Nature Conservation 40: 1–38 (2020)
doi: 10.3897/natureconservation.40.51633
http://natureconservation.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
Nature Conservation
Launched to accelerate biodiversity conservation

Polypores, *Agrobacterium* and ivy damage on Hungarian ancient trees

Márton Takács[1], Ágnes Szénási[2], Ákos Malatinszky[1]

1 *Szent István University, Department of Nature Conservation and Landscape Management, Gödöllő, Páter K. 1, Hungary* **2** *Szent István University, Institute of Plant Protection, Gödöllő, Páter K. 1, Hungary*

Corresponding author: Ákos Malatinszky (takacsmarton.msc@gmail.com, malatinszky79@gmail.com)

Academic editor: Josef Simmel | Received 1 March 2020 | Accepted 12 May 2020 | Published 18 June 2020

http://zoobank.org/85B71340-24B9-4635-9B5E-4BE1B73D84DF

Citation: Takács M, Szénási Á, Malatinszky Á (2020) Polypores, *Agrobacterium* and ivy damage on Hungarian ancient trees. Nature Conservation 40: 1–38. https://doi.org/10.3897/natureconservation.40.51633

Abstract
Ancient trees are important habitats, confer vital ecological roles and function as cultural legacies. Old trees with large girth are keystone structures in various ecosystems. We aim to present which species amongst the greatest Hungarian trees (and some other phanerophyte plants) are damaged by polypores (the most important agents of wood decay), *Agrobacterium tumefaciens* (usually causing root tumour) or ivy (competing against the native vegetation and causing windthrow damage) and at what extent and frequency; and whether there is a relationship between these types of damage and the origin of the species (native or adventive) or its situation (solitary or surrounded by other trees). We measured 2,000 trees, belonging to 29 native and 43 non-native species. Polypore infection could be detected in 12.2% of the observed 531 settlements, 22.8% are damaged by *Agrobacterium* and 29.6% by ivy, while 51.2% by other types of pests and diseases. Altogether, one third of the observed 2000 ancient or veteran trees suffered from one or more types of damage. A total of 33.5% of the native species (519 specimens out of 1550) and 28.7% of the adventives (129 trees out of 450) are damaged by any (or more than one) of the mentioned infections or ivy. Mostly, damage occurred to those old trees that stand in a park or forest, while the single (solitary) trees were usually healthy. The most infected regions are the western and south-western counties, while the Northern Hungarian Mountain Range is much less affected, despite its great sample size. Low damage was detected in the Great Hungarian Plain, but the number of sample areas and veteran trees was also low here. The damage to old trees remains without any management or healing in Hungary, since the only effective solution would be prevention.

Keywords
environmental history, notable tree, pest, plant protection, veteran tree, non-native

Introduction

Ancient trees have large girth and astonishing ecological value. The age when a tree can be considered ancient is species specific (Hartel and Plieninger 2014). They contain varied microhabitats, such as hollows or hollowing trunks or branches, cavities, wood mould, decaying wood in the crown, flaking bark which support exceptional numbers of specialised species including fungi, lichens, birds, small mammals and endangered species of wood-living insects (Ranius and Jansson 2000; Read 2000; Sverdrup-Thygeson et al. 2010; Bergman et al. 2012). This is why ancient tree-based systems are considered as global hotspots of biodiversity (Buse et al. 2010) and the old trees are keystone structures in natural, agricultural and urban ecosystems (Gibbons et al. 2008). Their great size and age provide ecological niches of value to specialised flora and fauna that cannot be provided by younger, smaller trees (Lindenmayer et al. 2014) and function as cultural-emotional legacies as well, linking the past to the present (Manning et al. 2006; Lonsdale 2013; Eriksson 2018). The preservation of landscapes, where there is still a high density of ancient trees, should be a priority for all European countries (Zapponi et al. 2017).

One of the reasons why we are so concerned about the ancient trees in Hungary is that we believe that they are of great importance when considering nature values and qualities in forests, agricultural landscapes, as well as cultural heritage and landscape features. This is why it is inevitable that we review their general data (girth, perimeter, height etc.), ethnographical and historical relations, health status and endangering factors to plan their active conservation. In Hungary, the first calls for the protection of ancient, giant trees date back to the early 20th century (e.g. Rapaics 1929). The respect towards them has led to the protection of several ancient trees, most of them within settlements (Tardy 1996). Their main data are registered in online databases (Pósfai Gy 2019, Monumental Trees 2019, Hungarian Monumental Trees 2019). The greatest Hungarian database (Pósfai Gy 2019) started as a private website, but as a good example of citizen science, everyone can send new data; however, these will be uploaded only after validation (visited and measured on the spot) by the founder. Overviews on the cult of the oak genus and presentation of some remarkable Hungarian oak trees were provided by Szakonyi (2018), while in the case of lime species and sweet chestnut, see our previous articles (Takács and Malatinszky 2012; Takács et al. 2015). Iváncsics and Filepné (2019) provide explanations to visual tree assessment.

There are thousands of ancient trees in Hungary and they need special care and protection. However, most of them are situated in hidden areas, far from parks and gardens, thus, without any special attention being given to their health state, maintenance or care. Our aim is to present which specimens and species amongst the greatest Hungarian trees (and other phanerophyte plants, such as black elder and hawthorn species) are damaged by well-known pests and diseases, such as polypores, *Agrobacterium* or ivy and to what extent and frequency. As far as we know, there has been no similar research so far. Our study covers every Hungarian region, about 2,000 very old, sizeable trees, some of them being champions with the largest species-specific girth or height in the country.

Polypores are a group of basidiomycetes fungi that form fruiting bodies with pores or tubes on the underside. They inhabit tree trunks or branches consuming the wood and, thus, they are the most important agents of wood decay. Even though saproxylic fungi act as keystone species in forest ecosystems (Moose et al. 2019), sustaining, for example, beetle communities (Andrési and Tuba 2018), several polypore species are serious pathogens of plantation trees and are major causes of timber spoilage. The most common polypore in Hungary is the tinder fungus (*Fomes fomentarius*), a stem decay fungal plant pathogen of beech and other deciduous trees, such as birch, poplar, willow and oak species (Igmándy 1991). Its mycelium penetrates the wood of trees through damaged bark or broken branches, causing white rot in the host. It continues to live on trees long after they have died, changing from a parasite to a decomposer (Baum et al. 2003). In Hungary, other polypores of significance are *Fuscoporia torulosa*, *Inonotus cuticularis*, *Daedaleopsis confragosa*, *D. c.* var. *tricolor*, *Phellinus igniarius*, *Ph. tremulae* and *Ganoderma applanatum* (Vasas and Locsmándi 2010; Gerhardt 2017).

Bacteria and viruses usually do not play a significant role in the diseases of old trees. However, injuries to the infected tissues are variable (Bartosiewicz and Siewniak 1979). *Agrobacterium* is a genus of Gram-negative bacteria that causes tumours in plants. *A. tumefaciens* causes crown-gall disease in plants, which is a tumour-like growth or gall on the infected plant, often at the junction between the root and the shoot. *A. rhizogenes* induces root tumours in apple and its relatives. Old trees are infected by *A. tumefaciens*, usually causing root tumour, but even shoots might be stressed in case of poplars, oaks, limes, sycamores and willows (Glits and Folk 2000). It may attack any tree species in Hungary, but the visible tumours on the shoot system are most remarkable on poplars (Szabó 2003). This pathogen penetrates the wood of trees through damaged bark. The bacterial tumour-inducing (Ti) plasmid penetrates into the genome of the host (Atherly 2004).

Ivies (*Hedera* spp.) create a dense, shade-tolerant evergreen cover that can spread through underground rhizomes and above-ground runners quickly and outcompete the native vegetation. In Europe, the harm caused by common ivy (*Hedera helix*) is generally minor, although trees climbed by ivy (as high as 25 metres) can suffer windthrow damage (Gencsi and Vancsura 1997). Oaks with their crown almost completely wrapped by ivy are quite common. Trees may show clear symptoms of decline, such as shoot withering and progressive crown reduction (Garfi and Ficarrotta 2003). Tree characteristics and spatial patterns of species significantly influence ivy distribution. Preferred hosts are large, isolated trees (Castagneri et al. 2013). Protection against ivy is cost and labour-intensive and usually remains without a real result (English Heritage 2010).

