UNIVERSITY OF PÉCS

Biological and Sportbiological Doctoral School

Archaeobotanical analysis of adobe bricks and the 150-year changes of the synanthropic flora in the Southern Transdanubia

PhD thesis

Tamás Henn

Supervisor:

Róbert Pál, PhD
associate professor

PÉCS, 2016

INTRODUCTION

Botanical and agricultural researches dealing with the weed vegetation and its multifunctional biological and ecological role have emerged recently in Europe. This is a very important objective, because the flora of agricultural landscapes and other disturbed habitats declined significantly after the 2nd World War, due to modernization of the agricultural practices. The high input agricultural production today left its mark on the recent weed vegetation and vanished the major part of the diverse weed vegetation of previous times. Due to this, a significant part of the European weed flora was destroyed without understanding and recovering its complex system and ecological role.

Howewer, Hungary has made significant progress in this aspect, because the changes in the weed flora are well-documented in the last six decades due to five Nationwide Weed Surveys starting from 1950. The original objective of these surveys was to recover the area and abundance of the most harmful weed species on agricultural fields. The surveys also showed that significant changes occured in the dominance relationships of arable weeds, some new weed species emerged while others declined significantly. Nevertheless, the biological, ecological and coenological procession of the retreating species were less emphasized than in other European countries.

The weed species are inseparable companions of our cultivated species and fields since the beginnings of the agriculture. Consequently, our knowledge about ancient and historical weed species and weed flora come from archaeobotanical researches. As in other parts of Europe, there were several archaeological excavations in Hungary, which resulted a large amount of plant remains. Analyzing these remains we received an overall picture of the emergence, development and changes of the Hungarian weed flora since the neolithic times until the medievals. However, we have much less information about the weed flora from the subsequent periods.

Nevertheless, adobe and other earth based buildings constructed between the late medievals and the 1950s may contain important information about the anthropogenic flora of this period. Namely, a large amount of plant material (primarily by-products of harvest and grain processing, ie. straw and chaff) was mixed to these building materials in order to improve and control the physical properties of building materials. The mixed plant parts are usually well-preserved, due to constant dry conditions. Therefore, the archaeobotanical

analyzis of these remains let us to reconstruct the flora of agricultural landscapes of the questionable period and know the cultivated species and related weeds.

In my PhD thesis, I examined the plant content (predominantly seeds and fruits) of adobe bricks from residential houses and outbuildings built in the 19th and early 20st century. Based on the recovered diaspores I reconstructed the contemportary anthropogenic flora and compared these results to the data of modern plot surves made in the 2000s. Besides, I also examined the most effective recovering techniques for archaeobotanical processing of old adobe bricks.

OBJECTIVES

In my PhD thesis, beyond the reconstruction of the historical weed vegetation, I tried to get a broad picture of the long-term changes of the weed flora in the surveyed area.

Beyond these, I asked the following questions: Are the classic archaeobotanical and seed bank techniques applicable to recover the plant remains and species spectra of natural building materials, especially adobe bricks? If yes, what techniques are the most effective? Are these data comparable to the results of modern plot surveys? If yes, can we get an insight to the continous, qualitative and quantitative development and changes of the weed vegetation?

To answer these questions my work was divided into three major parts. Within these, my specific objectives were:

1. Methodological examinations:
    - 1.1. To test the archaeobotanical and/or modern seed bank techniques to process adobe and mudbricks;
    - 1.2. To find the optimal method to recover plant remains preserved in adobes and the optimalization of the extraction technique;
    - 1.3. To clarify the parameters of the extraction by flotation extraction technique;
    - 1.4. To determine the minimal sample volume, that guarantees the recovery of all preserved plant species from adobe samples;
    - 1.5. To document the identification difficulties of the recovered diaspores.
2. Archaeobotanical examinations:
    - 2.1. To collect the preserved plant remains (predominantly seeds and fruits) from the processed adobe samples;
    - 2.2. To identify all of recovered diaspores;

2.3. To describe the composition and quantitative aspects of the historical weed vegetation.

3. Detection of changes in the weed flora:

3.1. To compare the composition and abundance relationships of the historical and current weed flora;

3.2. To compare the historical and current weed flora from coenosystematic, systematic, life forms and floristic points of view;

3.3. To detect the qualitative and quantitative changes in the distributions of rare, valuable and harmful invasive weed species.

