5 km × 5 km quadrant of the Fülöpházi sand dunes within the framework of the Hungarian National Biodiversity Monitoring. In her report, she points out the following: "Common milkweed is the most widespread and most significant invasive species in the quadrant. Apart from the wettest habitats and other extreme areas, common milkweed can be found in all habitats, often with a 100% incidence rate."

The question of how to get rid of this invasive species arose many years ago. As the area is protected, the use of chemicals was of course not the first solution that came to mind. First we wanted to test a method that comes with a lower environmental load, something that is not dangerous to the natural values of the area. This is why we first opted for trying mechanical control methods.

Methods used

We chose a 600 m^2 (20 m × 30 m) area of the Fülöpházi sand dunes of Kiskunság National Park to become the pilot area, as it was severely infested with common milkweed. The quadrant was located in the middle of a large area covered by common milkweed. During the experiment, two people manually uprooted the common milkweed sprouts at least once, possibly twice a year. After counting the sprouts, we removed them from the area. With this method, we not only removed the aboveground sprouts, but also some parts of the roots responsible for reproduction, which we assume might have further weakened the plant.

Experiences gained

The four-year results of the experiment are as follows.

27 July 1994	4047 sprouts
29 September 1994	3720 sprouts
20 June 1995	3500 sprouts
20 June 1996	3500 sprouts
22 May 1997	1880 sprouts
28 August 1997	1140 sprouts

As the data shows, mechanical treatment in small numbers (1–2 times per year) is not a feasible way of eradicating common milkweed even if it is done at the best of times (during blooming season). Of course, there was a chance of reinfestation from the surrounding areas, but we did not experience any difference in the number of sprouts between the edges and the middle of the pilot area. This result is further supported by another intervention (Hajós, 100 ha), where a similar extent of common milkweed infestation was treated by mowing for a period of three years, and the number of common milkweeds was reduced by two-thirds, their height decreased by 50%, but the plant did not die out.

Using this method is justified if chemical control method is intended to overcome the problem of common milkweed. Continuous mowing for years can weaken the plant and reduce the number of sprouts, so the required amount of chemicals will be less, which means a lower environmental load.

Experience of invasive alien plant management in the steppe oak woods of Nagykőrös and in Turjánvidék

György Verő and Annamária Csóka

Introduction

In this chapter the management experience of invasive alien plant species in LIFE 06NAT/HU/000098 project (carried out in 'Nagykőrösi pusztai tölgyesek' (HUDI20035) Natura 2000 site between 2006 and 2011) and LIFE 10NAT/HU/000020 on-going project (implemented in 'Turjánvidék' (HUDI20051) Natura 2000 site, launched in 2011) is summarized. Our two projects are linked: the most experience gained in the first one were put to use in the second one.

Natural characteristics of the area

In both projects the invasive management areas are situated in the northern part of the Danube–Tisza Interfluve. The areas have a steppe woodland climate. The sites are characterised by various sand soils (evolved on sand hills with a characteristic micro-relief), which have constantly decreasing water conditions. The sand vegetation, primarily the non-arboreal habitats are extremely rich in endemic species. However, these are seriously threatened by invasive alien plant species. The sand oak woods (and steppe oak woods in general) are among the forest types which have been already destroyed to an extent of over 90%. This is why their remnants represent an outstanding conservational value.

In the Nagykőrös target area we aimed the control of invasive alien species (IAS) in a fragmented 420 ha size area. The sites included were steppe woodlands of various cover, but with an overwhelming forest component and a well-developed shrub layer. Further target areas were black locust plantations wedged between steppe woods. Due to the combined effects of threatening factors (spread of IAS, fragmentation, drying, improper forestry use, excessive game stock and lack of information in society) these habitats became one of the most endangered ones in Hungary. The former extensive oak steppe woods were seriously damaged by the deforestation until the end of Turkish occupation and subsequently the overuse of the remaining forests (short rotation and overgrazing). From the 19th century onwards, the transformation of the remaining natural forests (due to the plantation of black locust and pine) brought the oak steppe woods to the verge of total disappearance. The fragmented remnants are scattered within a some-thousand-hectare large contiguous tree plantation.

In our ongoing project, in Turjánvidék Natura 2000 site, the main target area of IAS control is the over 1000-hectare sand habitat that is located on the periphery of Táborfalva. The whole area belongs to the Táborfalva Military Shooting Range and Training Area of the Hungarian Army. Compared to Nagykőrös, a main difference is the dominance of the non-arboreal sand habitats here. However, juniper-poplar forests (of various covers) are also present and homogeneous black locust plantations can be found in the management area as well. These are surrounded primarily by tree plantations. Since the area has functioned as a military training site from the second half of the 19th century, it is moderately affected by agricultural and forestry use and fragmentation is not characteristic here.

Initial conditions

The species sets of IAS in the two target areas and their surroundings are similar. In Táborfalva there are more species present with considerable quantities, however, the overall infestation rate is much lower than in Nagykőrös. In the latter case, immediate intervention was necessary, while in Táborfalva we have the possibility to considerably slow down the degradation of natural habitats (in a less infested state, partly as prevention).

We generally find planted or coppice black locust (*Robinia pseudoacacia*) plantations in the direct environment of the natural habitats. We can frequently observe the spread of black locust to the precious areas with root shoots. In Táborfalva, black locust patches which grew spontaneously after fires caused by military use (the so-called 'bomb-crater black locust forests') are also typical. The target area in Nagykőrös is rather fragmented; furthermore, in the first period of the development of black locust plantations the species was mainly settled in natural clearings, thus the whole target area was significantly infested by this IAS. On the contrary, in the target area of Táborfalva (nearly continuous area, over 1000 ha) the spread of IAS started from the neighbouring plantations and the edges are much more infested than the central parts.

In Nagykőrös, besides black locust the second most important IAS is black cherry (*Prunus serotina*). Its main infestation sources are the plantations (similar to the case of black locust); however, it spreads with a different strategy and pattern. We can hardly find homogeneous plantations of this IAS because it was planted in the rows of pine plantations. Its seeds can spread in large quantities and for long distances in the intestines of the birds consuming the fruits. In general, it formed the shrub layer in the whole target area sporadically; however, we could find even homogeneous patches of this IAS locally. In Táborfalva its presence is slightly observable.

In Táborfalva, another very important IAS is common milkweed (*Asclepias syriaca*) (apart from black locust). The main infestation sources are the hybrid poplar plantations bordering on the target area. These have good light conditions and their soil is hoed mechanically on a regular basis. As a consequence, their herbaceous layer contains common milkweed in sizes of even 10 ha and often with a cover over 50%. For this reason the infestation is concentrated along the edges. However, with the help of its seed which have a good dispersion capacity, this IAS also appeared in the target area centre in the disturbed soil made by military and forestry use, as well as overgrazing in the past. In Nagykőrös, the majority of the clearings was free of common milkweed.

Tree of heaven (*Ailanthus altissima*) dwells in both areas but it is more typical of Táborfalva. It appeared in the edge areas and in places where the soil was disturbed. It started to spread locally and now it shows a typical patchy pattern. Within a patch we can find some older trees and there are numerous young sprouts that surround them.

Russian olive (*Elaeagnus angustifolia*) is also more common in Táborfalva and present one by one. It cannot colonise the dry sand habitats rapidly, however, it spreads significantly in more humid habitats in other areas of the LIFE project.

In addition to the above-mentioned species, false indigo (*Amorpha fruticosa*), green ash (*Fraxinus pennsylvanica*), box elder (*Acer negundo*) and non-native goldenrod species (*Solidago* spp.) dwell in both target areas.

Methods used

If we go through the implementation of the two projects, this will reveal to us the progress of IAS control methods between 2008 and 2014. It is especially true for the woody species, while in common milkweed control slighter changes can be observed. When taking a method into consideration the main aspect is the efficiency of management and the character of the post-treatment (which cannot be avoided). Herbicides are used point-like (in an aimed way) for conservation purposes and in doses which are smaller by orders of magnitude than in intensive agriculture. As the indirect effects are relatively unknown, the method with the least absolute herbicide quantity and the slightest possible dispersion should be selected. Cost-effectiveness is another very important issue and there are further aspects depending on management volume and habitat physiognomy. It is far easier to manage in a non-arboreal habitat than in a heavily shrubbed one which is hard to roam. An invasive alien tree species can be present in more vegetation layers (canopy, shrub and herbaceous layers). Consequently, in the planning phase we have to consider that the individuals of different ages and sizes have to be eradicated with different methods.

The overwhelming majority of the applied methods are herbicide treatments.* If we use herbicides, the

* Attention! Experimental chemical control methods described in this chapter are subject to authorisation! Their practical application requires an emergency permit issued by the pesticide control authorities for the given area and period!

Table 1. Summary of IAS control methods used in the presented projects.

Method	Active substance (product)	Invasive alien plant species	Period of treatment	Treated plant part	Weather sensitivity of the treatment	Risk of herbicide drifting	Annual expenses/ ha (thousand HUF)[1]
Former cut stump treatment	triclopyr (Garlon 4E) – permit is withdrawn	woody species	01.09.–31.10.	cut stump surface	moderate	moderate	no data
New cut stump treatment	glyphosate (e.g. Medallon Premium)	Russian olive	01.09.–30.09.	cut stump surface	moderate	moderate	[2]1200
Trunk injection	glyphosate (e.g. Medallon Premium)	woody species (except Russian olive)	01.08.–30.09. (01.07.–31.10.)	trunk > 5 cm (herbicide is injected into drill holes)	low	low	[3]300–1000
Partial bark stripping treatment	glyphosate (e.g. Medallon Premium)	woody species	01.08.–30.09. (01.07.–31.10.)	trunk in every size (herbicide is painted on bark)	moderate	moderate	no data
Basal bark treatment without cut	glyphosate (e.g. Medallon Premium)	woody species with thin bark: black cherry, tree of heaven, boxelder maple, common hackberry, green ash	01.08.–30.09. (01.07.–31.10.)	trunk < 5 cm (herbicide is painted on bark)	moderate	moderate	[3]150–350
Foliar spraying (black locust)	clopyralid (Lontrel 300)	black locust	01.09.–30.09.	leaf	high	high	[3]150–350
Foliar spraying (other tree species)	glyphosate (e.g. Medallon Premium)	woody species	01.09.–30.09.	leaf	high	high	[3]150–350
Foliar wiping	glyphosate (e.g. Medallon Premium)	common milkweed	01.05.–15.06. (with post-treatments: –31.08.)	leaf	moderate	high	400–500
Manual uprooting of seedlings	–	black cherry, boxelder maple, common hackberry	01.09.– until leaf fall (black cherry: also from budding–30.04.)	almost the whole plant	low	–	no data
Machine-assisted uprooting of trees (not used in the presented projects)	–	Russian olive	no data	almost the whole plant	no data	–	no data

[1]The given budget refers to 100% cover of the species, for external assistance cost and includes the post-treatments in the same year.
[2]The budget includes cutting and removing the wood.
[3]The actual cost is primarily influenced by the accessibility of the area.

following factors should be taken into consideration in the planning phase: the contractor must comply with several legal regulations (according to the trade category of the herbicide). The agents/herbicides applied were developed primarily for the needs of intensive agriculture thus their use in conservation has to be preceded by management experiments. The herbicides are usually used in different dilutions and combinations, with a different equipment, in diverse environments, for various target species and with dissimilar aims compared to the ones the chemical producers took into account during the development process.

Due to the above-mentioned legislation and the management volume, treatments were carried out by companies who had a contract with Duna–Ipoly National Park Directorate (DINPD) or its project partners. As the contractors are in a competitive situation, the agents/products prescribed in the technical descriptions of the contracts are often used in a self-made combination and the exact compositions of these are not available in every case. In the contracts bound by DINPD it is the contactor who obtains the permits from the herbicide control authority (both ad hoc and emergency permits). The applied dilutions are usually set during the treatment according

Table 2. Annual schedule of the methods used in the presented projects.

Species	Size (trunk diameter)	March	April	May	June	July	August	September	October
Black locust	> 5 cm					(trunk injection)	trunk injection		(trunk injection)
	< 5 cm							foliar spraying	
Black cherry, Green ash, Common hackberry, Box elder	seedling < 1 m height (common hackberry: 40 cm height)	manual uprooting (black cherry)						manual uprooting	
	> 5 cm					(trunk injection)	trunk injection		(trunk injection)
	< 5 cm					(basal bark treatment without cut)	basal bark treatment without cut		(basal bark treatment without cut)
								foliar spraying	
Tree of heaven	> 5 cm					(trunk injection)	trunk injection		(trunk injection)
	< 5 cm					(basal bark treatment without cut)	basal bark treatment without cut		(basal bark treatment without cut)
								foliar spraying	
Russian olive	> 5 cm							cut stump treatment	
	< 5 cm							foliar spraying	
Common milkweed				1. foliar spraying		2–3. foliar spraying			

to the weather of the given year and the site conditions.

The main characteristics of the treatment methods are demonstrated in Table 1. In Table 2 the annual schedule of our technology series is shown by IAS.

The treatment of common milkweed basically remained the same from the start of the earlier project. We treated the plants 1–3 times (according to the weather of the given year) with total vegetation control herbicide with glyphosate agent, diluted in a 1:2 or 1:3 ratio (also dependent on the brand). We have to set the highest effective dilution ratio because using a too concentrated solution we risk that the herbicide scorches the shoots too rapidly and the agent cannot reach the underground vegetative reproductive structures. The effect of this improper treatment is very similar to that of mowing, as it induces intensive sprouting. To the solution we added a small portion of nitrogen fertiliser (one handful to 10 l) and surfactant (one capful to 10 l). The mixed herbicides were painted from a bucket with a long handle paintbrush (radiator paint brush) on the apex of the shoot and the upper leaves. The dispersion of the herbicide should be minimized. A common mistake is that from the paintbrush soaked with herbicide the surplus isn't pressed out on the inner wall of the bucket and the herbicide is dripping. Another mistake is that instead of painting the herbicide is sprinkled. The suitable treatment period lasts from the sprouting in May to the flowering in June. The products containing glyphosate are not labelled as toxic to bees, however, in absence of aimed research precaution is suggested and management during the flowering period should be suspended. In this case we advise preventing seed production with mowing the shoots that remain after management and using chemical treatment on the sprouting ones. In dry sites and sand habitats the quantity of the shoots emerging after the dried out ones is highly dependent on the weather in the particular year: in dry summers even the first management can be successful, while in more rainy years two post-treatments may be needed.