We aimed to select those types of damage that can easily be recognised, in order to use them in citizen science activities in the future for the large trees that now remain unattended. This is why we focused on polypores, *Agrobacterium* and ivy infections.

Methods

Inventory of general data of ancient trees

There is only one thorough online database that lists the greatest trees in Hungary, providing species, settlement, GPS coordinates, girth and year of its measurement (Pósfai Gy 2019). Our original aim was to observe every specimen listed in this database. Their total number was 700 in 2008, when we started our study. Meanwhile, this number now exceeds 3500 for 2020 and is still growing. This is why we present actual data of altogether 2000 trees that were listed in this database during our measurements between 2008 and 2017. For each specimen, we measured girth (at 1.3 m height), smallest trunk diameter (at 1.3 m height), smallest crown diameter and height, using a measuring tape, Waldmeister forestry caliper and Haglöf clinometer. Due to the high number of observed specimens, there were no repetitions.

We described the health status on a 5-points scale (1 = dead, 2 = bad condition, 3 = fair condition, 4 = good condition, 5 = excellent condition), based on the status of the crown, diseases, breaks, hollows and maintenance. For example, if only a decayed trunk has remained without branches and bark, then this value is 1. If there are pests or other organisms that cause damage or there is a hollow instead of the crown, but the tree is still able to grow new shoots (ie. is still vital), then this value is 3. While in case of no pests or other organisms that would cause damage and healthy bark and crown without broken branches, this value is 5. Accessibility was expressed by considering the quality (usability) of roads leading to each specimen, presence or absence of informative signs, distance from settlements or roads etc. (1 = very difficult, 2 = poor, 3 = medium, 4 = good, 5 = excellent). We did not aim to measure the age of the trees (due to technical difficulties, risk of damage etc.).

The rates of polypores, *Agrobacterium* and ivy damage are also described on a 5-point scale (Table 1). The majority of observed specimens are not damaged at all, thus, these trees are not presented here.

Measuring health status

To measure the health status of each tree, we used a Fakopp Arborsonic 3D Acoustic Tomograph that estimates the velocity at which sound is conducted through the tree. Acoustic tomography has been used for *in situ* inspection of trees since 1986 (Arciniegas et al. 2014). The tomograph distributes and receives sound waves across 10 sensors placed evenly around the circumference of a tree. The sensors are connected to a laptop. Each sensor is tapped a minimum of three times, an action which propagates sound across the tree. The Fakopp Arborsonic software records the length of time taken for the sound to be received by each sensor and this depends on the density of the substrate (Thompson et al. 2016). Then the software renders three-dimensional computer models of the internal tree density (Figs 21–23). The position of the sensors is important, but it does not markedly affect the result. It is no use measuring on the ground or

Table 1. Determination of each damage category.

Polypores infection categories	
1 = not infected	No conks on trunk, branches, visible roots
2 = sparsely infected	One active or few dead conks
3 = slightly infected	Less than 5 conks
4 = moderately infected	5 to 10, small conks
5 = acutely infected	More than 10 healthy conks
***Agrobacterium* infection categories**	
1 = not infected	No tumour on trunk, branches, visible roots
2 = sparsely infected	One tumour, with less than 20 cm diameter
3 = slightly infected	One tumour, with 20 to 40 cm diameter
4 = moderately infected	Several small tumours (galls)
5 = acutely infected	Totally spread on the tree
Ivy damage categories	
1 = not damaged	No shoots on trunk, branches, visible roots
2 = sparsely damaged	Few young shoots, up to 2 m height on the tree
3 = slightly damaged	Few young shoots, up to 4 m height on the tree
4 = moderately damaged	Young or thin shoots appear even on branches and totally cover the trunk
5 = acutely damaged	Total cover

at the first branches, because it may be misleading. The device is suitable for measuring trees up to 500 cm girth (the cables are too short). However, most of the tree species are greater when they are old. This is why we basically chose old wild pears, since it is a highly valuable species and its girth does not exceed this size even at higher age.

Studied tree specimens

We studied 2000 tree specimens in 531 Hungarian settlements (Fig. 1). Although there are significantly less observed trees on the eastern and south-eastern parts of the country (i.e. the Great Hungarian Plain), we consider this study to be representative, since the mentioned area belongs to the steppe climate zone, with a significantly lower rate of forested areas. Observed species and the minimum girth (at 1.3 m height) required for the study of each specimen are shown in Table 2. We included whether they are native or not, their number in the only thorough database (Pósfai Gy 2019) and the number of measured trees and the presence of pests and other organisms that cause damage (in case of more than one, they are shown in a separate column).

Results

Almost all (98%) of those old trees that are infected only by polypores (i.e. without other damage) are surrounded by other trees in a park or a forest (Table 2). This high ratio is understandable when we consider the fact that most of the affected trees are beech, since we found only a couple of solitary trees of this species. A total of 70 out of 400 measured beech trees (i.e. 17.5%) were infected by polypores (including the

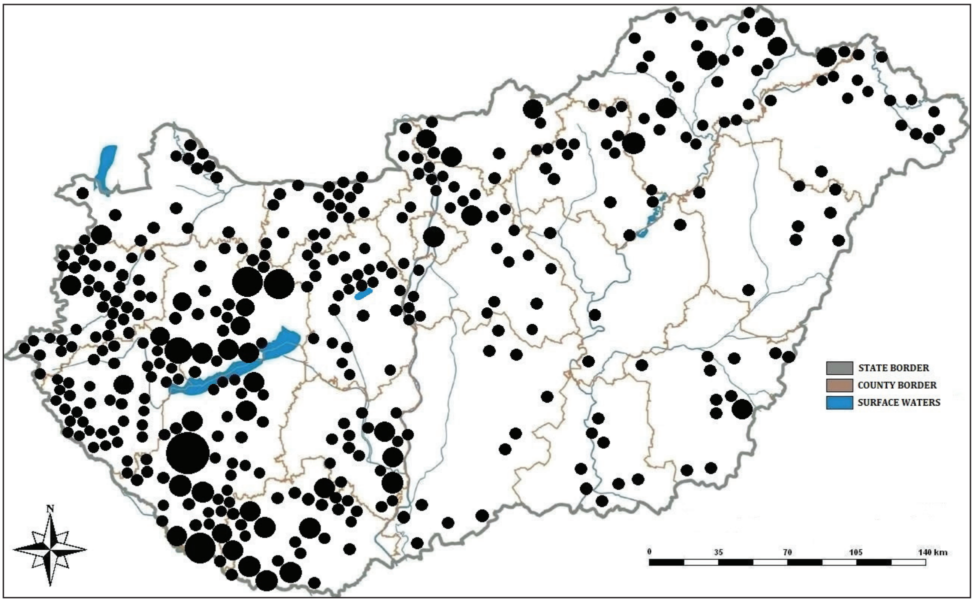

Figure 1. The situation of the observed settlements on the map of Hungary. A small dot indicates one settlement, a medium dot two or three settlements, while large dots refer to at least five settlements situated close to each other.

Table 2. List of the observed species and their main data. N = native, A = adventive [those taxa whose native nature is still under dispute in Hungary (*Abies alba*, *Castanea sativa*, *Juglans regia*, *Quercus frainetto*) and those that are native only in a limited percentage of the country, but occur in a much greater area (*Pinus sylvestris*, *Sorbus domestica*, *Taxus baccata* and *Tilia tomentosa*) are also here (based on Bartha 2000)]; *Agrob.* = *Agrobacterium* infection, S = single tree, F = surrounded by other trees in a park or forest, Comb. = combined infection/damage.