MATERIALS AND METHODS

Collecting and processing of adobe bricks

As the first step of my work, 60 adobe bricks were collected from the southern part of the Transdanubian region of Hungary. All of the collected bricks originated from walls of untenanted and/or ruined adobe dwelling-houses and related outbuildings. The provenance of the bricks and the years of construction of the buildings were also recorded. Most of the bricks were made between 1850 and 1930.

The collected bricks were crushed carefully with a hammer and in a mortar. The crushed or chopped-up brick samples were dry-sieved using 2.0, 1.0, and 0.5 mm meshes. After this, the distinction of the organic and inorganic components of the adobes extraction by flotation method was selected. This method based on the different specific gravity of organic and inorganic components.

The different fractions were floated separately with sodium chloride solution, because disintegration of the various sized lumps took different times. After sedimentation, the supernatants were sieved using a 0.25 mm mesh. After extraction by flotation, the plant materials were washed out gently under tap water and air-dried. As the applied chemicals are corrosive, the waste was collected in special receptacles and disposed of safely. The corrosive effects on the archaeological remains were insignificant, because the exposure time to the salt was usually short, up to 30 min.

Optimalization of the separation method

Based on literature data, I tested the effectiveness of some extraction by flotation techniques. Potassium carbonate, sodium carbonate (washing soda), calcium dichloride, zinc dichloride and sodium chloride (common salt) solutions with specific gravities between 1.17 and 1.60 g cm^{-3} as flotation media, and compared their efficiencies. Special 150 g experimental mudbricks consisting of 80 % clay, 18 % sand, 2 % straw and chaff and water were used for these examinations (the constitution of these experimental bricks was similar to those of the mudbricks in old buildings). 12 seeds each of six plant species were added to the mixture of seed-free chaff and straw. After crushing, experimental mudbrick samples were placed in a soaking container and 300 cm^3 of flotation solution was added from each solution (1.462 g cm^{-3} K_2CO_3; 1.169 g cm^{-3} Na_2CO_3; 1.411 g cm^{-3} $CaCl_2$; 1,.98 g cm^{-3} $ZnCl_2$ and 1.195 g cm^{-3} NaCl). The samples were thoroughly stirred and left to settle. The supernatant plant material was sieved using a 0.25 mm mesh and air-dried. The extraction was made in six repetitions.

After this, sodium chloride solutions with various specific gravities (1.0703; 1.0893; 1.1079; 1.1261; 1.1438; 1.1611; 1.1781; 1.1951 and 1.2109 g cm^{-3}) were also tested for their effectiveness following the previous protocol. Based on the data, a sodium chloride solution with a specific gravity of 1.1261 g cm^{-3} was selected for further examinations.

In a further experiment, the detection effectiveness of different sized seeds was also examined.

Separation and identification of diaspores

The diaspores were separated and identified under a binocular stereomicroscope. A reference collection of diaspores was used to identify the fruits and seeds, as well as special reference books and seed atlases. Only those seeds which were intact or could be unambiguously identified, including fragmented seeds, were evaluated.

Optimalization of the sampling volume

Because I have not found clear information about minimal sample volume in the literature, one of the first steps of my work was the optimalization of sampling volume. Ten of the mudbricks collected from old buildings were used for this investigation. The bricks were crushed and different subsamples with increasing volumes were taken randomly (35 cm^3, 70 cm^3, 105 cm^3, 140 cm^3, 210 cm^3, 420 cm^3, 840 cm^3, 1.680 cm^3, 3.360 cm^3 etc.). The numbers of taxa and diaspores were also counted in each subsample after flotation (1.1261

g/cm^3 NaCl solution). Based on the obtained data, the numbers of taxa per sample volume and diaspores per sample volume curves were calculated.

Collecting of field data

Field data were collected between 2000 and 2006 in the surroundings of the South-Transdanubian settlements from where the adobe bricks originated. The size of plots was 50 m^2 in cereals and on stubbles and 4 m^2 in vineyards. The survey method based on the UJVÁROSI-BALÁZS methodology. Square-shaped quadrats were used, but in some cases I used elongated quadrats in the same size.

Examination of germinability and viability of seeds

From the remains of the processed adobe samples, four species were selected for the germinability and viability experiments, these were: *Cirsium arvense*, *Malva pusilla*, *Stachys annua* and *Verbena officinalis*. To compare the results, recently (in 2013) collected seeds of the four taxa were also tested at the same time.