In the management of woody species more significant changes occurred in the past few years. We will begin with presenting each method and then continue with discussing the conclusions. The common objective of chemical treatment methods is to send the active substance to the underground structures and to eradicate not only the sprouts but the whole plant this way. To achieve this, in all methods the treatments focus on early autumn. This is the period when the sap flow towards the roots is the most intensive in the material cycle. Regarding the treatment period, methods show great variations. The exact timing of the management is influenced by several factors. Those techniques which can be followed by sprouting (if the implementation is improper) are usually used in September (cut stump treatment, foliar spraying). If the weather is mild, this period can be extended. However, as a frost in early October can hinder management (especially the foliar spraying of black locust), 30th of September is prescribed as execution deadline. Methods which are not accompanied by sprouting (trunk injection, partial bark stripping treatment, basal bark treatment without cut) can be applied from the beginning of August to the end of the vegetation period. If the quantity of the work and the available capacity make it necessary, these techniques can be used from as early as July.

In the Nagykőrös project we used the relatively cheap cut stump treatment method in most of the sites. By now, this method has lost its importance in the project areas. However, it is still in use in certain cases and with modifications. At first the cut stump surface was treated (with paintbrush) with Garlon 4E (of triclopyr agent; product has been withdrawn), in a 1:1 ratio mixture (using also gasoline and colorant) within three days after the tree had been cut. It is sufficient to paint the specimen only on the outer ring which is responsible for transporting nutrients. As post-treatment foliar spraying or painting of the emerging sprouts were carried out the following year (see below). Today, cut stump treatment is used exclusively for Russian olive, which is difficult to manage with other techniques. For this purpose, we use a coloured mixture with glyphosate basis (composed by a company after Garlon 4E was withdrawn), which has to be applied on the stump surface within 20 minutes after felling.

As the cut stump treatment has many drawbacks, we turned to the trunk injection method. (This technique had been previously known, but was disregarded because its high additional charges.) The main advantage of this method is that the herbicide use precedes the cut of the individual. Using this, we drill holes around the girth of the tree, at a comfortable working height, cca. three fingers distance from each other, 45° angle downwards, cca. 6 mm in diameter, reaching at least the phloem of the trunk (but not considerably deeper). We inject the mixed herbicide of glyphosate agent in the holes with a veterinary continuous injector. After this the holes are closed with silicone sealant. The shoots, which partly remained green or sprouted again can be post-treated with the same method in the same or next year. If we aim to cut the injected trees, it is safe to do so after we treated those in two vegetation periods (to avoid re-sprouting). Compared to other shoot-treating methods, trunk injection has a benefit; namely, that the herbicide is adsorbed in the inside of the plant and not from the outer surface, thus we do not risk its washing off and evaporation. Thanks to this, trunk injection can be carried out in various weather conditions (e.g. mizzling rain and wind).

Besides its numerous benefits trunk injection is definitely slow, requires high manpower capacity and due to this it is expensive. Another drawback is that under a certain trunk diameter hole-drilling is not feasible. Due to this fact, there are more alternative and supplementary techniques, of which we use the following ones.

In the case of smaller trees than 10-15 cm trunk diameter, the fastest alternative is the partial bark stripping method. We peel the bark longitudinally until the phloem with a machete or a chainsaw and the surface is painted with the herbicide mixture. The peeling shouldn't be carried out on the whole girth but only on two or three sides of the trunk (dependent on its diameter), in the vertical direction for at least 50 cm long.

Another possibility for treating larger trees is girdling (in the whole girth), but with a shorter vertical expansion, and here the peeled surface also has to be painted. This latter method was not used in the presented projects.

Naturally, not only tree-length individuals of different sizes, but also their seedlings and root and stump sprouts are present. When we started our work, the masses of black locust and black cherry shoots often appeared as a result of the cut stump treatment.

In some of the woody species (chiefly black cherry, box elder and common hackberry until 30–40 cm height) the seedlings can be uprooted. However, it is difficult to distinguish between the seedlings and stump sprouts of broken or cut younger trees, but the stump shoots can be often uprooted improperly (with roots left in the soil). The proportion of the roots torn in the soil is difficult to supervise during the implementation. We used this method in small scale, drawing in volunteers. However, we would like to develop a technique which makes this method reliable (primarily in the steppe oak woods of Nagykőrös, which are continuously re-infested by black cherry.)

We carried out the foliage spraying of stump and root shoots in early autumn with manual backpack sprayers which were set to spray narrow. The devices were generally filled up to 10 l. For this reason, the backpack sprayers had to be refilled more frequently but at the same time the workers carrying these could move easily. If the black locust sprouts reached a very high density in the area, occasionally motorised backpack sprayers were used as well.

We could do so, because for black locust the mixture of Lontrel 300 product was used (having clopyralid agent), which is selective for this species to a certain extent. It is safe to apply this product in forest plantations as the poplar and oak species are resistant to it. Despite this, in natural habitats we have to consider the unfavourable effect of drifting (but not the total vegetation control effect).

For the eradication of the other woody IAS the mixture of the total vegetation control herbicides with glyphosate active substance was used (same as for common milkweed). Here we did not use painting but directed foliar spraying so the risk of herbicide drifting was more serious. Hence, when choosing the method for the control of arboreal IAS it is very important to consider the expected rate of sprouting after the treatment. We have to aim to choose the method which induces the least possible sprouting.

Initially in the steppe oak woods of Nagykőrös the foliar spraying of the sprouts in early autumn was preceded by cutting off the shoots with a clearing saw in early summer. With this our target was to develop sprouts of ideal size by the time of the treatment (e.g.

possessing enough leaf surface, but not too high, in a shrub-free area approx. of 1 m height). After a while, we gave up this activity because of the additional costs of sprout-cutting and the heavy disturbance in the nesting season of birds. Our decision was also supported by the fact that we had to carry out the treatment in various habitats (ranging from grasslands through tall forests to heavily scrubbed areas) and it was difficult to give unified specifications for the ideal sprout size.

The most significant advance of the former years was the development of bark treatment techniques. This method is the most effective way to manage those sprouts that we cannot drill (due to the small trunk diameter). The shoots under 5 cm diameter of thin-barked tree species (black cherry, tree of heaven, box elder, common hackberry, green ash) were painted in the whole girth, in half-one meter trunk length. With this relatively quick method involving much less herbicide drift, we can treat those sprouts of small diameter, whose injection was slow, difficult or even impossible (these had previously been eradicated with spraying).

We will present two more mechanical methods used in Upper Kiskunság, although we haven't applied these so far. The partial sprout stripping method for tree of heaven can be carried out at 10–20 cm height (if sufficient capacity is available). In this case, the curved knife we used uproots the seedlings but only peels the sprouts. This way the seedlings die without any use of herbicides and at the same time we can avoid cutting the shoots, which has utmost importance in the treatment of tree of heaven. Another more common technique is uprooting Russian olive by a prime mover (generally with telescopic forklift). Because a part of the root system tears in the soil, root shoots of various quantities are likely to emerge. These could be controlled by spraying, regular mowing or grazing with the appropriate animal species. Due to this, the above-mentioned method is successful mainly in managed grasslands.

The expenses of the methods range between extremes. The costs are determined by the manpower and mechanical needs of the given method as well as the spatial distribution and accessibility of the sprouts to be managed. The costs of the herbicide treatment are defined by the specific price and the quantity needed. The manpower demand of the herbicide treatment techniques is different. The budget is also influenced by the legal construction of the implementation. Self-done implementation is suggested in the following cases: the IAS has not reached a certain quantity or it is difficult to make quantifications of the task. However, this concept can be rarely used if there are habitat management actions of high orders of magnitude. In Table 1 the eradication techniques of invasive alien plants are summarized. As a matter of information, the approximate current costs of the methods (in public tendering procedures) are indicated.

Experiences gained

Our method used for common milkweed control is slow. Furthermore, the poor implementation (deriving from hurried treatment) can generate significant herbicide drift, which is contradictory to our conservation aim. For this reason the main direction of development is to find selective acting substances and product combinations as well as mechanizing the painting. These innovations are made by economic operators, who – from time to time – test their developments in the project areas. The test results haven't achieved a breakthrough yet. The only significant innovation was the addition of a well-persisting blue colourant. As a result, the rate of unmanaged shoots left in the dense stands decreased notably. On the whole we can state that with careful implementation and post-treatments (relevant to the weather of the given year) the common milkweed can be effectively controlled in natural habitats.

During the large-scale use of cut stump treatment against black locust and black cherry in Nagykőrös, several drawbacks of this method were revealed. A part of these problems can be solved by other techniques. Where these are not feasible, certain elements of the cut stump treatment were modified. One year after the management we experienced intensive sprouting of black locust and black cherry in numerous locations. The sprouts emerged in a more dispersed pattern than the tree-length individuals: shoots are more difficult to find in the vegetation with developed shrub-layer thus larger quantities of herbicides are needed, as well as techniques which involve considerable herbicide drift. That is why our hopes failed regarding the cut stump treatment method. In our opinion, more factors could be responsible for the unfavourable effect: in the competition between the effect of the herbicide and the sprouting generated by felling only the treatment carried out in the optimum time was effective. However, optimum timing means a short period in practice and there is no method to exactly determine it. What is more, in case the treatment fails, there is no possibility for revision as the feedback is next year's sprouting itself. Another negative factor was that the herbicide treatment was carried out within 3 days after felling. In the cut stump treatment of today the surface of the stump has to be treated within 20 minutes after logging.

There is also an organisational difficulty: following the cut it is hard to find the stumps below a certain trunk diameter. Because of this, the proportion of the unmanaged stumps remains high.

Despite the above-mentioned problems, cut stump treatment method is still in use. It can be a cost-effective technique of small-scale eradication actions. Furthermore, for Russian olive this is the most frequently used herbicide treatment method in our projects. We have to note that (based on reports on other sites) in the case of tree of heaven it is strictly prohibited to use logging and the cut stump treatment method.

Based on the experience above, the methods separating cutting and herbicide treatment in time were given priority, e.g. trunk injection, partial bark stripping and basal bark treatment without cut. Their common benefit is that felling can be abandoned. If it is still needed there is a feedback on the effectivity of the first management and we can carry on with the post-treatment. This also has an organizational advantage: the management has a longer period, e.g. it can be launched even in July in case it is necessary. If we compare the above-mentioned techniques, trunk injection is the most herbicide-saving, least drifting, least weather-dependent, consequently, the safest and most effective method. However, as it requires high manpower capacity this is the most expensive method as well. If the adequate budget, time and manpower capacity are provided, we suggest using this technique for the eradication of woody invasive individuals (except for Russian olive), with sizes suitable to drill. The range of sprout sizes which can be managed with basal bark treatment without cut overlaps with the trunk diameter range suitable for drilling. However, this method is chiefly significant as a substitution of the unfavourable foliar spraying.

As for Russian olive, the trunk injection method hasn't proven to be effective so far. The cause of this may be the trunk, which is rather difficult to drill (due to the complex branch system) and physiological processes.

The shoots of the woody IAS can be eliminated efficiently with the foliar spraying method if it is carried out in accordance with the specifications. However, particularly in densely covered areas, herbicide drifting is inevitable. An additional problem is that in habitats with a well-developed shrub layer it is difficult to find all shoots. Foliar spraying is more sensitive to weather conditions than the other methods. This fact also determines the period of the treatment. Apart from the wind and rain, the impact of the early frosts has to be considered as well (especially for black locust). To sum up, in our management foliar spraying is a complementary method difficult to omit, which we aim to supplement with other methods as much as possible.

Issues raised

One of the development goals of IAS control technologies is to elaborate a trunk injection method applicable beyond the vegetation period. If the results were good, this would prolong the treatment period with the winter months, facilitating the organization significantly.

Apart from the questions regarding the eradication techniques, there are several other aspects of the invasive control in legislation, landscape ecology, landuse, communication and agricultural subsidies. The detailed elaboration of these is not included in our presented projects. However, we point out one aspect that also influences the technology. It is common knowledge that the results of the local control of invasive species can be easily destroyed by the heavily infested landscape even in a short time, where the areas valuable for nature conservation are usually located in fragments. Presently projects and financial sources for the invasive control of those transformed areas which border on the precious natural areas are scarce. These are often heavily infested sites with generally no outstanding natural value: tree plantations outside the protected or Natura 2000 areas, hedges, railways, roads or power lines, fallow lands but partly also subsided active agricultural areas. A possible way of technical innovation is to develop methods which are less precise (compared to the presented ones), suitable for larger areas and more or less mechanised. With the help of these, the areas infesting continuously the valuable natural areas can be freed of the IAS. The cheaper technology can lay a foundation for the control of IAS source populations even in those areas, where these actions cannot be incorporated into normal land use.

The conservation management of Canadian goldenrod in the Aggtelek National Park

Tamás Visnyovszky

Natural characteristics of the area

The experiments have been carried out in the Aggtelek National Park, in the region called "Baradlaeleje" near the settlement borders of Aggtelek; more specifically on the grasslands and grassed arable lands which are covered with Canadian goldenrod (*Solidago canadensis*) and have been abandoned for more than a decade.

Regarding its geological features, 50% of this small region is covered with Upper and Middle Triassic highly karstified limestone, with smaller surfaces of dolomite; 40% with Lower Triassic limestone, marl and sandstone; and about 10% with Pliocene gravel and sand.

The area is mainly covered with brown forest soils with clay illuviation, developed on loose Triassic sediments. Their mechanical composition is clayey adobe, which is characterized by low water conductive capacity and high water storage capacity. Soils are highly acidic. Soil fertility categorization is category VII. The majority of the area is under agricultural use.

The climate of the test area is moderately cold, semi-humid. Annual sunshine duration is over 1800 hours. Mean annual temperature is 8.5 °C, during the vegetation period 15.0–15.5 °C is the long-term average. Average annual precipitation is between 680 and 710 mm, with approx. 420 mm in the vegetation period.

Due to its physical geographical conditions, the flora and fauna of the region can be characterized most importantly as marginal and transitional. The gravel layer on the calcic bedrock of the site is covered with acidifying soils (covered karst), which host a flora featuring species similar to that of Western European heathlands. The dominant plant species is common heather (*Calluna vulgaris*). Other important plant species include the german greenweed (*Genista germanica*), buffalo grass (*Anthoxanthum odoratum*) and cudweed (*Antennaria dioica*).

Rich fen meadows are found at lower altitudes in areas that are regularly flooded in springtime and only dry out by the end of summer in dryer years. Characteristic plant species include the eared willow (*Salix aurita*), but smaller patches of rosemary leaved willow (*Salix repens* subsp. *rosmarinifolia*) also occur. In addition to stands of tall moor grass (*Molinia arundinacea*) and tufted hair grass (*Deschampsia caespitosa*), Siberian iris (*Iris sibirica*) also appears in the beginning of summer, and stands of the marsh gentian (*Gentiana pneumonante*) and great burnet (*Sanguisorba officinalis*) blossom in the fall.