Species	N/A	Min. girth (cm)	Number in the database of Pósfai	Number of measured trees S/F		Polypore		*Agrobact.*		Ivy		Comb.		Measured/ damaged (%)
				S	F	S	F	S	F	S	F	S	F	
Abies alba	A	300	6	1	4		1				3			80
Abies cephalonica	A	300	1		1						1			100
Abies numidica	A	300	3		1						1			100
Acer campestre	N	300	68	7	34				1	1	16	1		46.3
Acer negundo	A	300	19	2	7				1	1	2			44.4
Acer platanoides	N	300	37	2	18						7		1	40
Acer pseudoplatanus	N	300	35	2	15							2	3	29.4
Acer saccharinum	A	300	43	5	22		2		1	1	1			18.5
Aesculus flava	A	400	1		1									0
Aesculus hippocastanum	A	400	23	1	13						2		1	21.4
Ailanthus altissima	A	300	11	4	4						1			12.5
Alnus glutinosa	N	300	71		17				2		4		1	41.2
Betula pendula	N	200	25		7				2					28.6
Calocedrus decurrens	A	300	9		7						2			28.6
Carpinus betulus	N	300	171	2	74		6		2		9		3	26.3
Castanea sativa	A	500	96	17	36				3	4	3			18.9
Catalpa bignonioides	A	200	7	1	3						2			50
Cedrus deodora	A	500	1		1									0

Species	**N/A**	**Min. girth (cm)**	**Number in the database of Pósfai**	**Number of measured trees S/F**		**Polypore**		***Agrobact.***		**Ivy**		**Comb.**		**Measured/ damaged (%)**
						S	**F**	**S**	**F**	**S**	**F**	**S**	**F**	
Cedrus libani	A	400	1		1									0
Celtis occidentalis	A	300	55	7	24		1				7			25.8
Corylus colurna	A	300	9	4	4				1					12.5
Crataegus monogyna	N	100	9	1	1									0
Fagus sylvatica	N	400	529	3	397		66		8		26		4	26
Fraxinus angustifolia ssp. *pannonica*	N	400	42	1	12						4		1	38.5
Fraxinus excelsior	N	400	62	6	31		1	1			7		1	27
Ginkgo biloba	A	400	10	2	8				1	1	5			70
Gleditsia triacanthos	A	300	6		2									0
Gymnoclaudus dioicus	A	300	7		1						1			100
Hedera helix	N	50	3	2	1									0
Juglans nigra	A	300	11	1	6				1					14.3
Juglans regia	A	300	4	1										0
Larix decidua	A	300	8		5						1			20
Liriodendron tulipifera	A	400	11	1	6						2			28.6
Maclura pomifera	A	300	2		2				1		1			100
Magnolia acuminata	A	200	4		3						3			100
Morus alba	A	400	20	9	3					1				8.3
Paulownia tomentosa	A	300	16	1	3					1	1			50
Picea abies	A	300	46	2	20					1	1			9.1
Pinus nigra	A	300	17	3	12						6			40
Pinus sylvestris	A	300	20	1	5						2			33.3
Pinus strobus	A	300	6		1									0
Platanus × acerifolia	A	600	69	11	47			3	4		10	1	1	32.8
Populus alba	N	600	42	4	11				3		2			33.3
Populus × canescens	N	600	33	3	9						5			41.7
Populus nigra	N	600	395	25	174	1	1	8	91	4	5		13	61.8
Prunus avium	N	300	32	4	10				2	2	1			35.7
Pseudotsuga menziesii	A	300	60	1	4		1							20
Pterocaria stenoptera	A	600	2		1									0
Pyrus pyraster	N	300	34	6	16						2			9.1
Quercus cerris	N	500	56	6	23		1		4		1		1	24.1
Quercus frainetto	A	400	2		1						1			100
Quercus petraea	N	500	26	2	9		1				4			45.5
Quercus pubescens	N	400	4	3	1									0
Quercus robur	N	500	573	95	284	1	12	3	22	12	67	2	13	34.8
Quercus rubra	A	400	9		3		1				1			66.7
Robinia pseudoacacia	A	300	58	5	14									0
Salix alba	N	600	179	8	70		2	1	6		2			14.1
Salix caprea	N	200	2		1									0
Sambucus nigra	N	100	5	1	1									0
Sequoiadendron giganteum	A	500	21	2	12				1		3		1	35.7
Sophora japonica	A	400	28	7	14					2	10			57.1
Sorbus domestica	A	200	14	4	1					1				20
Sorbus torminalis	N	200	13		7						1		1	28.6
Taxodium distichum	A	300	41	1	23						9			37.5
Taxus baccata	A	200	36	4	9						2			15.4
Thuja plicata	A	300	7		3									0
Tilia cordata	N	400	73	19	40		1		5	1	9			27.1
Tilia platyphyllos	N	400	78	10	45		1		6		7	2		29.1
Tilia tomentosa	A	400	18	8	6		1				4			35.7
Ulmus glabra	N	400	4		2						1			50
Ulmus laevis	N	400	41	1	25				2		6			30.8
Ulmus minor	N	400	7	1	1						1			50
Total	–	–	**3487**	**320**	**1680**	**2**	**99**	**16**	**170**	**33**	**275**	**8**	**45**	**32.4**

combined infections as well). Only seven specimens of non-native trees were infected by polypores, two of them being silver maple (*Acer saccharinum*).

A total of 170 (91.4%) of those old trees that are infected only by *Agrobacterium* stand in a (relatively) closed forest or park (Table 2). Only 16 solitary trees were damaged by this infection, half of them being black poplar (*Populus nigra*). Including the combined infections as well, *Agrobacterium* was documented on 115 out of 226 measured black poplars (i.e. 51%). Seventeen non-native trees were infected by *Agrobacterium*, most of them (seven) being sycamores.

We found ivy on 33 solitary trees, meaning 10.7%, compared to 275 specimens within stands. Mostly oaks were damaged (101, meaning 28.5%) and ivy appeared on 23.6% of the measured oaks. The highest rate, however, was seen in case of the maple genus, being 31 out of 114 measured maple trees (27.2%) (combined case included for both genera). A total of 101 non-native trees were affected, mostly (in 12 cases) the Japanese pagoda tree (*Sophora japonica*).

Two or three types of damage were documented on 53 old trees. They belong to the worst health category, most of them having almost died. A total of 84.9% (i.e. 45 trees) stand in a group or forest, while only 8 solitary trees are affected by combined infections (Table 2).

In the following text, we present one example per damage category from our database.

Polypores infection

Not infected

- species: common oak (*Quercus robur*)
- locality: Battonya-Tompapuszta (Békés County, SE Hungary)
- habitat: grassland, abandoned farmyard
- girth: 574 cm
- trunk diameter: 1.5 m
- crown diameter: 30 m
- height: 18 m

Branches properly cut in the past; however, irregular fractures are seen lately. The area has been abandoned and unattended for several years. No visible rot, fungi, moss, *Agrobacterium* or ivy (Fig. 2).

Sparsely infected

- species: beech (*Fagus sylvatica*)
- locality: Gadány (Somogy County, SW Hungary)
- habitat: woody area, along a stream
- girth: 552 cm

Figure 2. Not infected *Quercus robur*.

- trunk diameter: 2.5 m
- crown diameter: 50 m
- height: 30 m

Not managed woody area. Sparse polypore infection: one conk of tinder fungus (*Fomes fomentarius*). The conk is healthy, fresh. The tree is in a fair health state besides the polypore, its foliage is lush and healthy and the branches are not dry (Fig. 3).

Slightly infected

- species: Norway maple (*Acer platanoides*)
- locality: Hencse (Somogy County, SW Hungary)
- habitat: previously Palace Park, currently Golf Club
- girth: 497 cm
- trunk diameter: 1.5 m
- crown diameter: 30 m
- height: 17 m

Its locality can be visited with permission. Old yews (*Taxus baccata*) surrounding. Ivy on its trunk, wasps in the hollow of the former branch. More than two fresh, healthy polypore conks on the lower part of the trunk. Although the park is well managed, no attention is paid to this infection (Fig. 4).

Moderately infected

- species: silver fir (*Abies alba*)
- locality: Fehérvárcsurgó (Fejér County, Central Hungary)
- habitat: Palace Park
- girth: 429 cm
- trunk diameter: 1.5 m
- crown diameter: 20 m
- height: 22 m

Several huge veteran trees in the Palace Park. This specimen is probably the oldest silver fir in Hungary (next to the pebble road leading through the park). Slight ivy infection. More than five tiny polypore conks, some of them several years old with dry conk (Fig. 5).

Acutely infected

- species: beech (*Fagus sylvatica*)
- locality: Becsehely (Zala County, W Hungary)

Figure 3. Sparsely infected *Fagus sylvatica*.