Before starting the germination, the seeds were stratified as follows: +10 ^{o}C for 3 days, then +5 ^{o}C for 31 days and finally +10 ^{o}C again for 1 day. After this treatment, the germination took place in the following lightin periodicity: 16 hours light (25 ^{o}C) / 8 hours dark (20 ^{o}C) and 70% relative humidity. 50-50 seeds of the selected species were placed on steril plastic Petri dishes with sterilized filter paper, sand and soil media. The germination media was moistened continously with a specific solution (1 l tap water + 2 cm^3 Vitaflora-3 plant nutrient solution). The proportion of $N:P_2O_5:K_2O$ of the Vitaflora-3 solution was 7:3:5, and it also containd micro-elements. The evaluation happened in every two days for a month.

For the viability examinations two different staining method were selected: vital staining with indigocarmine and use of redox indicatore (2,3,5-triphenyl-tetrazolium chloride, TTC). 100-100 pieces of the recovered and collected seeds of the selected species were examined. The seeds were swelled in tap water on room temperature for 24 hours before the examinations. The seeds were cutted in half with a razor blade as the iniciative step of the experiment. After this, the recovered seeds were soaked in a 0,15% indigocarmine solution for 30 minutes, while the collected seeds were soaked in 0,1% TTC solution in dark for 2 hours. After staining, seeds were washed out under tap water and evaluated under a binocular stereomicroscope (Leica Zoom 2000 – Model No. Z45V).

Data analysis

The data were entered in Turboveg 2.0 software and in MS Excel table. Statistical analyses (Repeated Measures of ANOVA, chi-squared tests, correlation tests) were carried out in R environment, version 2.15.2 and in PAST softwares.

RESULTS AND DISCUSSION

In my PhD thesis, I examined the qualitative and quantitative changes of the weed vegetation between the 1820s and nowadays in the southern part of the Transdanubian region of Hungary, based on archaeobotanical data and results of modern plot surveys. Archaeobotanical data came from the seed and fruit remains of old adobe bricks oroiginated from different settlements in the surveyed area. These data were compared to the results of modern coenological plot surveys recorded in the same region in the 2000s.

Because there was no standard methodology to examination of natural building materials from archaeobotanical point of view, the first step of my work was to find the adequate technical supports.

Methodological results

I found that the extraction by flotation separation technique used in seed bank research and also in archaeobotanical examinations is applicable for recovering the plant remains of adobe samples. In the literature, many of chemicals are used as extraction solutions, but water-soluble salts are the most effective. Based on these, I examined the extraction efficiency of five different (K_2CO_3, Na_2CO_3, $CaCl_2$, $ZnCl_2$ and NaCl) heavy solutions. Within these, the NaCl solution was the most effective, and this is also a less corrosive and cheap chemical. The second best effective solution was $ZnCl_2$ solution, while the other chemicals were significantly less effective. This result is rather considered novel, because I have not found other examples using the NaCl solution in archaeobotany, and its use in seed bank examinations is extremely rare.

Very different information was found about the specific gravity of solutions in the literature, every research used different solutions. Taking it into account, I tested the recovery efficiency of salt solutions with different species gravity using the NaCl solution. However, there was no significant difference in the efficiency of the examined solutions, the effectiveness of all solutions were better then that of pure water. Based on this, and my

empirical experiences, a solution with a midle specific gravity (1.126 g/cm^3) was selected for my further examinations.

In my PhD thesis, I examined firstly the recovery success of small-seeded plant species using the extraction be flotation method. I observed positive correlation between the seed size and the recovey efficiency. Based on this, I found that this technique is more reliable in the case of qualitative data than in the case of quantitative data – which needs to be handled with caution in the future.

I also described the minimum (~2.500 cm^3) and optimum (~3.000-3.500 cm^3) sample volume that guaranties the representation of all taxa for adobe brick samples in archaeobotanical researches. Similar studies were made only in some few cases before, but it would be reasonable to begin all of archaeobotanical researches with this examination in future to make easier the further work.

The examination and documentation of deformity types of desiccated diaspores is also a pioneer approach within my methodological results. Several recovered diaspores were deformed and fragmented. The documentation of these morphological changes – emphasizing four model species – can make the identification process of desiccated diaspores significantly easier in the future.

After putting down the methodological aspects of my research I applied them in the second part of my PhD work. This considered the collection of old adobe bricks and recover the preserved diaspores and plant species. Based on the identification of the recovered diaspores, I reconstructed the historical weed flora in the studied region.