The area boasts a rich fauna, arthropod species such as the scarce copper (*Lycanea virgaureae*), the large blue (*Maculinea arion*) and scarce large blue (*M. teleius*) are characteristic in the region. Typical vertebrate species include the common frog (*Rana temporaria*), the agile frog (*Rana dalmatina*), the common toad (*Bufo bufo*) and occasionally the Aesculapian snake (*Elaphe longissima*). One of the prominant bird species is the strictly protected corn crake (*Crex crex*), but species such as the grey partridge (*Perdix perdix*) and the common quail (*Coturnix coturnix*) can also occur here.

Initial conditions

It was in 1998 at the "Aggressive Adventive Plant Species and Conservation" conference that the need for a summary of our present knowledge, in the form of a manual, about the conservation management of these species was first raised. The manual was published in 2004, and apart from introducing the species concerned, presenting their origin, distribution, taxonomic and morphologic relations it also discusses the life-cycle, life-history, habitat requirements, biotic interactions as well as economic and conservational significance of these species. In addition to this, further conservation management – related knowledge is also included in the manual. Thus, it can serve as a good basis for creating a methodically developed management and control plan. The real challenge still lies in putting the theories in practice. The most serious and prevalent problem within the boundaries of the Aggtelek National Park is caused by goldenrod species (*Solidago canadensis* and *Solidago gigantea*) – for the purpose of simplicity hereinafter referred to as goldenrod – and *Ailanthus altissima*. Controlling the spread of these species could not be postponed any longer, due to their large-scale infestation and the uniqueness of the habitats they invaded – i.e. the protected species living in these habitats have been seriously endangered. However, intervention has to be carried out with much caution due to the high natural value of habitats.

The methodical eradication of goldenrod was started in 1998 by the Aggtelek National Park Directorate, and led by László Trungel. Works mostly comprised of the hand pulling of plants along the Jósva creek. In the course of the project individual plants were pulled out manually from the ground during the summer months, and then left on site. By 2004 it had become clear that this treatment can only be partly successful.

Although the spread of goldenrod was stopped, treated plants had not been eradicated nor significantly weakened. As goldenrod occurred in large numbers in the area concerned, it was feared that missing one treatment would result in a high volume of seed dispersal, which subsequently could render the efforts of previous years meaningless. Another serious issue was that areas thus treated represented only a small fragment of all affected areas found in the national park – the size of which just grew every year due to the lack of treatment, in accordance with habitat invasion trends.

Since at the time there was no technology available that was effective enough and protected natural values at the same time, I set the objective of developing a technology that serves both objectives and reaches the necessary level of effectiveness.

I wished to develop such a technology by combining the – mainly mechanical – eradication methods that had been used by the National Park Directorate for years, the newly introduced mechanical techniques (developed between 2005–2008) and a type of chemical treatment with the lowest possible level of chemical use (tested in 2009 and 2010). Based on research done prior to my experiments, I could decide on the substance to be used, namely glyphosate. This substance has been effectively used for the chemical control of goldenrod species; however, no prior surveys have been carried out regarding the minimum effective dose that causes the smallest possible environmental load. The only guideline available was the minimum 3% and maximum 5% dose in aqueous solutions prescribed by the manufacturer for general forestry practices. In order to find the most favourable technology I needed to examine the effect of different substance concentrations on the species in question. The results of these examinations have facilitated the creation of a technology that is most favourable from the point of view of nature conservation. The experiments aiming at refining the methodology of chemical treatments to be used alongside mechanical weakening practices were carried out on a larger plot of land from 2011 to 2014 (experiment in order to move to a larger scale and use the method in practice). At the same time, we began the systematic eradication of goldenrod from the central areas of the Aggtelek National Park, based on the protocol described below.

Methods used

In the following part I will summarize the results of the experiments and experiences of the last 16 years, without going into details about the methodology of certain experiments or scientifically analysing the results, with regards to the aim and scope of this publication. The methodology described below represents a synthesis of literary data and my experiences and experiments.

General principles

You should never start a treatment if you are uncertain whether you can carry out all of its steps, as most invasive species react to disturbances with aggressive vegetative spread.

When starting the treatment, the reproductive strategy of the plant always needs to be taken into account, and the spatial and temporal aspects of the treatment should be defined accordingly. This way the area already cleaned has a lower chance of re-infestation.

Our results support the principle that the control of invasive plants should primarily rely on mechanical methods.

The timing and method of mechanical treatment should optimally be adapted to the life-history of the species targeted.

The timing and method of mechanical treatment should ensure the conservation of concurrent (required) and protected species present in the area, to the highest possible extent.

In protected areas, chemical treatment can only be considered for the elimination of individual plants occurring rarely, one by one or in separate polycormons. The timing and method of mechanical treatment should optimally be adapted to the life-history of the species targeted!* This way it can be ensured that we are intervening in the phenological stage when the plants have the lowest amount of supplies, and are more vulnerable than usual.

In order to protect species that are not targeted, the chemical should be used in the smallest possible dose and the treatment repeated as few times as possible.

You should choose a chemical that poses the lowest level of environmental and health hazards.

The method of distribution should be chosen based on which one poses the lowest possible level of exposure, and consequently the lowest environmental and health risks. In protected areas all treatments require prior authorisation by nature conservation authorities.

Mechanical eradication and control methods

Based on results described in the available literature, and by integrating other procedures used in the Aggtelek National Park I recommend the following method for the control of goldenrod in grasslands:

Ploughing

In my experience, infested areas can be successfully treated by ploughing or disk harrow which cut up goldenrod plants; however, such full-scale interventions are to be excluded in the case of grasslands in protected natural areas, as they endanger protected natural values. This method may prove useful in the case of ruderal ploughlands that are to be converted into grasslands, combined with over-sowing with seeds originating from neighboring, more valuable grasslands.

Flail mowing

Flail mowing is to be carried out at 20 cm height between 15–30 August, before full flowering starts. At this 20-cm stubble height other (primarily monocotyledonous) grassland species have a higher chance of regeneration. Our results have confirmed the principle that flail mowing weakens the specimens of the examined species. With the right stubble height and timing, this treatment (seems to) have a favourable effect on the spread of certain orchid species, such as the green-winged orchid (*Orchis morio*): flail mowing thrashes out their (not yet dormant) seeds, which start to germinate in the soil.

As opposed to regular mowers, it is better to use flail mowers with hammer blades mounted on a horizontal shaft: this way the stems of goldenrod plants are damaged on a larger surface, causing the stem to dry out even below the treated height, and the majority of remaining sprouts to wither.

The recommended working width for the mower is max. 3 metres. At this width cost-efficiency is still satisfactory, and animals living in the grass still have a good chance to escape (further investigation required!)

(In accordance with literary data, my experience shows that as a result of flail mowing, the coverage of goldenrod in treated areas decreased significantly within 3–4 years, and the size of individuals also decreased by around 30%. However, it would take too long to achieve satisfactory results using this control method only.)

Grazing

As the species examined have only a very low number of phytophagous consumers in Hungary, and possible related environmental risks have not been assessed yet, I would not recommend the introduction of phytophagous species as a means of control. Instead, I suggest grazing by domestic animals. It must be mentioned here that goldenrod has an average of around 0.9–1.5% active saponin content. Subsequently, due to the risk of bloating, grazing by more sensitive ruminant species should be avoided. In my experience the best option is sheep grazing, as sheep are keen to chew off the young sprouts growing on the stems of goldenrod, appearing after flail mowing was carried out. Horses may replace sheep provided that grazing can be rotational (when the grazing area is divided into compartments). My experience so far shows that horses that are allowed to graze on large pastures do not consume readily the young sprouts of goldenrod. On lands infested with goldenrod and located within the boundaries of the Aggtelek National Park, the Directorate has been using sheep or Hungarian grey cattle for grazing. I could discern that plants treated with this method did not produce flowers or new stems in the same year, only an offset of bud leaves. (Combining flail mowing with sheep grazing resulted in a drastic decrease in the number of goldenrod plants in the treated area, and the remaining plants tended to grow single stems instead of larger "bushes".)

Chemical control

Chemical control is the most effective when used right before the beginning of full flowering; our experience shows that the chemical used managed to eradicate the target species with the expected level of effectiveness when it was applied in the first part of May (when plants have 10–15 leaves in average).

The active substance used: gliphosate-isopropilamin (pesticides used: 3% aqueous solutions of Medallon Premium, Kapazin, Gladiátor 480 SL, Glialka 480 Plus, etc.). Using wetting agents (e.g. Nonit) to increase the wettability of sprays is also recommended.

* Attention! Experimental chemical control methods described in this chapter are subject to authorisation! Their practical application requires an emergency permit issued by the pesticide control authorities for the given area and period!

Method of application: spot spraying with a handheld sprayer (as the treatment is usually carried out on difficult terrains for several weeks, we recommend using handheld sprayers with 1.5–2 liter capacity. Chemical treatment should only affect the representatives of the target species! The treatment should only be used in grasslands or forest edges for individually growing plants or plants forming patches of only a few square metres. Chemical control on wet, occasionally flooded areas and/or lands covered with *Sanguisorba* can only be carried out in the presence/under the supervision of a botanist.

Treated areas should be preferably checked again in September. At this time of year it is easier to find plants that may have been left out. Plants that incidentally survived the treatment should be sprayed again the following May in order to prevent the development of resistance.

Experiences gained

Using the treatment methodology described above in the experiment from 2011 to 2014, I carried out regular surveys on a test plot of 1.5 hectares.

During the time of the experiment the number of goldenrod plants dropped from 1239 to 211 (17%). (This number includes the newly appearing seedlings as well.)

The average number of shoots per plant decreased from 6.23 to 2.58.

The percentage of individuals surviving the treatment one year after the first treatment was 0.4%, then 0% for the two subsequent years. (This result is significantly better than the results of open field experiments carried out before the treatment.)

Another special factor is the size of the area where the surrounding vegetation has been damaged by the chemical used for the treatments. In the first year of treatment this was 0.31 m^2/plant, and 0.05 m^2/shoot. In the second year – most probably due to the decreased number of shoots – this number was 0.25 m^2/plant, or 0.1 m^2/shoot in average.

Another interesting figure is the percentage of seedlings, comparing plants prior to and after the treatment. This rate was 12.55% in 2012, 10.99% in 2013 and only 1.9% in 2014. Our experience shows that one-year-old seedlings in the grass cannot be found too effectively. Several-year-old stems treated in the second year comprised mainly of seedlings that could not be found in the first year. The rate of seedlings in 2014 dropped both in the test area and other areas treated at the same time. In my opinion, the in vivo seed viability of goldenrod seeds – the species is characterised by high seed production but low seed weight – is no more that 4–5 years (provided that the grass cover is not disturbed). Both the effectiveness of the treatment used and prior experience indicate that goldenrod can be eradicated to an acceptable extent within 4–5 years of treatment.

In conclusion: Provided that the conservation management body can ensure at least a low-intensity control in the long run, it is worth undertaking the funding of a 4–6 year program directed at the control of goldenrod in nationally protected areas, including areas that are highly infested. During this period, goldenrod can be eradicated from target areas to an acceptable extent. In the long run, however, it is necessary to keep up continuous, low-intensity controls in order to prevent re-infestation and provide protection against seeds that might keep their seed viability longer.

I would like to emphasize here that in line with the assessments of current international literature, our experiences also indicate that no efforts aimed at controlling invasive species can be successful without raising awareness and presenting the issue to the public. As it is often ornamental garden plants that become invasive species, and the presence of workers in the target area may worry the inhabitants or beekeepers, or raise the professional curiosity of foresters, it is of high importance to spend enough time discussing the issue with the public, informing them using traditional methods, and provide didactically and methodologically well established education to the new generations (at least in protected areas or puffer areas planned to be included in the project).

Issues raised

It is important to examine whether the methodology described above can fully eradicate goldenrod from the test area. Further investigations are needed to define the in vivo seed viability of goldenrod seeds more accurately. It would also be worth looking at what causes the differences in the effectiveness of flail mowing, the mechanical weakening method used (e.g. treatments in dryer habitats tend to be more effective than in wet habitats).

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Summary of invasive plant control experiments*

Ágnes Csiszár and Márton Korda

The present chapter summarizes the experiences gained from treatment experiments carried out to control invasive plant species, presenting results species by species. Apart from a few exceptions, all control techniques mentioned have been collated from the case studies included in this book with the assistance of the author of each chapter. Before each table you can find a short overview of the environmental significance of the given species and the characteristics that influence its control. Chemical, non-chemical and, occasionally, combined methods are detailed in separate charts for each species. For each method we have intended to tabulate all information and circumstances that might be significant in the light of the experience gained. As far as possible we have tried to define the Stand characteristics of the species treated. This field provides information about the parameters of the targeted species (e.g. height, trunk diameter, homogeneous or patchy occurrence, etc.) Also specified in the tables is the Timing of the treatment in each case. This field contains information about the time/period when the treatment should be carried out (e.g. season, month, phenological phase, etc.). The column titled Number of treatments is used to show the number of treatments necessary for achieving the effectiveness indicated for the method in question. When, based on experience in the field, the number of necessary treatments varies (e.g. one or two treatments are needed), then both numbers are shown, separated by a hyphen. A seemingly course three-point scale is used for measuring the effectiveness of each treatment after the percentage of specimens eliminated (ineffective: 0–60 %, moderately effective: 61–94% effective: 95–100%). The reason for using such a course scale is that populations that are „mathematically" well eradicated can still regenerate very quickly. (In this respect a method that leaves an *Ailanthus* population only about 80% eradicated, for example, can hardly be regarded as a successful.) The Comments field in each table contains all the important pieces of information that could significantly influence the results of the treatment method, while the Method field, which details non-chemical and combined methods employed, indicates the most important treatment technique. In the case of chemical treatments, important details under the main field Treatment are divided between several subfields: Method, Chemical, Additive and Concentration.

Table 1. Active substance and toxicity category of herbicides used during the treatments

Product	Active substance content	Toxicity category
Ally 20 DF	20% metszulfuron-metil	I.
Banvel 480 S	480 g/l dikamba	I.
Casper	50 g/kg proszulfuron + 647g/kg dikamba (sodium-salt)	I.
Clinic 480 SL	360 g/l glifozát	III.
Dominátor	360 g/l glifozát	III.
Figaro	360 g/l glifozát	III.
Fozát 480	360 g/l glifozát	III.
Garlon 4E	480 g/l triklopir	II.*
Gladiátor 480 SL	360 g/l glifozát	III.
Glialka 480 Plus	360 g/l glifozát	III.
Glyfos	360 g/l glifozát	III.
Granstar 50 SX	500 g/kg trinenuron-metil	I.
Kapazin	360 g/l glifozát	III.
Lontrell 300	300 g/l klopiralid	I.
Medallon Premium	360 g/l glifozát	III.
Mezzo	20% metszulfuron-metil	I.
NASA	360 g/l glifozát	III.
Savvy	200 g/kg metszulfuron-metil	I.
Taifun 360	360 g/l glifozát	III.
Titus Plus DF	3% rimszulfuron + 60% dikamba	I.
Tomigan 250 EC	360 g/l fluroxipir-meptil	I.