- habitat: young beech forest, with some old beech trees
- girth: 487 cm
- trunk diameter: 1.5 m
- crown diameter: 30 m
- height: 27 m

Figure 4. Slightly infected *Acer platanoides*

Figure 5. Moderately infected *Abies alba*.

Extended beech forests in the territory, with several old beech and hornbeam specimens on a plot of relatively-young trees. More than ten polypore conks on the trunk, moreover, the infection has appeared even on the branches. The area is not managed, with significant blackberry (*Rubus fruticosus*) coverage (Fig. 6).

Figure 6. Acutely infected *Fagus sylvatica*.

Polypore infection could be detected in 65 out of the observed 531 settlements, 123 per 2000 trees. This means 12.24% of the studied areas and 6.15% of the measured trees (Fig. 7). Polypores seem to be missing from veteran trees of the Great Hungarian Plain, but we have to add that the main host of the most frequent polypore, i.e. beech (*Fagus sylvatica*), is also missing from the area (although other polypores could occur). Veszprém, Zala, Baranya and Somogy Counties (i.e. South-Western and Central-Western) are moderately infected.

Agrobacterium infection

Not infected

- species: sweet chestnut (*Castanea sativa*)
- locality: Bak (Zala County, W Hungary)
- habitat: between wine cellars, private area
- girth: 606 cm
- trunk diameter: 2 m
- crown diameter: 20 m
- height: 20 m

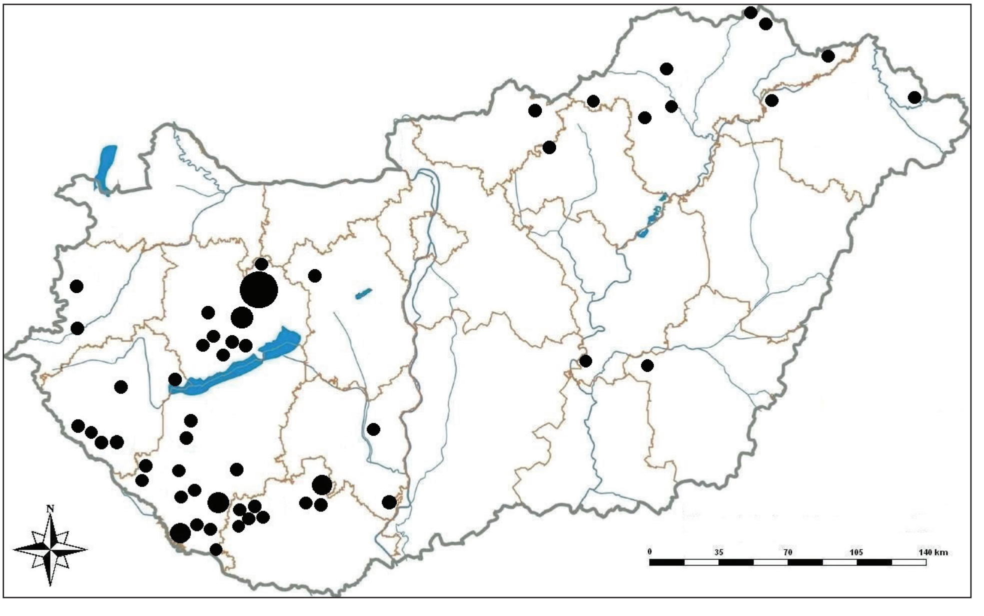

Figure 7. Settlements that host large trees infected by polypores (Hungary). A small dot indicates one settlement, a medium dot two or three settlements, while large dots refer to at least five settlements situated close to each other.

Walnut and chestnut trees were commonly planted around wine yards and cellars during the past centuries. According to its information board, this tree is 400 years old, under nature protection. No *Agrobacterium* and slight ivy infection. Branches cut back, without any rot (Fig. 8).

Figure 8. Not infected *Castanea sativa*.

Sparsely infected

- species: common oak (*Quercus robur*)
- locality: Káld (Vas County, W Hungary)
- habitat: young Scots Pine forest, clearing
- girth: 539 cm
- trunk diameter: 2 m
- crown diameter: 40 m
- height: 22 m

Enormous oak tree in a young Scots Pine stand. A tumour-like gall with 25 cm diameter makes its unique feature, with no other tumours. High coverage of mosses and ants on the tree, dense blackberry around (Fig. 9).

Slightly infected

- species: London plane (*Platanus* × *acerifolia*)
- locality: Pölöske (Zala County, W Hungary)
- habitat: backyard of a family house
- girth: 758 cm
- trunk diameter: 3 m
- crown diameter: 40 m
- height: 28 m

Private area at the end of Dózsa György Street in Pölöske village, officially nature protected, can be visited with permission. Two huge London planes, one is slightly infected with ivy and a tumour-like gall with 40 cm diameter at the junction between the root and the shoot (Fig. 10).

Moderately infected

- species: common oak (*Quercus robur*)
- locality: Nagyrécse (Zala County, W Hungary)
- habitat: young oak forest
- girth: 500 cm
- trunk diameter: 1.5 m
- crown diameter: 35 m
- height: 23 m

Figure 9. Sparsely infected *Quercus robur*.

Figure 10. Slightly infected *Platanus* × *acerifolia*.

Numerous old oaks in a young stand. No tumours on the trunk, but more than ten galls in the crown, none of them exceeding 10 cm in diameter. Several galls had fallen on the ground (Fig. 11).

Figure 11. Moderately infected *Quercus robur*.

Acutely infected

- species: black poplar (*Populus nigra*)
- locality: Tiszacsege (Hajdú-Bihar County, E Hungary)
- habitat: ferry station, holiday houses

- girth: 826 cm
- trunk diameter: 3 m
- crown diameter: 10 m
- height: 11 m

Huge, but highly infected poplar. Its original bark is missing, the whole trunk is covered by tumours, branches are cut back every year due to the galls since its crown is not safe from the infection. Its notable trunk diameter is a consequence of its disease (Fig. 12).

Agrobacterium infection could be detected in 121 places out of the observed 531 settlements, this means 22.79%. Amongst the studied veteran trees, 217 are infected by Agrobacterium, meaning 10.85% (Fig. 13). Considering the age and vulnerability of the trees and the fact that this disease cannot be managed easily, this rate is high. The most infected territories are Zala and Vas Counties (i.e. Western Hungary) and the South-Western region (Somogy and Baranya Counties). A notable result is that Borsod-Abaúj-Zemplén (Northern-Hungary) is almost free from this kind of infection, despite the high number of studied trees.

Ivy damage

Not damaged

- species: black locust (*Robinia pseudoacacia*)
- locality: Bábolna (Komárom-Esztergom County, NW Hungary)
- habitat: Bábolna National Stud area
- girth: 649 cm
- trunk diameter: 2.5 m
- crown diameter: 25 m
- height: 19 m

Hungary's oldest black locust specimen, planted in 1710. Unfavourable health state, but not damaged by ivy or other damage. Branches fixed to the trunk with a belt, trunk filled artificially (Fig. 14).

Sparsely damaged

- species: Hungarian oak (*Quercus frainetto*)
- locality: Deszk (Csongrád County, SE Hungary)
- habitat: hospital park
- girth: 561 cm
- trunk diameter: 1.5 m
- crown diameter: 30 m
- height: 18 m

Figure 12. Acutely infected *Populus nigra*.