Archaeobotanical results

Plant specimens (predominantly seeds and fruits) from adobe bricks which have remained continuously dry are well-preserved through desiccation. Identifying these remains we can can gain important conclusions about the vegetation influenced by human activities in the surroundings of the sampled settlements at the time of the building construction, including plant species composition and abundance relationships.

A total of 24.634 diaspores were recovered from the processed adobe samples. The average number of diaspores varied greatly between the samples (between 36 and 1.649), while the species number varied between 10 and 59. I found that the main soil types of the samples did not significantly influence the diaspores and the number of taxa. Similar observations were made in the case of the cultivated plant species of adobes.

The recovered diaspores belonged to 303 taxa. 91.1% of them could be identified to the species level, while 7.53% and 1.37% of them could be only identified to genera or family level. Within the identified taxa, 14 cultivated species were observed with an average of 1.342 diaspore number. The diaspores of *Triticum aestivum*, *Avena sativa*, *Vitis vinifera* and *Brassica* × *napus* ssp. *napus* were the most common in the examined samples. Beside the cultivated species 23.292 of the diaspores originated from wild species, and 289 taxa were identified among them. Almost 85% of them were weedy species, the proportion of Secalietea and Chenopodietea elements were the highest.

Results of germinability and viability tests

Viable and germinable diaspores were also recovered from the examined adobe samples. Only one *Malva pusilla* seed germinated from the tested adobe samples, while the seeds of *Cirsium arvense*, *Malva pusilla*, *Stachys annua* and *Verbena officinalis* germinated well from the newly collected seeds. At the same time, there was no significant difference in the internal construction between the recovered and collected seeds. In parallel, many of viable diaspores were found within the recovered seeds, and there was no difference in the case of the collected and recovered seeds.

Results of recent plot surveys

A total of 311 weed species were registered in the surveyed area between 2000 and 2006. 261 species were found on arable fields, while 196 species were registered in vineyards and 146 of them were overlapping. The coverage of the weed vegetation varied greatly, the lowest value was 27% in cereals, the highest was 187% (due to the multi-structured weed vegetation). In parallel on stubbles, the lowest total cover was 6.13% and the highest was 171%. The number of weed species did not vary greatly, it was between 5-41 in cereals, and 5-42 on stubbles. At the same time, there were higher cover values in vineyards, it varied between 43.5% and 157.5%. The species numbers varied between 6 and 29.

Some cultivated species among the registered species were present as weeds on several fields. These were e.g. *Avena sativa*, *Helianthus annuus*, *Medicago sativa* and *Panicum miliaceum* on arable fields and *Cerasus avium* in vineyards. Beyond the cultivated species, a total of 258 and 195 wild species were registered on arable fields and in vineyars, respectively. These results reflect the results of the 5th Nationwide Weed Survey (2007-2008) in Hungary.

In the third part of my study I conducted a comparative evaluation of the present and historic weed flora. Based on this I gained a comprehensive overview about the quantitative and qualitative changes and the evolution of the weed vegetation.

Changes in the historic weed vegetation

Based on the numerical analyses of presence and absence data I concluded that the weed flora recovered from the adobe bricks showed a high similarity with the weed flora of contemporary cereals more specifically with fallows. This might be due to the application of trashing refuse in the process of adobe brick production.

The distribution of the social behavior types, based on Borhidi showed a similar picture in the case of the recovered and the recently surveyed species. There was a prevailing dominance of weeds and disturbance tolerant species. The vegetation analyises revieled that both the recovered and the surveyed taxa belongs to the herbcaous plant communities of disturbed habitats (mainly the Chenopodietea, Secalietea, and Artemisietea classes). Besides, there was a high contribution of indifferent plant species in both cases. These results coincide with most of the earlier archaeobotanical findings, except neither of them indicated a similar importance of indifferent plant species.

Investigating the species composition of the samples recovered from adobe bricks I concluded that the 303 species comprises a large portion of adventive species (112 species). Out of these 88.38% proved to be archaeophyte taxa while the proportion of neophytes was only 4.29%. Today a significant increase of neophyte taxa can be observed. In paralell the significant decrease of diversity values was detected both in the case of frequent and infrequent species.