* Authorisation for this product has been withdrawn

* Compiled based on the works of the authors of case studies.

In the case of chemical treatments, it must be emphasized that any use deviating from standards included in herbicide permit documents (either in terms of concentration or method of application) requires an emergency permit issued by the pesticide control authorities for the given area and period. The tables below describe several treatments that could only be implemented after obtaining an emergency permit. If you wish to carry out the control of invasive plant species based on the experiences detailed below, we strongly advise you to familiarize yourself with the legal background and obtain the necessary permits.

The active substance content and toxicity category of pesticides used during the chemical treatments are shown in Table 1.

Green ash (*Fraxinus pennsylvanica*)

In the 1920s green ash was thought to be the most suitable tree species for the afforestation of alkaline soils. However, as it does not produce a suitable amount and quality of timber, it was later used to transform willow-poplar floodplain forests, and was planted into the second canopy level of riparian hybrid poplar forests. Nowadays green ash is a common tree species in all regions of Hungary except for our mid-mountains; its occurrence mainly concentrates around river valleys, wetlands and saline areas. Due to its fast growth, relatively low soil nutrient requirements, allelopathic effect and its low number of pathogens and consumers, green ash has become an invasive species. Its spread is facilitated by its regular and abundant seed production. Seeds of the green ash keep their seed viability for 2–3 years, and these can be dispersed over long distances by water and wind. Juvenile growth is fast and the species sprouts easily from the trunk, so when damaged the tree is able to regenerate in vegetative and in generative ways. Its temperature requirements allow the species to tolerate the extremities of a continental climate;

its water tolerance is excellent, and even though its light demand is high, the shade tolerance of young seedlings is longer than in the case of the European ash or the narrow-leafed ash. Young sprouts of green ash have a high coumarin content, meaning that leaf-feeding insects avoid it more than indigenous ash species. Also, the surface of their stem transforms into bark sooner, so wildlife damages only affect it at a younger age. Owing to its rapid spread and the high number of stands planted, green ash is present all over the country, appearing along river valleys and floodplains, while its dense regrowth can hinder the regeneration of native tree species. Control of green ash requires a high time input owing to the uninterrupted propagule supply provided by river waters. Chemical control of the species using methods commonly employed for woody species can be carried out effectively.

Non-chemical methods for controlling green ash (*Fraxinus pennsylvanica*)

Method	Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
Manual removal of seedlings	Seedlings	Vegetation season	1	Effective	– Easiest to notice in the spring after bud burst
	Seedlings, height < 1m	September–October	1	Effective	
Felling and removal of sprouts	All trunk sizes	1st treatment: May 2nd treatment: July 3rd treatment: end of Aug–beginning of Sept	3	Moderate	– Last treatment should be timed in a way that the new shoots freeze

False indigo (*Amorpha fruticosa*)

False indigo used to be planted mainly for forestry purposes, specifically for soil protection and improvement. In the period after the First World War it became quite widespread along the Danube and Tisza rivers. Its spread was further accelerated by the decline in riparian grazing, the abandonment of arable lands and increasingly more frequent floods. Today false indigo occurs in large numbers, primarily on plains, along water courses and channels, in gallery forests and hybrid poplar forests, and in wet meadows. Introduced stands can be found in dryer sites, as well, particularly on sandy or alkaline soils. Its establishment and spread is facilitated by its seed longevity and effective seed dispersal, which is mainly by water, river sediment and birds. It has a relatively short lifespan but begins production quite early. Its flowers are insect-pollinated and are good nectar producers. False indigo has good sprouting ability with strong stem sprouting. Due to the species' intensive adventitious shoot production, shoots that had been mowed down or pressed close to the ground by floods take root easily. It grows best on temporarily flooded, less shaded areas with loose soil which is rich in nutrients, but survives on drift sand, stony soil and alkaline soil, as well. Due to its high light demand false indigo is most likely to spread in treeless habitats, but also occurs in lightly shaded poplar forests and gallery forests. However, it cannot grow well in areas strongly

shaded by a closed canopy layer, so planting tree species with rapid growth and canopy closure can reduce its further spread. False indigo causes nature conservation problems mainly in riparian, treeless habitats, especially when these have not been mowed or grazed properly. After the seeds carried in mass by water have germinated, false indigo forms tall, impassably dense populations within a few years. Besides giving shade, it also has a significant allelopathic and nitrogen-enriching effect caused by its nitrogen-fixing bacteria and the high nitrogen content of its leaf litter. Removal of the species is made more difficult by the fact that these flooded habitats are often found near river waters, so there is limited opportunity for using chemicals. There are a number of non-chemical removal methods in practice. Several livestock species, especially grey cattle, have been known to readily consume the leaves and young shoots of false indigo. Grey cattle can be used to open up dense populations not only by grazing but also by trampling and scratching. In those cases of former pastures and hayfields highly infested with false indigo, forestry mulcher can be used to stop the spread of the species, and the former use can be restored after a few treatments. Young shoots can be removed by either grazing or mowing. It must be emphasised here that treatments need to be carried out regularly in order to maintain the results. Its wood is commonly used as firewood, as well as for flood prevention purposes and for creating artificial stork nests.

Results of combined treatment experiments conducted to control false indigo (*Amorpha fruticosa*)

Method	Treatment			Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
	Chemical	Additive	Concentration					
Felling, bundling, stacking, cut stump treatment, root-raking, forestation	1 l diesel oil and 1.5 dl Garlon 4E*			Uninterrupted stands, on floodplains	Outside the vegetation period	1	Effective	– Bales can be used for flood prevention or as fuel

* Authorisation for this product has been withdrawn

Non-chemical control treatments of false indigo (*Amorpha fruticosa*)

<table>
<tr><th colspan="2">Method</th><th>Stand characteristics</th><th>Timing</th><th>Number of treatments</th><th>Effectiveness</th><th>Comments</th></tr>
<tr><td colspan="2">Manual removal techniques</td><td>In riparian zones of channels, at the foot of dams, forest edges</td><td>Autumn, winter</td><td>Regularly every year</td><td>Effective</td><td>– Can be utilised as firewood</td></tr>
<tr><td>Grazing</td><td>Grey cattle</td><td>1–2-year-old stands max. 1 m tall, forming a mosaic with grasslands,</td><td>End of April–November</td><td>In rotation, 3 to 5 times a year; grazing it to the ground in 1 week–10 days, then return when it grows green again</td><td>Effective</td><td>– Flail mowing and mowing at the end of the grazing season
– Turns into grassland in 2–3 years
– In floodplains treatments must be carried out regularly to maintain results due to the constant seed dispersion</td></tr>
<tr><td rowspan="5">Flail mowing followed by grazing</td><td>Grey cattle</td><td rowspan="4">Dense, tall and moderately tall sprouting stands, in floodplains</td><td rowspan="4">Flail mowing: grazing in the winter: May–November</td><td rowspan="4">Regularly every year</td><td rowspan="4">Effective</td><td rowspan="4"></td></tr>
<tr><td>Hungarian pied cow</td></tr>
<tr><td>Hungarian pied cow, grey cattle, buffalo and goat</td></tr>
<tr><td>Hungarian pied cow, grey cattle, horse, donkey and goat</td></tr>
<tr><td>Grey cattle</td><td>2–6 m tall, thick stem, homogeneous, or forms mosaics with smaller patches of grass</td><td>Flail mowing: autumn–winter grazing: end of April–November</td><td>Flail mowing twice a year, grazing in stages, 3 to 5 times a year; graze it to the ground in a week–10 days, then return when it grows green again</td><td>Effective</td><td>– Removing mowing residue is useful
– Turns into grassland in 4-5 years
– In floodplains treatments must be carried out regularly to maintain results due to the constant seed dispersion
– Very dense stands require flail mowing in the summer as well</td></tr>
<tr><td colspan="2">Flail mowing followed by mowing</td><td>2–3 m tall, dense stands and shorter stands re-sprouting after flail mowing</td><td>May–November</td><td>Regularly every year</td><td>Effective</td><td>– The condition of grasslands can be maintained and improved with continuous treatments</td></tr>
<tr><td rowspan="3">Habitat reconstruction</td><td>Flail mowing followed by afforestation</td><td>Extensive homogeneous stand</td><td colspan="2">According to forestry practices</td><td>Effective</td><td>– Mulcher residue helps to fertilize the soil
– After clearing the area forestation requires continuous care</td></tr>
<tr><td>Replacing hybrid poplar forests with forests of indigenous tree species</td><td>Forest sub-compartment level</td><td colspan="2">According to forestry practices</td><td>Effective</td><td>– Suppressed after canopy of new stands closes</td></tr>
<tr><td>Grass treatment after clearing away channel tracks</td><td>Mature seed-producing stands along channel tracks</td><td>All year</td><td>Regular grass management after filling up the channels</td><td>Effective</td><td>– It becomes possible to mow grasslands as one
– Populations providing the seed supply disappears</td></tr>
</table>

Black locust (*Robinia pseudoacacia*)

Black locust is one of the most important forestry species in Hungary and has very high economic significance, covering the largest part of forested area in the country: based on 2010 data black locust occupies 457 000 ha-s in Hungary, or 23.9% of all forested areas. Cultivation of the species is facilitated by its quick growth, relatively strong drought resistance, moderate nutrient demand and good vegetative regeneration capacity. It produces excellent firewood and serves as a versatile timber for the wood industry. In the past black locust was widely used in the fixation of shifting sand ravines and in the afforestation of mountainsides and hillsides. Nowadays, it also plays a role in the re-cultivation of overburden dumps and spoils. Its economic significance is further enhanced by the fact that almost half of Hungarian honey production relies on the excellent nectar-producing character of this species. The very same characteristics that make black locust an excellent species for cultivation and regeneration also make it very dangerous from the point of view of nature conservation. Once the species has been introduced to, or spontaneously starts to grow in, an environment, it becomes increasingly difficult to remove it due to its excellent sprouting capacity both from root and stem, and its persistent seed bank. Its seeds maintain their germination capacity for several decades; their dormancy is often broken by human intervention (e.g. burning, trampling, deep ploughing, removal of stumps, etc.). The negative ecological processes that are characteristic of locust groves include the nitrogen enrichment of the soil caused by bacteria found in the root nodules of the species, the transformation of the herb layer species pool, and the spread of weeds and nitrophilous species. The transformation of black locust sites is further supported by the allelopathic effect of the species' leaf litter and the way black locust one-sidedly „extorts" the soil nutrient supply. When planning the control of the species we need to take into consideration not only the sprouts and root suckers that keep coming up for years, but the possibility of plant regeneration from seeds, the latter which is relevant for decades. In most cases using mechanical methods only is either insufficient or takes too long to take effect. If the grazing of non-lignified young seedlings that emerge after felling is practicable, then it can offer a non-chemical solution. The chemical eradication of woody species carried out with commonly used methods can be performed successfully.

Non-chemical methods for controlling black locust (*Robinia pseudoacacia*)

Method		Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
Felling and removal of sprouts		All trunk sizes	Outside the vegetation period (all year if necessary)	Annual re-treatment necessary after the first treatment	Ineffective	– New sprouts keep coming up – Follow-up treatments are necessary
Grazing	**Sheep** **Cattle**	Young sprouts	In the vegetation period	Continuously for at least two years	Effective	– Only young shoots are grazed

Results of chemical treatment experiments performed on black locust (*Robinia pseudoacacia*)

Method	Treatment			Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
	Chemical	Additive	Concentration					
Spraying	Medallon Premium	Silwet L-77	3.5%	Sprouts, height = 60-150 cm	September–October	1	Effective	– The largest possible surface of leaves need to be treated
	Medallon Premium Fozát 480 Glyfos	Nonit	3.5–5%	Sprouts	Leafy period	1–2	Effective	– Low pressure, coarser droplet size results in a lower risk of drift – After the removal of trees the regeneration from seeds can be significant
	Dominátor	Nonit	3.5%	Sprouts, green shoots of young trees	In the vegetation period	2	Effective	– More effective in warm, sunny weather

Method	Treatment			Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
	Chemical	Additive	Concentration					
Spraying	Lontrell 300	–	0.7 l of chemical + 500 l of water	In young mixed stands, over 5% of coverage	In the leafy period (15 July–15 Sept)	1	Effective	– More effective for black locust patches of lower height
		–	33–50 % vol.	Trunk diameter < 5 cm	September	1–2	Effective	– High weather sensitivity and high risk of drift
		N-fertilizer	10%	Stump and root suckers	1st treatment: October 2nd treatment: May	2	Moderate / Effective	– Reason for differing levels of effectiveness unknown
Partial bark stripping	Medallon Premium	N-fertilizer, food colorant	50–100 % vol.	Trunk diameter < 5 cm	(July)-August-September-(October)	1–2	Effective	– Medium level of weather sensitivity and risk of drift
		Nonit + fertilizer (ammonium-nitrate, -sulphate)	75%	Trunk diameter < 5 cm	May	1–2	Moderate	– Less time-consuming – Requires relatively small amount of chemicals – In the case of trees with thicker trunks, further re-treatments might be necessary – Effective in lower concentrations as well – Most effective in the autumn
					June		Moderate	
					September		Effective	
					October		Effective	
			50%		May		Moderate	
					June		Moderate	
					September		Effective	
					October		Effective	
		Silwet Star + fertilizer (ammonium-nitrate, -sulphate)	75%		May		Moderate	
					June		Moderate	
					September		Effective	
					October		Effective	
			50%		May		Moderate	
					June		Moderate	
					September		Effective	
					October		Effective	
	Fozát 480 Figaro Clinic 480 SL NASA Medallon Premium	–	100%	Trunk diameter < 8 cm	August–October	1–2	Effective	– 100% selective – Repeat treatment is rarely necessary
Trunk injection	Medallon Premium	–	100%	Trunk diameter > 8 cm	In the vegetation period	1–2	Effective	– Most effective at the end of August–beginning of September
				Middle-aged and old trees	Middle of July–end of August	1–2	Effective	– 1 drill hole per 5 cm trunk diameter – Follow–up treatment is rarely necessary
			50–100 tf%	Trunk diameter > 5 cm	(July)–August–September–(October)	1–2	Effective	– Requires small amount of chemicals but high amount of labour – Low weather sensitivity and low risk of drift – Cutting is not necessary