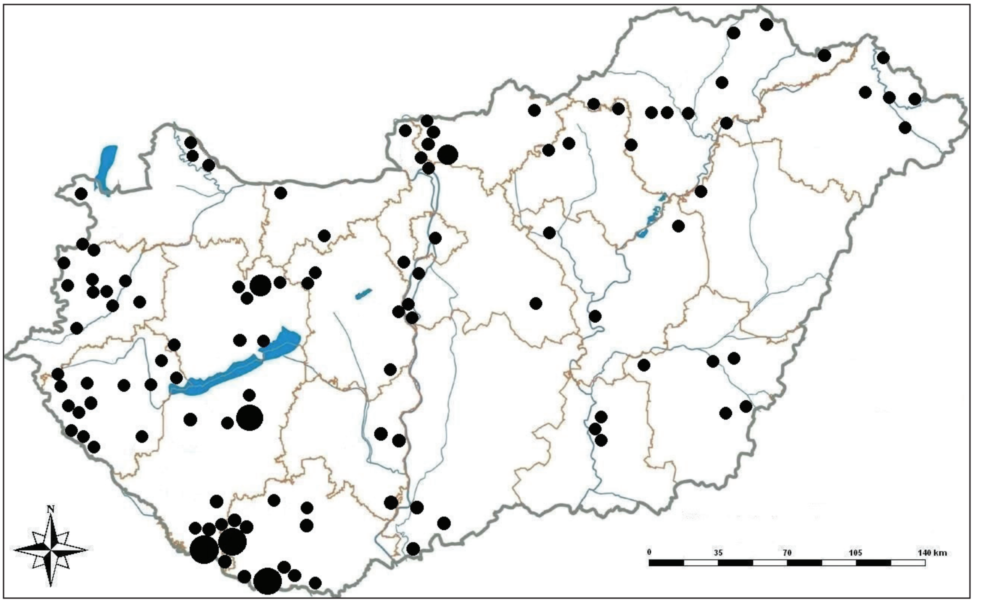

Figure 13. Settlements that host large trees infected by *Agrobacterium* (Hungary). A small dot indicates one settlement, while larger dots refer to more settlements situated close to each other.

Thin ivy sprouts (runners), up to 1.5 m height, with tiny leaves. They are currently not causing any serious injury, but now is the time for protection, as later interventions may not be effective (Fig. 15).

Slightly damaged

- species: large-leaved linden (*Tilia platyphyllos*)
- locality: Pápa (Veszprém County, W Hungary)
- habitat: Castle Park
- girth: 420 cm
- trunk diameter: 1.5 m
- crown diameter: 30 m
- height: 23 m

The central part of the Castle Park is characterised by an old linden tree. Its trunk is densely covered by ivy up to 3 m height. Ivy leaves are still small and fresh and do not overgrow the foliage; thus, its elimination is still possible (Fig. 16).

Figure 14. Not damaged *Robinia pseudoacacia*.

Moderately damaged

- species: common oak (*Quercus robur*)
- locality: Zsennye (Vas County, W Hungary)
- habitat: Palace Park

Figure 15. Sparsely damaged *Quercus frainetto*.

Figure 16. Slightly damaged *Tilia platyphyllos*.

- girth: 535 cm
- trunk diameter: 2 m
- crown diameter: 30 m
- height: 25 m

Numerous notable oaks rule the (not properly managed) park of the Bezerédj Palace in Zsennye, all of them damaged by ivy, even in their foliage. Leaves are great and sprouts form constant foliage, although not reaching the tips. Protection would be very complicated at this stage (Fig. 17).

Acutely damaged

- species: common oak (*Quercus robur*)
- locality: Szőcsénypuszta (Somogy County, SW Hungary)
- habitat: lumberyard
- girth: 573 cm
- trunk diameter: 2 m
- crown diameter: 30 m
- height: 18 m

Hard to see and measure due to enormous ivy mass and the tree has grown on to the fence. The trunk is totally hidden by ivy sprouts and leaves, which reach the tips. Protection is impossible at this stage (Fig. 18).

A total of 157 of the observed 531 settlements and 353 of the measured 2000 trees showed ivy damage, meaning 29.57% and 17.65%, respectively (Fig. 19). The highest rate was detected in Somogy, Zala, Baranya, Veszprém and Vas Counties (i.e. Western and South-Western Hungary). The Northern Hungarian Mountain Range is almost free from ivy damage, despite the high number of samples. North-Western, Eastern and Southern Hungary are also almost free of ivy.

Other damage

Besides those mentioned above, we also noticed some other types of damage. Most of them are general, such as mistletoe species (*Loranthus* sp., *Viscum* sp.), mosses and lichens. Some other, less well-known pests and diseases that we detected on ancient trees are old man's beard (*Clematis vitalba*), wild grapes (e.g. *Parthenocissus inserta*), hedge bindweed (*Calystegia sepium*), dewberries (*Rubus* spp.), epiphyte lichens and mosses, honey fungus (*Armillaria mellea*), pear-shaped puffball (*Lycoperdon pyriforme*), gall wasps (*Cynipidae*), mite that forms the lime nail gall (*Eriophyes tiliae*), chestnut gall wasp (*Dryocosmus kuriphilus*), beech gall midge (*Mikiola fagi*), firebug (*Pyrrhocoris apterus*), horse-chestnut leaf miner (*Cameraria ohridella*), ants (*Formicidae*), European hornet (*Vespa crabro*), woodpeckers (*Picinae*) and several species of games (*Cervus elaphus*, *Sus scrofa*).

Figure 17. Moderately damaged *Quercus robur*.

Figure 18. Acutely damaged *Quercus robur*.

A total of 51.22% of the observed 272 settlements host ancient trees that are damaged by one or some of the above listed damage-causing organisms. A total of 31.70% of the measured trees (i.e. 634 trees) are damaged by one or combined organisms (Fig. 20). Veteran trees in the Great Hungarian Plain are almost free of damage,

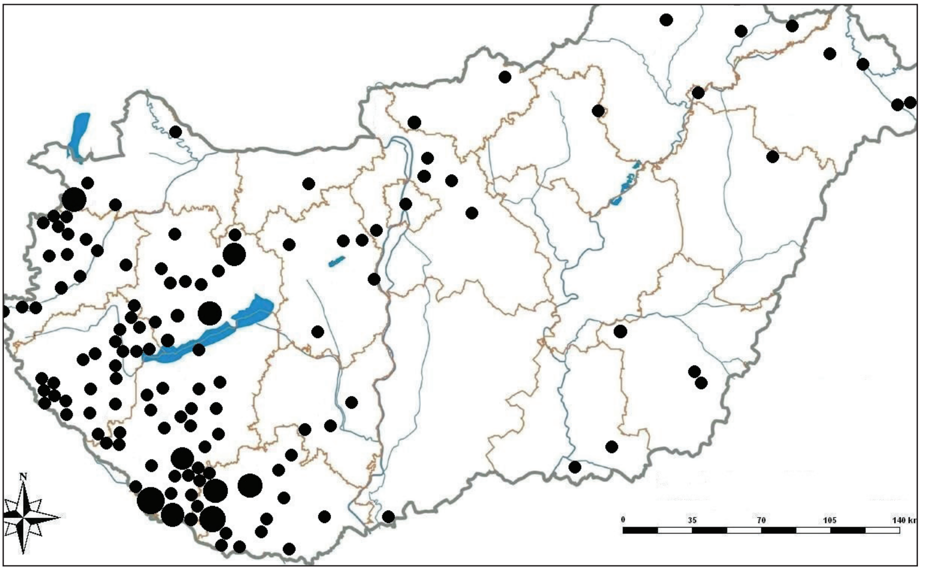

Figure 19. Settlements that host large trees damaged by ivy (Hungary). A small dot indicates one settlement, while larger dots refer to more settlements situated close to each other.

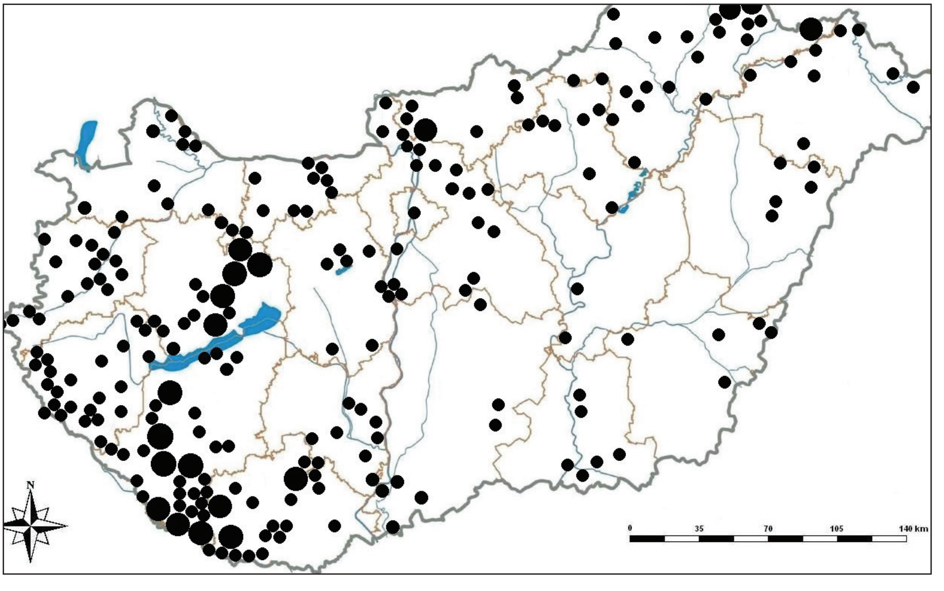

Figure 20. Settlements that host large trees suffered by other types of damage (Hungary). A small dot indicates one settlement, while larger dots refer to more settlements situated close to each other.

probably due to the low sample size. The most damaged regions are Somogy, Baranya and Veszprém Counties (i.e. Western, South-Western Hungary), each with a large sample size.