The taxa recovered from the adobe brics can be classified into 47 plant families, however, 71.19% of the species belongs to 11 families of which *Asteraceae*, *Poaceae*, *Fabaceae*, *Lamiaceae*, *Polygonaceae*, and *Caryophyllaceae* were the most significant. If we compare these results with the results of the recent field surveys only slight differences can be observed in the order of the most important plant families. Both in Hungary and worldwide the *Asteraceae*, and the *Poaceae* families contain the most weed species. Based on the species and diaspore number the majority of the recovered seeds belonged to the therophyte group, but the hemicryptophyte, the biannual and the geophyte groups were also significant. As the largest part (82.19%) of the recovered plants were weeds, I also examined the distribution of the Ujvárosi life forms. Among the therophytes, late summer annuals (T4) and the fall germinating early summer annuals (T2) had the largest contribution. Among the geophytes stoloniferous rhizomes (G1), among the hemicryptophytes adventitious roots (H3) were the

most frequent types. Compering these results with the field surweys I found that the contribution of the hemicryptophytes and hemitherophytes significantly increased (by 4.18% and 8.38 % consequently), while the contribution of the therophytes decreased by 12.89%. There were only slight differences considering the Ujvárosi life forms, however, it is notable that the proportion of the valuable bulbous geophytes (G4) increased by 1.61%. Regarding the flora elements almost half (46.25%) of the plant species from the adobe bricks belonged to the European group, among which the Eurasian species were the most frequent (33.99%). As I found mainly weed species the high proportion of cosmopolitan (20.16%) and adventive (10.28%) elements is not surprising. The mediterranean group also contributed a large proportion (12%) to the species composition, among which the submediterranean elements were highest (9.88%). The changes of flora elements was also only slight, however, it is important to emphasize the incease of the mediterranean group by 4.31%.

Rare and endangered species were also excavated from the adobe bricks and were also found in the recent field surveys. Besides the protected *Dianthus pontederae* other Pannonian endemic species (*Achillea asplenifolia, Melampyrum barbatum, Thesium dollinerii*) were also present in the dataset of recent plot survey. Among the taxa recovered from the adobe bricks, 85 had some kind of conservational importance in Hungary. Four species are nationally protected (*Agrostemma githago*, *Dianthus deltoides*, *Erysimum odoratum*, *Lathyrus nissolia*), 23 are included in the Hungarian Red List of vascular plants, 38 are valuable from floristic and ecological aspects (e.g. important farm bird food sources) and further 64 species are considered regionally important. Among these valuable plants 61.18% are achaeophytes, and they represent 30% of all the archaeophyte species in Hungary. Today 48 species already disapeared from the studied region and one of them completely extinct (*Linaria arvensis*) from Hungary. In contrast 42 valuable species appeared during our recent field surveys that were not present in the adobe samples. Taking this into consideration only 28.57% of all valuable species is present on the arable fields of the studied region since the mid 19th century. Between 2001 and 2006 the registered number of Red List species were significanty lower (19 species total), and they represent a lower threat status. In contrast the number of protected species increased by today. From the six species only one (*A. githago*) was present in the adobe bricks.

Studying the past and recent weed flora an increasing number of neophytes and agressively spreading weeds can be detected. Among them invasive neophytes were the most important (69.23% and 77.78% of all neophytes). Past problem weeds (e.g. *Amaranthus* fajok, *Echinochloa crus-galli*, *Panicum ruderale*, *Sorghum halapense*) are still problematic. Nevertheless it is importat to mention that besides these weeds the modern day problem

weeds (pl. *Ambrosia artemisiifolia*, *Asclepias syriaca*, *Conyza canadensis*, *Erigeron annuus*, *Galinsoga parviflora*) were not present in the adobe bricks.

SUMMARY OF NEW SCIENTIFIC RESULTS

My research resulted several new findings in the field of archeobotany that are significant nationally and internationally.

Below I shortly summarize my main findings:

1. Demonstrate the application of flotation method in archaeobotanical research.
2. Test of different flotation solutions and elaborate the detailed parameters of sodium chloride (NaCl) method.
3. Deatiled analyses of the recovery of small sized seeds (describe a trend in the recovery of different sized seeds).
4. Determine the minimum and optimum sample volumes for earth buildings and adobe bricks.
5. Evaluation of desiccated and deformed diaspores, the first detailed description of size changes in diaspores.
6. Demonstrate and document the longterm changes of weed vegetation based on archaeobotanical and contemporary field data.
7. The discovery of the seeds of *Linaria arvensis* from an adobe sample of 1898, a weed species that already had extinct.