Method	Treatment			Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
	Chemical	Additive	Concentration					
Trunk injection	Medallon Premium	Fertilizer (ammonium nitrate, -sulphate)	50%	Trunk diameter > 5 cm	May	1–2	Effective	– Requires small amounts of chemical – Time consuming – Repeat treatments required if necessary – Effective in both concentrations – Most successful in the autumn – Environmentally friendly
					June			
			75%		May			
					June			
		Silwet Star + fertilizer (ammonium nitrate, -sulphate)	50%	Trunk diameter > 5 cm	September	1–2	Effective	
					October			
			75%		September			
					October			
	Fozát 480	–	100%	Trunk diameter > 8 cm	August–October	1–2	Effective	– 100% selective – 1 drill hole per every 5 cm trunk perimeter
	Figaro							
	Clinic 480 SL							
	NASA							
	Medallon Premium							
	Medallon Premium	–	50–100%	Sporadically occurring trees	End of summer-autumn	1–2	Effective	– Root suckers may appear following cutting
	Fozát 480							
	Glyfos							
Cut stump treatment	Medallon Premium	–	100%	All trunk sizes	In the vegetation period	2	Effective	– Improved effectiveness by adding diesel oil
	Fozát 480			Trunk diameter < 5 cm	Summer–autumn	1–2	Moderate	– Less effective in years with high precipitation
	Glyfos							
	Garlon 4E*		50%	30–35 year old trees	October–November	1	Moderate	– Root and stump suckers may spring up
	Garlon 4E*, diesel oil	food colourant	50 % vol. Diesel oil	All trunk sizes	September–October	1	Ineffective	
Cut stump treatment – spraying of sprouts	Medallon Premium	Silwet Star + fertilizer (ammonium nitrate,-sulphate)	50%	Closed stands and individuals found in degraded grasslands	June	2	Moderate	– Time consuming – Higher amount of chemicals required – Limited timeframe for execution – Less selective – Follow–up treatment necessary (shoot spraying) – 2nd treatment requires less chemical – Treatments performed in the autumn require fewer shoot sprayings
					September		Effective	
			33%		June		Moderate	
					September		Effective	
		Nonit + fertilizer (ammonium nitrate,-sulphate)	50%		June		Moderate	
					September		Effective	
			33%		June		Moderate	
					September		Effective	
	Taifun 360	Silwet Star + fertilizer (ammonium nitrate,-sulphate)	50%	Closed stands and individuals found in degraded grasslands	June	2	Moderate	
					September		Effective	
			33%		June		Moderate	
					September		Effective	
		Nonit + fertilizer (ammonium nitrate,-sulphate)	50%		June		Moderate	
					September		Effective	
			33%		June		Moderate	
					September		Effective	

*Authorisation for this product has been withdrawn

Black pine (*Pinus nigra*)

The introduction of black pine to Hungary began at the end of the 19th century, primarily in our hills and mid-mountains, mainly on dolomite barrens. The main objective of their introduction was to stop erosion and protect the soil. At the beginning of the 20th century, introduced stands of black pine covered increasingly large surfaces of the sandy areas of the Great Plain; its largest populations can still be found in the Danube-Tisza interfluve. Black pine adapted well to the hot dry habitats unsuitable for many other tree species, so its introduction became increasingly important for timber production purposes, as well. Today around 3.6% of forested area is covered by unmixed stands of black pine. Due to the closed canopy level and winter-persistent foliage, dense stands of black pine create extremely poor light conditions, where species of the former vegetation are unable to survive, and these slowly disappear from the herb layer. Ultimately, the decrease in plant diversity leads to decreased animal diversity. The thick layer of slowly decomposing pine needle litter in black pine forests makes the habitat highly flammable. Unmixed stands which had often been introduced to sites not optimal for the species are becoming increasingly vulnerable; populations from several different sites in the country are being destroyed by the combined damage caused by drought, fungal pathogens and bark beetle species. There is no professional consensus as to whether black pine is an invasive species. Nevertheless, it is an indisputable fact that there is a large number of seedlings in neighbouring dry grasslands that are presently in good condition which, in the long run, can lead to the shrinkage of grasslands. Eradication of the species can be successfully achieved by mechanical methods. After being cut down, trees – including young ones – do not produce sprouts. Spontaneously appearing seedlings and young trees can be pulled out by hand, sometimes even those that are a few years old. There are a few chemical treatment methods as well but thanks to the positive results of non-chemical methods their application is not recommended.

Non-chemical treatment of black pine (*Pinus nigra*)

Method	Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
Manual removal of seedlings	Seedlings	All year	1	Effective	
Felling	All trunk sizes	Outside the vegetation period (all year if necessary)	1	Effective	– Does not resprout – No chemical follow-up treatment needed

Results of chemical treatment experiments performed on black pine (*Pinus nigra*)

Method	Treatment			Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
	Chemical	Additive	Concentration					
Spraying	Dominátor	Nonit	3,5%	Applied to apical shoots of young trees	In the vegetation period	2	Effective	– More effective in warm, sunny weather – Chemical treatment not recommended as non-chemical treatments are 100% successful

Black cherry (*Prunus serotina*)

Black cherry was introduced in Hungary to the lower canopy layer of cultivated forests of sandy areas, to scots pine and black pine forests, and to black locust and hybrid poplar forests in order to improve these sites and support the growth of the primary tree species. Owing to the large scale introduction projects in the 1960s, the species was able to reach many disturbed and semi-natural areas, chiefly through dispersion by birds and small mammals. Although it occurs in wet habitats, gallery and alluvial forests as well, black cherry primarily spreads in sandy forests. Its occurrence concentrates around sandy areas, where it appears in massive numbers both in semi-natural and plantation-like forests. Alongside the biological characteristics of black cherry, the disturbance of sites also facilitates the spread of the species. Black cherry has a short seed longevity but instead of seed banks it does produce „seedling banks": its short seedlings can survive in the understory for years while light conditions are poor, and then start to grow when light conditions become favourable. Young trees grow quickly, and after the 10th year they begin to produce abundant crops of fruits. Black cherry is unable to grow root suckers, but re-sprouts easily from the trunk: this capacity is maintained in old trees as well. The species occurs on different types of soil from compacted to loose sandy soils, and it tolerates a broad range of conditions as far as water requirements are concerned, from temporary flooding to shorter dry periods.

Non-chemical methods for controlling black cherry (*Prunus serotina*)

<table>
<tr><th colspan="3">Method</th><th>Stand characteristics</th><th>Timing</th><th>Number of treatments</th><th>Effectiveness</th><th>Comments</th></tr>
<tr><td colspan="3">Manual removal of seedlings</td><td>Saplings, young trees (up to 1–1.5 m in height)</td><td>From bud burst to defoliation</td><td>1</td><td>Effective</td><td></td></tr>
<tr><td rowspan="4">Girdling</td><td rowspan="3">Chain saw</td><td>Ring with a single chain</td><td rowspan="3">Trunk diameter = 1–16 cm</td><td rowspan="3">February</td><td rowspan="3">1</td><td>Ineffective</td><td rowspan="2">– Tree often grew over the ring, canopy at least partly survived
– Often the canopy died but the trunk below the ring stayed alive</td></tr>
<tr><td>Ring with double chain</td><td>Moderate</td></tr>
<tr><td>Two rings with double chain, one 10–15 cm below the other</td><td>Moderate</td><td>– The majority of the canopy (>80%) withered, but in the case of trees with trunks thicker than 12 cm the trunk below the rings survived by producing water sprouts</td></tr>
<tr><td>Machete, drawknife</td><td>15–20 cm wide girdle</td><td>Trunk diameter = 3–20 cm</td><td>Summer–autumn</td><td>1</td><td>Moderate/ Effective</td><td>– Trunk produced long water sprouts below the girdle but these died after the canopy withered
– In years with higher precipitation water sprouts did not wither and the lower part of the tree stayed alive</td></tr>
</table>

In Europe black cherry has failed to meet the expectations placed on it, and its presence is also problematic from the perspective of forest management.

Seedlings of black cherry, which appear in masses, form a closed shrub layer, thus preventing indigenous species from regeneration, forcing out species with high light requirements and causing biodiversity loss. Besides its competitive effect, it has been also proven to have an allelopathic effect. Its drupe can be dispersed over long distances by birds. Except for its young leaves, its sprouts, bark and leaves are all poisonous, so wild game do not like to consume it. Due to its intensive stump sprouting capacity, felling cannot be successful in itself. Successful mechanical methods include girdling and the hand-pulling of seedlings. In sandy areas the latter can be effective for older plants as well. Chemical control of the species using methods commonly used for woody species can be carried out effectively. As its leaves have a leathery texture, in the case of foliar spraying it is recommended to use surfactants to help it adhere to leaves.

Results of chemical treatment experiments performed on black cherry (*Prunus serotina*)

Method	Treatment			Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
	Chemical	Additive	Concentration					
Spot spraying	Medallon Premium	–	33–50% vol.	Sprouts	September	1–2	Moderate	– High level of weather sensitivity and high risk of drift
	Medallon Premium	Nonit	3.5–5%	Sprouts	In the vegetation period	1–2	Effective	– Slightly leathery leaves require the use of surfactants
	Fozát 480							
	Glyfos							
Partial bark stripping	Medallon Premium	–	50–100% vol.	All trunk sizes	August–September	1–2	Effective	
	Fozát 480	–	100%	Trunk diameter < 8 cm	August–October	1–2	Effective	– Repeat treatment is rarely necessary – 100% selective
	Figaro							
	Clinic 480 SL							
	NASA							
Basal bark treatment without cuts	Medallon Premium	–	50–100 tf%	Trunk diameter < 5 cm	August–September	1–2	Effective	– Apply all around the girth at 0.5–1 m length
Trunk injection	Fozát 480	–	100%	Trunk diameter > 8 cm	August–October	1–2	Effective	– 1 hole per 5cm of perimeter
	Figaro							
	Clinic 480 SL							
	NASA							
	Medallon Premium							
	Medallon Premium	–	50–100% vol.	Trunk diameter > 5 cm	August–September	1–2	Effective	
	Fozát 480	–	50–100%	All sizes suitable for drilling	In the vegetation period	1	Effective	
	Glyfos							
	Medallon Premium							
Cut stump treatment	Medallon Premium	–	50–100% vol.	Trunk diameter > 5 cm	August–September	1–2	Effective	
	Fozát 480	–	100%	All trunk sizes	In the vegetation period	1	Effective	– Edges of the stump need to be treated with precision – Effective under a variety of precipitation conditions
	Glyfos							
	Medallon Premium							

Russian olive (*Elaeagnus angustifolia*)

Russian olive in Hungary has been primarily introduced in order to afforest alkaline soils and different ruderal soils and ruderal areas; but it has also been extensively used in forest edges, wind-breaks, shelter-belts and hedgerows, as well. The species can be found primarily on plains in Hungary; it rarely appears in the mid-mountains. Its spread is discernible in several different habitats, from loose sandy soils and alkaline soils to wet meadows and habitats along rivers and channels. The establishment and spread of Russian olive is largely facilitated by its good nitrogen-fixing and regenerative capacity, and its broad temperature and moisture tolerance. Its seed dispersal agents include several species of birds and small mammals, but water dispersal is also possible. Due to its appearance in treeless habitats, species with high light requirements can be locally forced out; its nitrogen-fixing actinomycete fungi can accelerate the spread of nitrophilous weeds, all of which can lead to the suppression of many rare and protected plant species. One of the highly selective mechanical treatment methods is the removal of specimens with the help of various automotive equipment; however, this technique requires specific soil conditions. Mechanical treatment is made all the more difficult as, even though its vegetative regeneration capacity without disturbances is low, when damaged Russian olive can effectively regenerate with suckers growing from the root collar or more distant roots. Timber removed during the treatment can be utilized as firewood, and should be processed and removed right away, as dry Russian olive wood is difficult to split. The eradication process is further hindered by its extensive, thorny branch system, which makes it difficult to reach the trunk. In order to solve this issue, target areas are often grazed by grey cattle, which clear the way to the trunk by rubbing themselves against the branches; they also consume young shoots.

Non-chemical methods for controlling Russian olive (*Elaeagnus angustifolia*)

Method		**Stand characteristics**	**Timing**	**Number of treatments**	**Effectiveness**	**Comments**
Uprooting	**With sand loader or tractor equipped with a lifting fork**	For trunks of any diameter that can be lifted out with the loader (2-3.5 tons depending on the type of machine)	Anytime during the year except for the nesting period	1	Effective	– Under suitable soil conditions – Minimum root suckers can be observed, which can be treated in the following year with partial bark stripping method treatment
Felling and removal of sprouts		Any trunk diameter	Outside the vegetation period (all year if necessary)	The treatment needs to be repeated at least once	Ineffective	– Continuous resprouting – Chemical follow-up treatments needed

Results of chemical treatment experiments performed on Russian olive (*Elaeagnus angustifolia*)

Method	**Treatment**			**Stand characteristics**	**Timing**	**Number of treatments**	**Effectiveness**	**Comments**
	Chemical	**Additive**	**Concentration**					
Spraying	Medallon Premium	Nonit or Silwet Star and N-fertilizer	33–50 % vol.	Trunk diameter < 5 cm	September	1–2	Effective	– High weather sensitivity and high risk of drift
	Dominátor	Nonit	3.5%	shoots	In the vegetation period	1	Effective	– More effective in sunny and warm weather
Partial bark stripping	Medallon Premium Fozát 480 Figaro Clinic 480 SL NASA	–	100%	Trunk diameter < 8 cm	August–October	1–2	Effective	– Repeat treatment rarely necessary – 100% selective
Trunk injection	Medallon Premium	–	100%	Trunk diameter > 8 cm	In the vegetation period	1–2	Effective	– Most effective from end of August to September
	Fozát 480 Figaro Clinic 480 SL NASA				August–October	1–2	Effective	– 1 drill hole per every 5 cm of trunk girth – 100% selective
Cut stump treatment	Medallon Premium	–	100%	Any trunk diameter	In the vegetation period	2	Effective	– Higher effectiveness if mixed with diesel oil
		Oil emulsion		Trunk diameter > 5 cm	September	1	Moderate	– Cost effective – Medium level of weather sensitivity and risk of drift

Common lilac (*Syringa vulgaris*)

Common lilac has been planted all over Hungary for around two hundred years, and due to its popularity it can be found in many urban and rural gardens. Planted stands usually reproduce with root suckers and appear near settlements at forest edges, with shrubs, in forest strips, vineyards, and areas with small parcels, and along roads. Wild populations are found in our mid-mountains in dolomite and limestone habitats, as well as in loess and sandy habitats on the plains. It is characterised by good seed germination capacity and moderately fast vegetative growth. Common lilac spreads effectively owing to its excellent regenerative capacity: it is capable of growing sprouts easily from both the stem and root. It is a drought-tolerant species with high light and temperature requirements and an extensive, rich root system. It also grows well in polluted urban air conditions. Commensurate with its ecological needs, it causes nature conservation issues, primarily in warm, dry habitats, slope steppes, rock grasslands, and shrub forests. Abandoned farms, gardens, orchards and vineyards can become important starting points for its spread. Due to its intensive root sucker production and effective regenerative capacity, common lilac can also grow on steeper slopes with gravel cover, leading to a decrease in the biodiversity of indigenous communities. The species can be successfully controlled with a few years of regular flail mowing and sprout control, possibly in tandem with sheep grazing. Chemical treatments usually exclude stem injections due to the size of its stem. The majority of successful interventions include cut stump treatment and spraying/wiping herbicides on the leaves. When treating the canopy it is important to use surfactants as leaves have a hard and leathery surface.