Health status

We measured the health status of 7 trees with a Fakopp Arborsonic 3D Acoustic Tomograph in 2012, at different layers and heights (Table 3). Different shapes (roller trunk or fork shape) and measurability (sprout, shrub) justified different measurement methods.

We present one example per decay status category from our database.

Slight decay status

- species: black walnut (*Juglans nigra*)
- locality: Martonvásár (Fejer County, C Hungary)
- habitat: little island in the middle of the castle park
- girth: 444 cm
- trunk diameter: 1.5 m
- crown diameter: 25 m
- height: 25 m

Sensors were placed at 30 and 130 cm height (i.e. two layers). Measured decay: 17 and 2%, respectively. The average decay level of this black walnut is 9.5%, i.e. very low (Fig. 21).

Medium decay status

- species: wild pear (*Pyrus pyraster*)
- locality: Gödöllő (Pest County, C Hungary)
- habitat: Botanical Garden
- girth: 317 cm
- trunk diameter: 1 m
- crown diameter: 15 m
- height: 12 m

Sensors were placed at 5 heights: 30, 70, 110, 150 and 190 cm. Measured decay at the different layers: 57, 41, 25, 26 and 42%. The average decay level of this wild pear is 38.2%, i.e. medium level (Fig. 22).

*Strong decay s***tatus**

- species: Turkish hazel (Corylus colurna)
- locality: Gyöngyös (Heves County, N Hungary)
- habitat: Castle Park

Table 3. Decay status of trees measured with a tomograph.

Locality	Species	Girth (CM)	Number of layers	Decay status per layers	Status/ Average (%)
Csokonyavisonta	(%)	400	2	1: 2; 2: 30	16 (slight)
Csokonyavisonta	*Pyrus pyraster*	322	2	1: 41; 2: 39	40 (medium)
Gödöllő	*Pyrus pyraster*	317	5	1: 57; 2: 41; 3: 25; 4: 26; 5: 42	38.2 (medium)
Gyöngyös	*Corylus colurna*	426	2	1: 69; 2: 70	69.5 (strong)
Kaposvár-Kaposfüred	*Pyrus pyraster*	321	2	1: 54; 2: 53	53.5 (strong)
Martonvásár	*Juglans nigra*	444	2	1:17; 2: 2	9.5 (slight)
Túristvándi	*Pyrus pyraster*	329	2	1: 72; 2: 76	74 (strong)

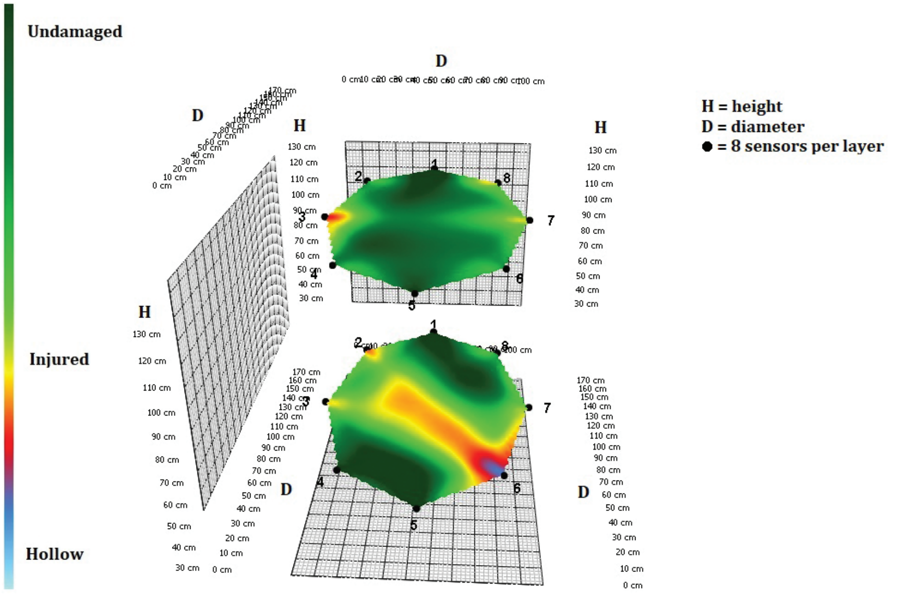

Figure 21. Three-dimensional computer model of internal tree density of the black walnut in Martonvásár, Hungary (at two different heights).

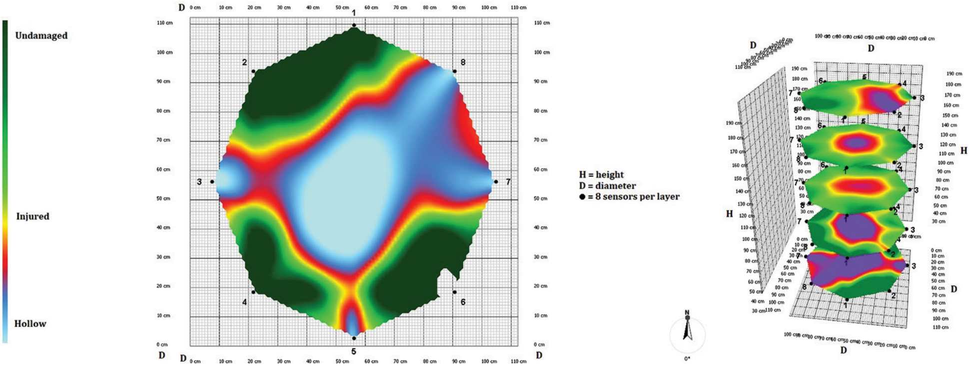

Figure 22. Three-dimensional computer model of internal tree density of the old wild pear in Gödöllő, Hungary (left: layer at 30 cm height; right: 3D-image at 5 different heights).

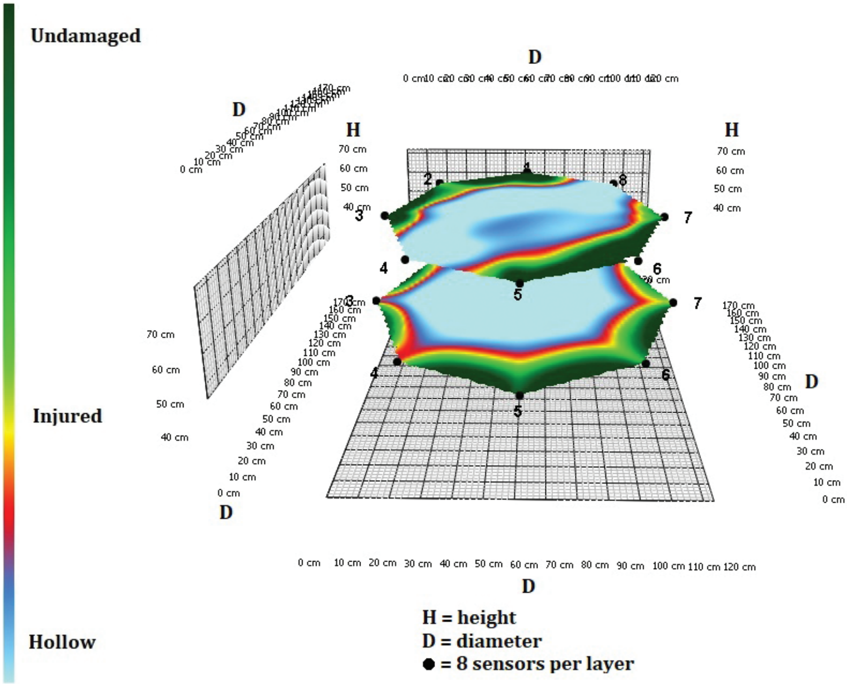

Figure 23. Three-dimensional computer model of internal tree density of the Turkish hazel in Gyöngyös, Hungary (at two different heights).