PUBLICATIONS

I. Publications related to the thesis:

HENN, T., NAGY, U.D. and PÁL, R.W. (2015): Adobe bricks can help identify historic weed flora – a case study from south-western Hungary. *Plant Ecology & Diversity*, DOI: 10.1080/17550874.2015.1060643. **IF: 1,766**

HENN, T. and PÁL, R.W. (2015): Evaluation of desiccated and deformed diaspores from natural building materials. *Ethnobiology Letters*, **6**(1): 10-24.

HENN, T., JACOMET, S., NAGY U.D. and PÁL, R.W. (2015): Desiccated diaspores from building materials: methodological aspects of processing mudbrick for archaeobotanical studies and first results of a study of earth buildings in southwest Hungary. *Vegetation History and Archaeobotany*, **24**(3): 427-440. **IF: 2,648**

HENN, T., CZIGLER, M. and PÁL, R. (2014): Vályogfalak gyomnövényei: a hazai gyomflóra átalakulása és elszegényedése. *Növényvédelem*, **50**(7): 331-338.

II. Conference abstracts and posters related to the thesis:

HENN, T., CZIGLER, M. and PÁL, R. (2012): Délnyugat-magyarországi települések korabeli épületeiből származó vályogtéglák magkészletének elemzése. Aktuális Flóra- és Vegetációkutatás a Kárpát-medencében IX. Gödöllő, 2012. február 24-26.

HENN, T., CZIGLER, M. and PÁL, R. (2012): Régi vályogtéglák magkészletének vizsgálata. Magyar Biológiai Társaság Pécsi Csoportjának 246. szakülése. Pécs, 2012. május 3.

HENN, T., CZIGLER, M. and PÁL, R. (2012): Seed bank analysis of adobe bricks from Southwestern Hungary. János Szentágothai Memorial Conference and Student Competition. Pécs, 2012. október 29-30.

HENN, T. and PÁL, R. (2013): Amiről a vályogfalak mesélnek: veszélyeztetett gyomnövényeink egykor és ma. Magyar Biológiai Társaság Botanikai Szakosztályának 1456. szakülése. Budapest, 2013. április 22.

HENN, T. and PÁL, R. (2013): Vályogtéglák, mint időkapszulák: gyomnövényeink egykor és ma. Magyar Biológiai Társaság Pécsi Csoportjának 256. szakülése. Pécs, 2013. október 10.

III. Other scientific publications:

PÁL, R., **HENN, T.** and NYULASI, J. (2010): Adatok a Dél-Dunántúl gyomflórájának ismeretéhez. *Baranya Megyei Múzeum Dunántúli Dolgozatok Természettudományi Sorozat*, **12**: 97-135.

HENN, T. and PÁL, R. (2010): A szántóföldi gyomnövényzet összetételének változása Baranya megyében az utóbbi négy évtized során. *Magyar Gyomkutatás és Technológia*, **9**(2): 19-30.

HENN, T. and PÁL, R. (2011): A Pécselyi-medence szőlőültetvényeinek gyomnövényzete. *Növényvédelem*, **47**(12): 489-496.

HENN, T. and PÁL, R. (2012): A Pécselyi-medence szőlőültetvényeinek gyomnövényzete II. *Növényvédelem*, **48**(7): 311-318.

IV. Other conference abstracts and posters:

HENN, T. and PÁL, R. (2010): Comparative analysis of arable weed flora of different crops in Southwestern Hungary. 19th European Vegetation Survey Workshop. Pécs, 2010. április 29-május 2.

HENN, T. and PÁL, R. (2011): Változások a Dél-Dunántúli szegetális gyomflóra összetételében és diverzitás-viszonyaiban az utóbbi négy évtized során. 57. Növényvédelmi Tudományos Napok. Budapest, 2011. február 24.

PÁL, R.W., **HENN, T.**, FILEP, R., RAUSCHERT, E.S.J. and NAGY, D.U. (2015): The effectiveness of control methods on giant goldenrod (*Solidago gigantea*) invasion. *In*: Abstracts of 13th Conference on Ecology and Management of Alien Plant Invasions, p. 74. Waikoloa Village, Hawaii, 22-24. September 2015.

Bibliometric data:
Cumulative impact factors (2014) of the publications related to the thesis: **4,414**
Cumulative impact factors (2014) of all publications: **4,414**
Number of citations: **3** (independent within these: 0)