Non-chemical methods for controlling common lilac (*Syringa vulgaris*)

Method	Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
Felling	All trunk sizes	Outside the vegetation period (all year if necessary)	1	Moderate	– Continuous re-sprouting – Chemical follow-up treatments needed (for 3–5 years)
Removal of sprouts	Root and trunk suckers	In the vegetation period	Re-treatments needed at least once a year after the first	Moderate	

Results of chemical treatment experiments performed on common lilac (*Syringa vulgaris*)

Method	Treatment			Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
	Chemical	Additive	Concentration					
Applying herbicide on leaves	Medallon Premium	Nonit	100%	Sprouts	In the vegetation period	Annually for 3–5 years Once	Effective	– More effective in warm, sunny weather
Cut stump treatment	Medallon Premium	–	100%	All trunk sizes	In the vegetation period	1	Effective	

Tree of heaven (*Ailanthus altissima*)

As a result of deliberate planting and spontaneous spread, tree of heaven has been an established tree species in Hungary since the mid-20th century; today it can be found almost everywhere in hills and flatlands with a warmer climate. Those characteristics that initially were positive from the point of view of introduction have largely facilitated its invasion and made it an invasive species that causes one of the gravest nature conservation problems in Hungary. The tree can easily be propagated by seed – its seedlings are easy to cultivate and grow quickly – and it is characterised by remarkable root suckering ability, which all originally supported its widespread introduction. Being also a good nectar producer, it is sometimes cultivated intentionally. Its primary root grows deep, the lateral roots fan outward close to the surface, some of these serving as storage organs. Adventitious shoots forming on the roots facilitate the development of a thick growth of suckers around the base and quick vegetative reproduction. Nature conservation issues caused by tree of heaven can be explained primarily by the species' capability for effective vegetative reproduction. In addition, it also reproduces generatively, bearing abundant fruits almost every year. The samara is large and twisted at the tips, making it spin as it falls and enabling it to move sideways even in still air. Its spread is aided by its high drought tolerance, strong competitive ability and the allelopathic effect it has on several other plant species. There are no significant consumers or pathogens known in Hungary that would influence its spread. Tree of heaven has been the most dangerous invasive plant species from the standpoint of nature conservation, and because of its recent spread to forested areas it has now become increasingly problematic from the viewpoint of forestry as well. The species not only infests the colonized habitats, but due to their competitive and allelopathic effects and the high amounts of leaf litter shed annually, they also transform the habitat structure, its ecological characteristics and natural species composition. It significantly endangers valuable dry grasslands, xerothermophilous oak forests, and sandy habitats, and appears more and more frequently in humid areas, as well. Within settlement limits it causes damage by cracking the surface of pavements and buildings, and it spreads outward along roads and especially railways. Disturbed and semi-natural areas are ideal sites for the species, especially if the canopy layer is not closed. Controlling the spread of tree of heaven is made extremely difficult by its exceptional suckering ability. To our present knowledge there are no non-chemical treatments that can successfully halt the spread of the species; moreover, mechanical treatments usually just intensify the infestation. Since it is one of the most problematic invasive tree species, several chemical control technologies have been developed in the last few years, including many successful ones. The most widespread methods for younger specimen and seedlings are foliage spraying and wiping herbicide on the foliage or bark. The basal application of herbicide is often combined with the partial bark stripping method treatment technique, but the most recent treatments appear to be effective without cuts as well: this can significantly simplify the eradication process. Trunk injection is a best practice for older trees. The cutting of trees can lead to the mass germination of seeds in the soil, which should be considered when planning measures to be taken.

Non-chemical methods for controlling tree of heaven (*Ailanthus altissima*)

Method	Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
Felling	All trunk sizes	All year	1	Ineffective	– Continuous mass re-sprouting even meters away from the cut down tree – Using this method in itself is prohibited!

Results of chemical treatment experiments performed on tree of heaven (*Ailanthus altissima*)

Method	Treatment			Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
	Chemical	Additive	Concentration					
Spraying	With herbicides that affect underground growth (agent: metsulfuron methyl) Mezzo, Savvy, Ally 20 DF	–	40–100 g/ha	Seedlings from forest regeneration	March–June	1	Effective	– Chemicals of category I are subject to authorisation! – Does not have an effect on stand-forming seedlings before bud burst
Spot spraying	Medallon Premium	–	15%	Sprouts; height: ~1 m, small trunk diameter	End of July–beginning of September	1	Effective	– Treatment should not be carried out in wet, windy weather
			5%			1	Effective	
			3.5%	Sprouts	September	1–2	Effective	
		Silwet L-77	3.5%	Homogeneous stand of sprouts (height 30–40 cm)	1st treatment: May–June 2nd treatment: August–October 3rd treatment: following spring	3	Moderate	– The largest possible surface of leaves needs to be treated – Treating the apex of the primary shoot is crucial
	Glyphosate based herbicides	–	5 l / ha	Seedlings, max height 30 cm	In the vegetation period, when one-year-old seedlings are no more than 30 cm tall	3	Effective	– Backpack sprayer and spray wand equipped with a full cone or adjustable cone spray tip – 3 treatments are necessary to eradicate newly germinated seedlings
Wiping herbicide on seedlings	Glyphosate based herbicides	Fertilizer with ammonium content, Silwet	3.5–10%	Seedlings, height = 10–50 cm	In the vegetation period	3	Effective	– 3 treatments are necessary to eradicate newly germinated seedlings
Wiping herbicide on sprouts	Medallon Premium	Fertilizer with ammonium content, Silwet	10%	One year-old, non-lignified sprouts	May–October	3	Effective	– Applicable to both leaves or stem – 3 treatments are necessary to eradicate newly germinated seedlings sprouts
		Nonit	50%	Sprouts	In the vegetation period	1	Moderate	– More effective in warm, sunny weather
Partial bark stripping	Fozát 480	–	100%	Trunk diameter < 8 cm	August–October	1–2	Effective	– Repeat treatment is rarely necessary – 100% selective
	Figaro							
	Clinic 480 SL							
	NASA							
	Medallon Premium							
	Medallon Premium	–	50–100 % vol.	All trunk sizes	August–September	1–2	Effective	
			50%		May–October	2–3	Moderate	– Often re-sprouts after being cut down, so spraying with 3.5% solution of Medallon Premium or Taifun 360 is necessary near the end of summer – Time needed for the treatment: min. 3 years
			75%					
	Titus Plus DF	–	50%	All trunk sizes	May–October		Ineffective	
			75%					

Method	Treatment			Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
	Chemical	Additive	Concentration					
Basal bark treatment without cuts	Medallon Premium	oil emulsion		Younger trees with thin bark Sporadically or in patches	1st treatment: August–October, March–May 2nd treatment: August–October 3rd treatment: following spring	3	Effective	– Absorption is best on non-lignified stems, but a few-cm-thick seedlings can absorb it too – In the absorption is best on non-lignified stems, but a few-cm-thick case of green shoots, it is sufficient to apply herbicide from one direction, but seedlings with stems thicker than a finger need to be treated all around the stem
		–	50–100 % vol.	Trunk diameter < 5 cm	August–September	1–2	Effective	
	Experimental oil emulsion with Medallon Premium			Few-year-old sprouts, average trunk diameter < 8 cm	June–September	1	Effective	– Apply around the trunk in a 10-15 cm strip with 40 cm width – It is recommended to add distinctly coloured, slowly decomposing dye to the herbicide used
	Garlon 4E*	Fertilizer with predominant N-content	50%	Young sprouts when the bark has not yet furrowed	September–November	1	Moderate	
Trunk injection	Medallon Premium	–	2 cm^3 75% solution	Mature and seed producing trees	August–October	1	Effective	– In the case of trunks 6-8 cm thick it is sufficient to drill 2 holes on opposite sides; trees with thicker stem require drill holes 8–10 cm apart
			75%	Average trunk diameter > 8 cm	September	1	Effective	– 1ml of injected solution per drill hole – Follow-up treatment required if there are live branches left
			100%	Trunk diameter > 8 cm	In the vegetation period	1	Effective	– End of August–September is the most effective
			50–100 % vol.	Trunk diameter > 5 cm	August–September	1–2	Effective	
	Fozát 480 Figaro Clinic 480 SL NASA Medallon Premium	–	100%	Trunk diameter > 8 cm	August–October	1–2	Effective	– 1 drill hole per every 5 cm of girth
	Garlon 4E* – Medallon Premium	–	1/3–1/3	Mature and seed producing trees	September–November	1	Effective	– Aqueous solution
	Experimental oil emulsion with Medallon Premium				All year round	1–2	Effective	– According to results of preliminary experiments it is effective in the winter as well

Method	Treatment			Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
	Chemical	Additive	Concentration					
Trunk injection	Taifun 360/Medallon Premium	–	75%	Closed stands	May–October	1–2	Effective	
	Medallon Premium 75% + Mezzo (4g/l) surfactant 3,5 ml/l + fertilizer (ammonium-sulphate, -nitrate) 15 g/l			Trunk diameter > 5 cm	In the vegetation period	1–2	Effective	– Minimum 3 yrs of treatment is necessary
Hack and squirt treatment	Medallon Premium	–	15%	Height >1 m	End of July–beginning of September	1	Effective	– For a 25 cm trunk diameter you need one incision that is 5 cm long and 3 cm deep – Incisions every 2–3 cm
Root collar injection	Medallon Premium	–	100%	Trunk diameter > 8 cm	In the vegetation period	1	Effective	– Under test
Cut stump treatment	Medallon Premium	–	50–100 % vol.	Trunk diameter > 5 cm	August–September	1–2	Effective	

*Authorisation for this product has been withdrawn

Common hackberry (*Celtis occidentalis*)

In the last century common hackberry has been introduced to enrich the second canopy layer of cultivated forests, black locust stands, hybrid poplar forests, and Scots and black pine forests. It tolerates well the dry, warm polluted air of urban areas, as well as regular pruning and road salting, which make it one of the most frequently planted alley trees. Nowadays, it mainly spreads in riparian and sandy areas, and also appears in suburban forests, tree alleys and settlements. It is only rarely found in hills or mountains; rather its occurrence is concentrated on the plains. Young trees are fast growing. The root system of the common hackberry is richly branched and extends sometimes as deep as 3–6 metres into the soil; thus it can survive in dryer habitats. Is usually bears abundant crops of fruit, which remain on the branches even in the wintertime and are eagerly consumed by birds; water dispersal is also a possibility. Under ideal conditions hackberry seeds maintain their germination capacity for several years, but under natural conditions seedlings only grow from soil seed banks in the first and second year following the seed shed. It grows stump sprouts but not root suckers. It has an excellent regenerative capacity; it withstands root pruning, bark injuries and crown pruning. It grows best in wet, nutrient-rich soil, but as far as structure is concerned it thrives in a variety of different soils, such as sands, clay or adobe. It tolerates shade when young, but with age it develops higher light requirements. Regarding soil moisture it has a broad tolerance; it can also withstand dryer periods or periodical flooding. Today the spread of common hackberry in riparian areas is discernible not only along the Danube but along some other rivers as well. It spreads easily near its introduced stands, mainly by bird-mediated dispersal. Seedlings of the species can potentially appear in masses in degraded forests, hybrid poplar forests, black locust stands, planted Scots and black pine forests, and semi-natural forests. Pulling 1–2(3)-year-old seedlings

from the ground can be an effective non-chemical treatment option, provided that the seed dispersing plants had been removed. Commonly used chemical control techniques such as trunk injection, bark and cut stump treatment, and spraying of seedlings are also successful with this species. From the nature conservation perspective, it may be interesting that common hackberry is one of the host plants of the European beak (*Libythea celtis*) caterpillars.

Non-chemical methods for controlling common hackberry (*Celtis occidentalis*) vegyszermentes kezelése

Method	Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
Manual removal of seedlings	1–3 year old trees	All year, mainly October–December	1	Effective	– Only useful if re-formation of seed banks is prevented
	Seedling, height < 30–40 cm	September–defoliation	1	Effective	
Felling and removal of sprouts	Any trunk diameter	Outside the vegetation period (all year if necessary)	Re-treatments needed at least once a year after the first treatment	Ineffective	– New sprouts keep coming up – Follow-up treatments are necessary

Results of chemical treatment experiments performed on common hackberry (*Celtis occidentalis*)

Method	Treatment			Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
	Chemical	Additive	Concentration					
Spraying	Medallon Premium	–	10%	1–3-year- old trees	September–November	1	Effective	
			33–50 % vol.	Sprouts	September	1–2	Effective	– High weather sensitivity and high risk of drift
			3.5%	Sprouts	In the vegetation period	1	Effective	– More effective in warm, sunny weather
	Dominátor	Nonit	3.5%	Sprouts				
Basal bark treatment	Medallon Premium	–	100%	Trunk diameter < 8 cm	August–October	1–2	Effective	– Re-treatment rarely needed
	Fozát 480							
	Figaro							
	Clinic 480 SL							
	NASA							
Basal bark treatment without cuts	Medallon Premium	–	50–100 % vol.	Trunk diameter < 5 cm	August–September	1–2	Effective	
Trunk injection	Medallon Premium	–	100%	Trunk diameter > 8 cm	In the vegetation period	1–2	Effective	– End of August–September is the most effective
			50–100 % vol.	Trunk diameter > 5 cm	August–September	1–2	Effective	
	Medallon Premium	–	100%	Trunk diameter > 8 cm	August–October	1–2	Effective	– Re-treatment rarely needed – 1 drill hole per every 5 cm of trunk girth
	Fozát 480							
	Figaro							
	Clinic 480 SL							
	NASA							
Cut stump treatment	Garlon 4E*	–	50%	Seed dispersing trees	September–November	1	Moderate	– 40% of treated specimens re-sprouted
		Diesel oil, food colorant	50% vol. Diesel oil	Any trunk	September–October	1	Ineffective	
	Medallon Premium	–	100%	Any trunk	In the vegetation period	2	Effective	– Higher effectiveness if mixed with Diesel oil

*Authorisation for this product has been withdrawn

Box elder (*Acer negundo*)

Box elder has been widely introduced to riparian areas and sandy soils since the 1960s; by now it has become a transformer invasive species present in all regions of the country. It occurs in significant numbers mainly in flatlands. It is characterised by rapid juvenile growth, a deep-rooting primary root with shallow lateral roots, and with a germination period extending from April to September. In the case of damage it quickly regenerates with a high number of sprouts growing from the trunk and root collar. Low hanging branches of regenerated, multi-stemmed specimens can also grow roots. Box elder bears abundant fruit which are dispersed long distances primarily by wind and water, but sometimes by animals as well. With regards to the moisture and nutrient content of the soil, the species has a broad tolerance; it can withstand dryer periods and also periodical flooding. It finds optimum habitat conditions on alluvial soil, but survives on dry and nutrient-poor soils, as well. It is a pioneer species with high light requirements, but it tolerates shade at a young age: regrowth withstands poorer light conditions too. In Hungary, box elder raises environmental issues primarily in riparian softwood and hardwood gallery forests, abandoned riparian meadows and pastures. Its extremely thick regrowth may hinder the natural renewal of willows and poplars. Besides the habitats mentioned above, it establishes itself in dryer, open and disturbed habitats, in or near settlements, and along train tracks and roads. Control of the species is made more difficult by the fact that infested areas are often located near rivers, which carry a continuous supply of propagules and render chemical control treatments impossible. Box elder is one of the host plants of the fall webworm (*Hyphantria cunea*), which damages several fruit tree species. Experience gained to date shows that the only successful non-chemical control technique is the uprooting of seedlings. It can be effectively eradicated with commonly used chemical control techniques.