- girth: 426 cm
- trunk diameter: 1.5 m
- crown diameter: 20 m
- height: 13 m

Sensors were placed at 35 and 70 cm height (i.e. two layers). Measured decay: 69 and 70%, respectively. The average decay level of this Turkish hazel is 69.5%, i.e. considerably high (Fig. 23).

Conclusions

The number of veteran trees in the online database of Pósfai (Pósfai Gy 2019) is constantly growing (from 700 in 2008 onto 3,500 in 2020) and this reflects the popularity of the large trees, emerging citizen science activities and is a consequence of our digital word as well. From this perspective, we should mention the European Tree of the Year competition as well. This programme started in 2002 and Hungarian trees have been involved since 2010. The emotional value, i.e., the role of the tree in the everyday life of the local community plays an essential role in this competition. Most of the Hungarian winners are sizable trees and thus, we have measured them as well.

Based on our results, we state that one third of the observed ancient trees (648 out of 2,000) suffer from polypores, *Agrobacterium* or ivy.

Polypores were detected on altogether 16 species. The well-known *Agrobacterium* that usually infects poplars was found on 23 different species. Ivy was documented from 56 tree species.

Amongst the observed 72 tree species, beech was the most infected by polypores. Seventy out of 400 (17.5%) measured beech trees were damaged by polypores and 56.7% of all documented damage affected the beech species. Our map suggests that the damage caused by polypores is not more remarkable than other pests and diseases. However, when we add the other fungal species (honey fungus, pear-shaped puffball etc.), then this taxonomic group (i.e. fungi tribes) significantly affect the state of the Hungarian ancient trees. Protection against polypores is not successful in Hungary (as in other countries). Literature sources on the description of polypores in Hungary (Gerhardt 2017, Szabó 2003, Vasas and Locsmándi 2010) mention almost every tree genus that we found to be infected by polypores, except for the *Celtis*, the *Pseudotsuga* and the *Sequoiadendron* genera, on which we found these infections as well. However, as these sources usually write generally about exotic trees in parks and gardens, the infections found on the mentioned three genera cannot be evaluated as new scientific results.

Altogether, 217 trees were infected by *Agrobacterium* species. Not surprisingly, mostly poplars suffered from these bacteria, 51% of the observed specimens (115 out of 226); while 53% of all the documented injuries belong to this pest. Hungarian literature (Szabó 2003) mentions basically the poplars in case of old trees, but still we found the bacteria on altogether 23 species. There are no efforts in order to protect the ancient trees against *Agrobacterium*, only in case of young trees in tree nurseries (Dreistadt 2001). Its only benefit (besides its use in gene techniques) is for the timber industry, that the cutting of a processed tumour-like growth or gall from a poplar is beautiful in an ornamental sense (Thomas and Schumann 1993).

Ivy was found on 353 trees, 101 of them are oaks (28.5%). Thirty one of the 114 observed maples were damaged by ivy (27.2%). From a nature conservation aspect, it is harder to evaluate ivy as absolutely negative (such as in case of polypores or *Agrobacterium*). Although it harms the tree with shading, it might host nesting birds and carries aesthetic value as well, especially in parks and palace gardens. Protection against ivy usually means cutting its shoots to dry out, but the dead biomass remains on the tree.

The measured diseases and damage-causing organisms usually attack those trees that are surrounded by other trees, ensuring a good chance for pest reproduction. Almost no solitary trees were damaged amongst the ornamental non-native species, since their old specimens usually appear in parks and arboretums, surrounded by other trees. However, it is obvious, even in case of the oaks, maples and wild pear (i.e. those species that usually stand as solitary), that the presented damage mostly appears in denser stands.

We measured 29 native and 43 non-native tree species. A total of 1550 out of 2000 measured specimens are native. All the three damage types were mostly documented on native trees, but the thorough rate of damaged trees is about the same in case of native and adventive species. A total of 33.5% of the native specimens (519 out of 1550) and 28.7% of the adventives (129 trees out of 450) are damaged by any (or more than one) of the mentioned infections or ivy. However, we have to add that, in case of ivy (and without combined infection), 101 out of 308 trees are non-native. This phenomenon can be explained by the fact that ivy appears mostly in arboretums, castle and mansion parks and town parks, where the highest rate of non-native, ornamental trees are planted. Preventive measures are well-known in the case of polypores and ivy. To protect old trees against polypores, we should avoid scars on the bark. When a forested plot is harvested, a few monumental trees are usually left (e.g. in order to renew the forest with their acorns). These specimens face a lot more pests and altered environmental conditions (e.g. stagnating water in the scars and hollows serves the appearance of pests). Ivy damage can be avoided by eliminating its young sprouts and shoots from the trunk. Unfortunately, ivy is usually realised only in a later stage, when it starts to overgrow the foliage. Tree protection is almost impossible at this stage. In case of *Agrobacterium*, prevention means the use of healthy products from the nursery garden, but this is obviously not relevant for greater trees.

In order to measure the health status, we could use the Fakopp Arborsonic 3D Acoustic Tomograph only for a couple of trees due to its weight (10 kg including laptop) and time-consuming assemblage (e.g. placing its sensors on the tree). Its main defect is that it cannot be used for trees above 450–500 cm girth (cables are too short) and thus, we could not measure the decay status of the observed oaks, willows, poplars and sycamores. Thus, we state that the Fakopp 3D Tomograph is suitable for measuring the health status of the old trees as well, but only in case of those species that do not exceed 500 cm girth, such as wild pear, maples and hornbeam.

It can be stated that the old trees are usually not covered by nature protection areas in Hungary, since most of them stand in isolated, hardly reachable places or in the middle of pastures and meadows, sometimes croplands. Lack of protection is mainly the result of economic factors, as their management, pest protection etc. is not economically viable for the owners, foresters or park gardeners; other reasons may lie in the lack of adequate knowledge or missing responsibilities. There is no case that one tree specimen is protected at national level, although there is an alley that is protected via IUCN IV category (nature conservation area) on its own. However, some local municipalities protect one or more concrete ancient trees in their own municipal decrees, based on the right given to them by the Hungarian Nature Conservation Act, referring to IUCN category III (natural monument). Some examples for local-level protection are the oaks in Kétújfalu, the Turkish hazel in Pécs, the giant lime tree in Szőkedencs, the '1000-year-old oak' in Zsennye or the sweet chestnuts in Surd (Nature conservation areas under local protection in Hungary 2018). Some trees that we measured stand in castle (or mansion) parks that are protected at national (e.g. Alcsútdoboz and Gödöllő) or local level (e.g. Lengyel and Sellye). That type of protection does not mean pest control, but it can help draw attention to preserving the condition of those trees.

We recommend preserving the state of the current trees, even if it is hard to improve. One should improve their protection against the main pests with preventative measures and, if possible, during the first and second damage level. In case of more severe damage, there is practically no solution. In case of *Agrobacterium* infecting the tree, we are already late even when realising the first infection level.

Protection against the presented pests and diseases is very complicated and, in practice, almost impossible. The Hungarian practice shows that these types of damage remain without any management or healing due to lack of time, financial background or energy, but mostly because the only effective solution would be prevention.

While the age of trees is generally not a precondition to being emotionally important for the local community, many of the trees documented are in fact amongst the country's oldest. We, therefore, concluded that old-growth assets have a considerable intrinsic worth that can and should be valued.

Only a very small proportion of the greatest Hungarian trees are covered by local nature protection and even some of the protected ones are close to death. The main causes of this negative phenomenon are the lack of caring or management, the presented pests and diseases or environmental factors, such as storm, wind or frost damage.

Acknowledgements

We are grateful for all the verbal information provided by György Pósfai, founder of the database on the greatest trees of Hungary and the numerous majors, nature conservation guards, as well as the local people for their stories, attached to each ancient tree. The device for acoustic tomography was provided by the Fakopp Bt.