Non-chemical methods for controlling box elder (*Acer negundo*)

Method	Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
Manual removal of seedlings	Seedlings	In the vegetation period	1	Effective	– Seedlings are easiest to spot after bud burst
Felling and removal of sprouts	All trunk sizes	Outside the vegetation period (all year if necessary)	Treatment needs to be repeated at least once a year after the first treatment	Ineffective	– New sprouts keep coming up – Chemical follow-up treatments needed
	Diameter at the base = 10–50 mm	1st treatment: May 2nd treatment: July 3rd treatment: end of August–beginning of September	3	Moderate	– Final treatment should be timed in a way that the new sprouts freeze

*Authorisation for this product has been withdrawn

Results of chemical treatment experiments performed on box elder (*Acer negundo*)

Method	Treatment			Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
	Chemical	Additive	Concentration					
Spraying	Medallon Premium	–	5 l of chemical + 300 l of water	Sprouts, height = 30–50 cm	In the vegetation period	2	Effective	– Only in the case of dense, closed stands of sprouts or patches of regrowth
			33–50% vol.	Sprouts	September	1–2	Effective	– High weather sensitivity and high risk of drift
Applying herbicide on leaves	Medallon Premium	–	100%	Regrowth	In the vegetation period	2	Effective	– Method worth using where box elder appears mixed with native species
Partial bark stripping	Medallon Premium	–	50–100% vol.	All trunk sizes	August–September	1–2	Effective	
	Fozát 480	–	100%	Trunk diameter < 8 cm	August–October	1–2	Effective	– Repeat treatment is rarely necessary
	Figaro							
	Clinic 480 SL							
	NASA							
	Medallon Premium							
Basal bark treatment without cuts	Medallon Premium	–	50–100% vol.	Trunk diameter < 5 cm	August–September	1–2	Effective	
Trunk injection	Medallon Premium	–	100%	Trunk diameter > 8 cm	In the vegetation period	1–2	Effective	– Most effective at the end of August–September
			50–100% vol.	Trunk diameter > 5 cm	August–September	1–2	Effective	
	Garlon 4E*–Medallon Premium	–	1/3–1/3	Trees occurring sporadically	October–November	1	Effective	– Aqueous solution
	Fozát 480	–	100%	Trunk diameter > 8 cm	August–October	1–2	Effective	– Repeat treatment is rarely necessary – 1 drill hole per every 5 cm of the girth
	Figaro							
	Clinic 480 SL							
	NASA							
Cut stump treatment	Medallon Premium	–	100%	All trunk sizes	In the vegetation period	2	Effective	– Improved effectiveness by adding gasoline
	Garlon 4E*	–	50%	Trunk diameter = 2–15 cm	August	2	Effective	– ~ 20% resprouted; half of these needed to be treated again; other half resprouted then sagged
				Trunk diameter = 15–50 cm			Effective	– Herbicide to be applied as soon as possible after cutting
				Old trees (trunk diameter = 2–2.5 m)	November	1	Effective	– To be performed right after felling
		Diesel oil, food colorant	50% vol. Diesel oil	All trunk sizes	September–October	1	Ineffective	

*Authorisation for this product has been withdrawn

Himalayan balsam (*Impatiens glandulifera*)

Himalayan balsam was introduced to Hungary as an ornamental plant. Its spread accelerated after the 1960s and the species soon appeared not only along major rivers in Western Hungary, but also along rivers, streams and channels in other parts of the country. Its occurrence still concentrates in the western regions of Hungary, with stands along water courses, in willow-poplar floodplain forests, alluvial weed and scrub communities, and occasionally in (streamside) ash-alder forests in hilly or mountainous areas. Spreading from these habitats, it has occasionally established itself in wet fallows, meadows and pastures. Himalayan balsam is a tall annual plant with shallow roots and shoots that are quick to develop adventitious roots if broken down or laying to the soil surface. Its flowers can bloom from the end of June to as late as November, attracting a high number of insect species. The plant develops dynamochor capsules which explode when disturbed, scattering the seeds up to seven metres away. The seeds are then able to disperse

over long distances via water and alluvium. Himalayan balsam does not form permanent soil seed banks; however, the continuous propagule supply provided by drift water makes its control highly difficult. With its high water content the plant is sensitive to frost: late spring frosts can cause significant damage to the seedlings growing in masses. It has high water requirements. Willow-poplar forests providing relatively light shade are ideal habitats for the species, which tolerates direct sunshine only if the necessary water supplies are provided. Himalayan balsam is primarily an invasive weed species from the standpoint of nature conservation, obstructing the regeneration of native plant species with dense stands and a high volume of slowly decomposing leaf litter. Owing to is relatively small and shallow root system it can be easily uprooted. Before fruit ripening, mechanical eradication methods (hand-pulling, grazing, mowing) may be effective, but due to the constant propagule supply provided by the current they do not bring lasting results. Long-term control can only be carried out successfully if upstream habitats are cleared beforehand. Mechanical control techniques can be problematic as stands are often found in habitats which are difficult to access.

Non-chemical control of Himalayan balsam (*Impatiens glandulifera*)

Method	Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
Manual removal	Any type of stand	Before flowering, in May	Regular	Effective	– Selective – Cheap, not many tools needed – Should be carried out over multiple years

Ágnes Csiszár and Márton Korda

Giant hogweed (*Heracleum mantegazzianum*)

Giant hogweed is a tall perennial species typically reaching heights of 3–5 m, which was introduced to Hungarian botanic gardens and arboretums as an ornament based on its size and decorativeness; it started to spread starting mainly from these places. Only a few occurrences are known in Hungary, these being along streams, rivers and roads, in degraded pastures, clearcuts and near settlements. Its infestation is more significant, both from environmental and economical points of view, in the cooler, more humid climates of Western Europe. In the absence of any disturbance, giant hogweed flowers in the third or fourth year after germination; however, if the area is mowed, flowers may appear as early as the second year. One specimen can produce large volumes (up to 29 000) of schizocarps in compound umbel inflorescence. Seeds are dispersed over long distances by water and wind, and maintain their germination capacity for as long as 15 years in the soil. In Hungary, sites most ideal for the germination of seeds are wet riparian and streamside habitats, but the plant is known to establish in ruderal fringe communities, tallgrass meadows, cutting areas, and abandoned pastures too. Its spread is facilitated by its quick growth and strong competitive effect. Pests and pathogens do not hinder its infestation, even though it has several known (mainly polyphagous) insect consumers. Due to its tall size and large leaves, it provides relatively heavy shade, thus forcing away those species with high light requirements. The problems caused by its invasiveness is further aggravated by the human health risks it poses: the sap of giant hogweed contains photoactive substances which, when coming into contact with the skin and exposed to light, cause severe dermatitis in humans. The negative effects listed above all underline the importance of stopping its spread and re-introduction. Giant hogweed is difficult to control, but by mowing stands between flowering and seed maturation, and subsequently injecting the hollow stems with a glyphosate-based product it can be successfully eradicated.

Results of combined control treatment experiments of giant hogweed (*Heracleum mantegazzianum*)

Method	Treatment			Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
	Chemical	Additive	Concentration					
Mowing followed by injection	Glialka 480 Plus	–	100%	Sporadically or in specimen occurring in points	Mowing: between flowering and seed maturation (end of June–beginning of July) Injection: right after mowing, re-treatment if needed: beginning of September	1–2	Moderate	– Highly difficult to eradicate, stand size decreases slowly but can be controlled – Mow close to the ground – wearing protective gear required – Depending on the size of specimen, 10–20 ml of herbicide to be injected into each hollow stem after mowing
	Medallon Premium							
	Taifun 360							

Common milkweed (*Asclepias syriaca*)

The spread of milkweed in Hungary was significantly accelerated by its intensive cultivation between 1870 and 1950. The species was considered to be utilizable in a wide array of different ways: its flowers were used to produce volatile oil, syrup and wine, its fibres to produce paper and wallpaper, its latex in rubber production and seed in silk production, and its shoots were consumed as "asparagus". Nowadays, it is realized as having practical significance only as a nectar producer, so previously established stands have been abandoned and have started to spread quickly via root suckers and through the hairy seeds that aid wind dispersal. Its spread is intensified in disturbed habitats with loose soil, from dry, open sandy grasslands to wet riparian habitats. The colonization of new sites is facilitated by its wind-dispersed seeds having long seed longevity, strong competitive capacity and drought tolerance. Owing to its rhizome-like root system it forms large clones. The majority of its thick roots grow laterally and close to the surface, but some can extend as deep as 1–1.5 metres. Flowers blossom from June to August, and are pollinated by bees and several other insect species. Common milkweed is a thermophilous, drought-tolerant plant species with high light requirements. It can nonetheless tolerate moderate shading, so it can form larger stands in gallery forests with loose canopies, and in the herb layer of black locust, hybrid poplar and planted pine stands, as well. It is known to spread in orchards and vineyards, and in the last few decades it has become a significant arable weed. Being a good nectar producer, in several known cases the species was deliberately introduced.

According to our present knowledge non-chemical eradication is practically impossible, even with years of persistent mowing, grazing and hand-pulling. All kinds of disturbances and mechanical injuries typically result in intensive resprouting and the growth of stands. Based on experience, the species can be effectively eradicated within 1-3 years by spraying and wiping stands with glyphosate-based herbicides. When planning herbicide treatment it must be considered that bees like to gather nectar from its flowers.

Non-chemical methods for controlling common milkweed (*Asclepias syriaca*)

Method		Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
Hoeing, hand-pulling		In the case of low density	Before flowering	1	– To obstruct seed dispersion: effective – To eradicate: ineffective	– If the use of herbicides is not allowed
Mowing, flail mowing		In the case of low density	1st treatment: before flowering 2nd treatment: end of summer–autumn	2	– To obstruct seed dispersion: effective – To eradicate: ineffective	– Results in the growth of patches
		Dense stands	1st treatment: before flowering 2nd treatment: when treated stand resprouted	2	Ineffective	– Incapable of eradicating the species in 10 years – Continuous resprouting – Often regenerates with an increased number of shoots
Grazing	**Goat and sheep**	Patches of 100 m^2		Regular	Effective	– Proved effective only on a single occasion – Success was probably largely influenced by drought
Removal of inflorescence		In the case of low density	Before flowering	2	– To obstruct seed dispersion: effective – To eradicate: ineffective	– If the use of herbicides is not allowed

Results of chemical control treatment experiments performed on common milkweed (*Asclepias syriaca*)

Method	Treatment			Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
	Chemical	Additive	Concentration					
Spraying	Medallon Premium	3.5 ml Silwet Star + 1515 g of fertilizer (ammonium-nitrate, -sulphate)	10%	Homogeneous stands	End of May–beginning of June	1–2	Effective	– Necessary time requirements: min. 3 years
			33%					
			50%					– Necessary time requirements: min. 3 years – High collateral damage
	Tomigan 250 EC 1 l/ha and Banvel 480 S 1.5 l/ha + Silwet L-77			Patchy occurrences	May	3	Moderate	– Under farming conditions – Significant damage to surrounding vegetation
Spot spraying	Fozát 480	Pétisó (calcium ammonium nitrate) + Nonit	2.5%	Plants not in bloom	May–October	1–2	Effective	– High temperature and strong sunshine reduce effectiveness – The repeated cutting of blossoming plants can prolong the period suitable for treatment – 2nd treatment 10 days after the1st one when surviving/left-out stems become visible – Highly selective
	Figaro							
	Clinic 480 SL							
	Medallon Premium							
		Nonit	3.5–5%	Smaller patches	1. treatment: before flowering 2. treatment: for re-sprouted stands	1–2	Effective	– Cooler weather more favourable – Warm weather often stimulates resprouting
		ammonium-nitrate + Hyspray	5%	Smaller patches	1. treatment: May 2. treatment: August–September	2	Effective	– Optimal in the morning hours in warm and humid weather
	Medallon Premium and Glialka 480 Plus	–	5%	Smaller patches		2	Moderate	
	Gladiátor 480SL	–	2–5%			2	Effective	
	Glialka 480 Plus	–	10%			2	Moderate	– Too high concentration – Optimal in the morning hrs in warm & humid weather
	Fozát 480	Nonit	3.5–5%	Smaller patches	1. treatment: before flowering 2. treatment: for re-sprouted stands	1–2	Effective	– Cooler weather more favourable, – Warm weather often stimulates resprouting
	Glyfos							
	0.2 g Granstar 50 SX + 3.5 ml Silwet Star + 15 g fertilizer (ammonium nitrate, -sulphate) in 1 l of water			Any type of stand	May	1	Ineffective	
	0.4 g Granstar 50 SX + 3.5 ml Silwet Star + 15 g fertilizer (ammonium nitrate, -sulphate) in 1 l of water							
	0.8 g Granstar 50 SX + 3.5 ml Silwet Star + 15 g fertilizer (ammonium nitrate, -sulphate) in 1 l of water							
	0.3 g Mezzo + 3.5 ml Silwet Star + 15 g fertilizer (ammonium nitrate, -sulphate) in 1 l of water							

Method	Treatment			Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
	Chemical	Additive	Concentration					
	0.6 g Mezzo + 3.5 ml Silwet Star + 15 g fertilizer (ammonium nitrate, -sulphate) in 1 l of water							
	1.2 g Mezzo + 3.5 ml Silwet Star + 15 g fertilizer (ammonium nitrate, -sulphate) in 1 l of water							
	0.3 g Titus Plus DF + 3.5 ml Silwet Star + 15 g fertilizer (ammonium nitrate, -sulphate) in 1 l of water							
	0.6 g Titus Plus DF + 3.5 ml Silwet Star + 15 g fertilizer (ammonium nitrate, -sulphate) in 1 l of water							
	1.2 g Titus Plus DF + 3.5 ml Silwet Star + 15 g fertilizer (ammonium nitrate, -sulphate) in 1 l of water							
	0.2 g Granstar 50 SX + 3.33 ml Tomigan 250 EC + 3.5 ml Silwet Star + 15 g fertilizer (ammonium nitrate, -sulphate) in 1 l of water						Ineffective	
	0.4 g Granstar 50 SX + 6.66 ml Tomigan 250 EC + 3.5 ml Silwet Star + 15 g fertilizer (ammonium nitrate, -sulphate) in 1 l of water							
Spot spraying	0.8 g Granstar 50 SX + 13.32 ml Tomigan 250 EC + 3.5 ml Silwet Star + 15 g fertilizer (ammonium nitrate, -sulphate) in 1 l of water			Any type of stand	May	1		
	0.33 g Titus Plus DF + 3.33 ml Tomigan 250 EC + 3.5 ml Silwet Star + 15 g fertilizer (ammonium nitrate, -sulphate) in 1 l of water							
	0.66 g Titus Plus DF + 6.66 ml Tomigan 250 EC + 3.5 ml Silwet Star + 15 g fertilizer (ammonium nitrate, -sulphate) in 1 l of water							
	1.32 g Titus Plus DF + 13.32 ml Tomigan 250 EC + 3.5 ml Silwet Star + 15 g fertilizer (ammonium nitrate, -sulphate) in 1 l of water							
	2 g Casper + 3.33 ml Tomigan 250 EC + 3.5 ml Silwet Star + 15 g fertilizer (ammonium nitrate, -sulphate) in 1 l of water						Moderate	– Around 1/3 survived – Significant damage to surrounding vegetation
	4 g Casper + 6.66 ml Tomigan 250 EC + 3.5 ml Silwet Star + 15 g fertilizer (ammonium nitrate, -sulphate) in 1 l of water						Ineffective	
	8 g Casper + 13.32 ml Tomigan 250 EC + 3.5 ml Silwet Star + 15 g fertilizer (ammonium nitrate, -sulphate) in 1 l of water						Moderate	– Around 1/3 survived – Significant damage to surrounding vegetation

Method	Treatment			Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
	Chemical	Additive	Concentration					
Applying herbicide on leaves	Medallon Premium	3.5 ml Silwet Star + 15 g fertilizer (ammonium nitrate, -sulphate) in 1 l of water	10% 33% 50%	Occurrences, sporadically growing plants in grasslands of good conservation status	End of May – beginning of June	1–2	Effective	– Under farming conditions
		–	10%	Any type of stand	Before flowering		Moderate/ Effective	– Can be used only for smaller stands
		N-fertilizer + Nonit + food colourant	33–50 % vol.	Any stand before flowering	1st treatment: May–June 2nd and 3rd treatment: July–August	1–3	Moderate	– Can be used only for smaller stands, high risk of drift – One treatment needed for dry summers, 2–3 for summers with high precipitation
Partly mechanical application	Medallon Premium	3.5 ml Silwet Star + 15 g fertilizer (ammonium nitrate, -sulphate)	10% 33% 50%	Any type of stand	May	1	Ineffective	– Right concentration, but method of application unsuitable – surfactant hardens into the textile used for application
Mechanical application (with quad equipped with an adapter)	Medallon Premium	3.5 ml Silwet Star + 15 g fertilizer (ammonium nitrate, -sulphate)	10% 33% 50%	Any type of stand	May	1	Effective	– Lot of collateral damage

Giant and Canadian goldenrod (*Solidago gigantea*, *Solidago canadensis*)

The giant and Canadian goldenrod species were introduced to Hungary in the mid-1800s as ornamentals. The spread of giant goldenrod has been more intensive and affects a bigger part of the country. Giant goldenrod is common in most parts of the Transdanubian region, and occurs mainly along streams and in river valleys in the Hungarian mid-mountains and the Hungarian Great Plain. Canadian goldenrod, on the other hand, is less common, and appears in larger stands mainly along the Transdanubian and northern mid-mountains near big cities. Both species are geophytes growing from rhizomes; the rhizomes of Canadian goldenrod are shorter but live longer, meaning that its stands are usually smaller, with higher density. They can establish in new habitats with the help of their pappus on wind-dispersed cypselas, then densely populate it with rhizomes and create mono-dominant stands. Both species have high light requirements and relatively broad tolerance as far as the supply of nutrients is concerned; however, their site-preferences are slightly different. Giant goldenrod prefers wet, humid, occasionally compacted soils and more natural habitats, whereas Canadian goldenrod prefers disturbed habitats with looser soils (sand, loess) that warm up more rapidly. Both are good nectar producers and are used as herbs for a variety of medical purposes, but with flowers that can cause pollen allergies. In addition to the environmental issues they raise, they can also infest forest nurseries and newly established plantations as weeds, hindering natural renewal and afforestation. Changes in land use and lack of mowing and grazing in treeless habitats are proven to assist their invasion. Their closed stands force out species of the former vegetation, thus leading to a decline in floral diversity, which in turn reduces the species richness of vertebrate and invertebrate fauna. Their tall, dense stands diminish the habitats of ground-nesting birds, and are also impassable for some vertebrate species. Control treatments against goldenrod are primarily non-chemical. Young shoots can be grazed by many domestic livestock species, but cattle, for instance, only graze it prior to flowering. Horses and donkeys are observed to consume the flowering shoots, as well. Mowing is a commonly used control method; however, experience shows that mowing only once a year does not bring results, and occasionally triggers further vegetative infestation. Stands can usually be decreased by mowing conducted twice a year (in the beginning of summer and in the autumn). Chemical control methods are less common, and are often used only to supplement the non-chemical treatments mentioned. The restoration of the water regimes of wet, humid habitats has also proved to bring positive results: goldenrod populations have dramatically decreased even in habitats that had previously been homogeneously covered by its stands.

Non-chemical methods for controlling giant goldenrod (*Solidago gigantea*)

Method		Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
Mechanical mowing		Stands in stream-side grasslands with diverse water conditions (<50%)	Beginning of June	Regularly, once a year	Moderate; Ineffective in areas that are drying up, elsewhere	– Does not produce flowers if mowed early – Resprouting is followed by large scale clonal propagation – With drum mower (stubble height: 8–10 cm)
			Beginning of September		Moderate	– Coverage kept at a lower level, or even reduced
		Stands in stream-side grasslands with diverse water conditions (around 20%)	Beginning of June and beginning of September	Regularly, twice a year	Effective in most cases	– Effectively stops further spread, able to eradicate if conducted regularly – With drum mower (stubble height: 8–10 cm)
		Homogeneous and mixed with grass	May	Regularly, once a year	Ineffective	– Hardly decreased coverage after 2 years with 3 mowings per year – In the Hanság region coverage decreased by 10% after seven years of mowing (carried out once a year)
			May and July	Regularly, twice a year	Moderate	
			May, July and September	Three times a year, regularly	Moderate	
			Between flowering and seed maturation outside the vegetation period (November–February)	Regularly, twice a year	Moderate/Effective	– Mowing should be carried out on a regular basis as maintenance – Debris left by mowing should be removed – Effectiveness depends on the natural water regime, effective if carried out regularly
Flail mowing		Stands mixed with shrubs	Between flowering and seed maturation outside the vegetation period (November–February)	Twice a year for 2–3 years	Moderate/Effective	– When shrubs have been eradicated must switch to mowing – Debris left by mulching should be removed from site – Effectiveness depends on the natural water regime, effective if carried out regularly
Grazing after mowing and flail mowing	Grey cattle	Mainly homogeneous stands	Flail mowing, mowing in the flowering period, then continuous grasing except the winter time	Regular	Effective	
	Buffalo					
Inundation		Homogeneous or mixed with grass	Should be stopped 2-3 weeks before the planned date of mowing so that the area can be accessed	Regular	Moderate / Effective	– In accordance with natural water regimes – Only in habitats where the periodical appearance of excess water is a natural feature
Inundation	20-60 cm water depth	Mainly homogeneous stands with sedges	Continuous	Continuous	Effective	– Habitat transformed into grey willow scrubs with tall sedges that form a mosaic with patches of open water surfaces

Results of chemical treatment experiments performed on giant goldenrod (*Solidago gigantea*)

Method	Treatment			Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
	Chemical	**Additive**	**Concentration**					
Spot spraying	Medallon Premium Fozát 480 Figaro Clinic 480 SL	Ammonium fertilezer + 2–3 ml Nonit	2.5%	Plants not in bloom	June–October (until the first frost the latest)	1–2	Effective	– High temperature and strong sunshine drastically reduces effectiveness
	Dominátor	Nonit	3.5%	Any type of stand	In the vegetation period	1–2	Effective	– More effective in warm, sunny weather

Non-chemical methods for controlling Canadian goldenrod (*Solidago canadensis*)

Method	Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
Mowing	Stand height: min. 30 cm	Right before flowering (beginning of June)	Regular (at least twice a year)	Moderate	– Proved effective only after several years

Results of chemical treatment experiments performed on Canadian goldenrod (*Solidago canadensis*)

Method	Treatment			Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
	Chemical	Additive	Concentration					
Spot spraying	Medallon Premium Fozát 480 Figaro Clinic 480 SL	N-fertilizer + 2–3 ml Nonit	2.5%	Plants not in bloom	June–October (before the first frost at the latest)	1–2	Effective	– High temperature and strong sunshine drastically reduces effectiveness
	Dominátor	Nonit	3.5%	Any type of stand	In the vegetation period	1–2	Effective	– More effective in warm, sunny weather

Results of combined treatment experiments conducted to control Canadian goldenrod (*Solidago canadensis*)

Method	Treatment			Stand characteristics	Timing	Number of treatments	Effectiveness	Comments
	Chemical	Additive	Concentration					
Flail mowing and sheep grazing followed by spot spraying	Medallon Premium Kapazin Gladiátor 480 SL Glialka 480 Plus	Nonit	3% aqueous solution	– Flail mowing and grazing in homogeneous stands – Residual and individual plants, and plants forming patches of a few sq m	– Flail mowing: before full bloom – Grazing: after or instead of flail mowing – Spraying: for a month before the first frost expected, after grazing	1	Effective	– The most effective, fresh, re-sprouting shoots are readily consumed by sheep
Flail mowing and horse grazing followed by spot spraying	Medallon Premium Kapazin Gladiátor 480 SL Glialka 480 Plus	Nonit	3% aqueous solution			1	Effective	– Only if grazing can be rotational, otherwise not consumed readily by livestock
Spot spraying following flail mowing	Medallon Premium Kapazin Gladiátor 480 SL Glialka 480 Plus	Nonit	3% aqueous solution		– Flail mowing: before full bloom – Spraying: for a month before the expected first frosts	1	Effective	– Flail mowing: 20 cm stubble height
Flail mowing and/or grazing supplemented by spot spraying	MedallonPremium Kapazin Gladiátor 480 SL Glialka 480 Plus	Nonit	3% aqueous solution	For individual plants and plants forming patches of a few sq meters (where grazing is not an option, e.g. fringes, forest…)	From the beginning of May until a month before the expected first frosts	2	Effective	– With manual sprayer small with medium pressure and a spot spray pattern

Wild cucumber (*Echinocystis lobata*)

Wild cucumber was probably introduced to Hungary as an ornamental plant, and thanks to its rapid spread it had already been considered an established species by the 1950s in the western and south-western Transdanubian regions and in the Hungarian mid-mountains. Nowadays, it can be found almost everywhere in the country, but it is relatively rare in the Little Hungarian Plain and the Danube-Tisza interfluve. It appears in masses mainly in riparian areas and floodplains, in gallery forests, alluvial willow scrubs, and in tall riparian weed communities. Besides these habitats, it may also establish itself in streamside tall herb communities in hilly and mountainous areas and in semi-humid, wet forest habitats. Its seeds and fruits (which float on the surface of the water) can be dispersed over long distances by the current. As seed dormancy is broken by exposure to cold winter weather it quickly germinates in moist, nutrient-rich soils.

Seedlings and mature plants both have high light requirements, and climb to a height of 7-8 metres with their vines while shading out the plants they use as supports. Owing to their heavy foliage mass they are often able to pull smaller saplings to the ground. Wild cucumber is common in wet, humid soils or soils with changing water regimes, humic alluvial soils as well as clay and cob soils. It withstands degradation of habitats but is sensitive to early and late frosts. Owing to its climbing shoots it has a significant negative effect on the species richness and composition of indigenous communities. It serves as a host plant for a number of pathogens, primarily viruses, which can damage representatives of the native flora and some cultivated plant species as well. As wild cucumber uses other plants as support, it is practically impossible to ensure the selectivity of chemical treatments; and as it mainly occurs near water courses or other bodies of water, herbicide application has legal barriers as well. Based on the results of a habitat-reconstruction experiment, the species can be effectively eradicated by inundating the area.

Non-chemical methods for controlling wild cucumber (*Echinocystis lobata*)

Method		**Stand characteristics**	**Timing**	**Number of treatments**	**Effectiveness**	**Comments**
Inundation	**20-60 cm water depth**	Homogeneous goldenrod stands with sedges and wild cucumber	Continuous	Continuous	Effective	– Habitat transformed into grey willow scrubs with tall sedges that form a mosaic with patches of open water surfaces

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Invasive plant species pose major agricultural, silvicultural, human health and ecological problems worldwide, and are considered the most significant threat for nature conservation. Species invading natural areas in Hungary have been described by a number of books published in the last few years. A great amount of experience has been gathered about the control of these species in some areas, which we can read about in an increasing number of articles; however, no book has been published with regards to the whole country.

Invasions affecting larger areas require high energy and cost input, and the effectiveness and successfulness of control can be influenced by a number of factors. The development of effective, widely applicable control and eradication technologies is preceded by experiments and examinations which are based on a lot of practical experience and often loaded with negative experiences. National park directorates, forest and agricultural managers and NGOs in many parts of Hungary are combatting the spread of invasive species; however, the exchange of information and conclusion of experiences among the managing bodies is indispensable.

The aim of the present volume is to facilitate this by summarizing experiences and the methods applied in practice; which, we hope, will enable us to successfully stop the further spread of invasive plant species and effectively protect our natural values.

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