References

Andrési R, Tuba K (2018) Comparative study of the *Fomes fomentarius* and *Trametes gibbosa* beetle communities in Hidegvíz Valley, Sopron Mts., Hungary. Community Ecology 19(2): 141–147. https://doi.org/10.1556/168.2018.19.2.6

Arciniegas A, Prieto F, Brancheriau L, Lasaygues P (2014) Literature review of acoustic and ultrasonic tomography in standing trees. Trees (Berlin) 28(6): 1559–1567. https://doi.org/10.1007/s00468-014-1062-6

Atherly AG (2004) *Agrobacterium*, *Rhizobium*, and other gram-negative soil bacteria. Transformation of Plants and Soil Microorganisms 3: 23–33. https://doi.org/10.1017/CBO9780511752261.005

Bartha D (2000) Black List. Adventive Trees and Shrubs in Hungary. Published by the author. Sopron, 31 pp.

Bartosiewicz A, Siewniak M (1979) Öreg Fák, Díszfák Ápolása. Mezőgazdasági Kiadó, Budapest, 182 pp.

Baum S, Sieber T, Schwarze F, Fink S (2003) Latent infections of *Fomes fomentarius* in the xylem of European beech (*Fagus sylvatica*). Mycological Progress 2(2): 141–148. https://doi.org/10.1007/s11557-006-0052-5

Bergman KO, Jansson N, Claesson K, Palmer MW, Milberg P (2012) How much and at what scale? Multiscale analyses as decision support for conservation of saproxylic oak beetles. Forest Ecology and Management 265: 133–141. https://doi.org/10.1016/j.foreco.2011.10.030

Buse J, Levanony T, Timm A, Dayan T, Assmann T (2010) Saproxylic beetle assemblages in the Mediterranean region: Impact of forest management on richness and structure. Forest Ecology and Management 259(8): 1376–1384. https://doi.org/10.1016/j.foreco.2010.01.004

Castagneri D, Garbarino M, Nola P (2013) Host preference and growth patterns of ivy (Hedera helix L.) in a temperate alluvial forest. Plant Ecology 214(1): 1–9. https://doi.org/10.1007/s11258-012-0130-5

Dreistadt SH (2001) Integrated Pest Management for Floriculture and Nurseries. University of California, 102–104.

English Heritage (2010) Ivy on Walls. Seminar Reports, 62 pp.

Eriksson O (2018) What is biological cultural heritage and why should we care about it? An example from Swedish rural landscapes and forests. Nature Conservation 28: 1–32. https://doi.org/10.3897/natureconservation.28.25067

Garfi G, Ficarrotta S (2003) Influence of ivy (Hedera helix L.) on the growth of downy oak (Quercus pubescens sl) in the Monte Carcaci nature reserve (central-western Sicily). Ecologia Mediterranea: Revue internationale d'écologie méditerranéenne. International Journal of Mediterranean Ecology 29(1): 5–14. https://doi.org/10.3406/ecmed.2003.1524

Gencsi L, Vancsura R (1997) Dendrológia. Mezőgazda Kiadó, Budapest, 223–226.

Gerhardt E (2017) Gombászok Kézikönyve. Cser Kiadó, Budapest, 720 pp.

Gibbons P, Lindenmayer DB, Fischer J, Manning AD, Weinberg A, Seddon J, Ryan P, Barrett G (2008) The future of scattered trees in agricultural landscapes. Conservation Biology 22(5): 1309–1319. https://doi.org/10.1111/j.1523-1739.2008.00997.x

Glits M, Folk Gy (2000) Kertészeti Növénykórtan. 3., Átdolgozott és Bővített Kiadás. Mezőgazda Kiadó, Budapest, 582 pp.

Hartel T, Plieninger T (2014) European wood pastures in transition. A social-ecological approach. Routledge, New York, 322 pp. https://doi.org/10.4324/9780203797082

Hungarian Monumental Trees (2019) http://oregfak.emk.nyme.hu [Accessed on 11.10.2019]

Igmándy Z (1991) A Magyar Erdők Taplógombái. Akadémiai Kiadó, Budapest, 112 pp.

Iváncsics V, Filepné KK (2019) Assessment methodology of green infrastructure – the case of Keszthely town. Hungarian Journal of Landscape Ecology 17(2): 193–208.

Lindenmayer DB, Laurance WF, Franklin JF, Likens GE, Banks SC, Blanchard W, Gibbons P, Ikin K, Blair D, McBurney L, Manning AD, Stein JAR (2014) New policies for old trees: Averting a global crisis in a keystone ecological structure. Conservation Letters 7(1): 61–69. https://doi.org/10.1111/conl.12013

Lonsdale D (2013) The recognition of functional units as an aid to tree management, with particular reference to veteran trees. Arboricultural Journal 35(4): 188–201. https://doi.org/10.1080/03071375.2013.883214

Manning AD, Fisher J, Lindenmayer DB (2006) Scattered trees are keystone structures – implications for conservation. Biological Conservation 132(3): 11–321. https://doi.org/10.1016/j.biocon.2006.04.023
Monumental Trees (2019) http://monumentaltrees.com [Accessed on 10.09.2019]
Moose RA, Schigel D, Kirby LJ, Shumskaya M (2019) Dead wood fungi in North America: An insight into research and conservation potential. Nature Conservation 32: 1–17. https://doi.org/10.3897/natureconservation.32.30875
Nature conservation areas under local protection in Hungary (2018) http://www.termeszetvedelem.hu/helyi-jelentosegu-vedett-termeszeti-teruletek [Accessed on 11.20.2018]
Pósfai Gy (2019) Thickest trees of Hungary http://www.dendromania.hu/index.php?old=foold [Accessed on 18.12.2019]
Ranius T, Jansson N (2000) The influence of forest regrowth, original canopy cover and tree size on saproxylic beetles associated with old oaks. Biological Conservation 95(1): 85–94. https://doi.org/10.1016/S0006-3207(00)00007-0
Rapaics R (1929) Öreg fák, ősi legendák. Természettudományi Közlöny 61: 721–735.
Read H (2000) Veteran Trees: a Guide to Good Management, 169 pp. http://publications.naturalengland.org.uk/publication/75035
Sverdrup-Thygeson A, Skarpaas O, Odegaard F (2010) Hollow oaks and beetle conservation: The significance of the surroundings. Biodiversity and Conservation 19(3): 837–852. https://doi.org/10.1007/s10531-009-9739-7
Szabó I (2003) Erdei Fák Betegségei. Szaktudás Kiadó Ház Zrt, Budapest, 316 pp.
Szakonyi Z Sz (2018) An overview on the cult of oak genus and presentation of some remarkable Hungarian oak trees. Hungarian Journal of Landscape Ecology 16(1): 35–43.
Takács M, Malatinszky Á (2012) An overview on the cult of sweet chestnut and presentation of the greatest Hungarian sweet chestnut trees. Hungarian Journal of Landscape Ecology 10(2): 457–466.
Takács M, Mravcsik Z, Malatinszky Á (2015) Legendary lime trees of the Carpathian Basin. Annals of Faculty of Engineering Hunedoara – International Journal of Engineering 13(1): 29–32.
Tardy J (1996) Magyarországi Települések Védett Természeti Értékei. Mezőgazda Kiadó, Budapest, 665 pp.
Thomas MG, Schumann DR (1993) Income Opportunities in Special Forest Products. Agriculture Information Bulletin U.S. Department of Agriculture, Washington, 206 pp.
Thompson KET, Bankoff RJ, Louis Jr EE, Perry GH (2016) Deadwood structural properties may influence Aye-Aye (*Daubentonia madagascariensis*) Extractive foraging behavior. International Journal of Primatology 37(2): 281–295. https://doi.org/10.1007/s10764-016-9901-5
Vasas G, Locsmándi Cs (2010) Gyakoribb Gombáink. Műszaki Kiadó, Budapest, 204 pp.
Zapponi L, Mazza G, Farina A, Fedrigoli L, Mazzocchi F, Roversi PF, Sabbatini Peverieri G, Mason F (2017) The role of monumental trees for the preservation of saproxylic biodiversity: re-thinking their management in cultural landscapes. In: Campanaro A, Hardersen S, Sabbatini Peverieri G, Carpaneto GM (Eds) Monitoring of saproxylic beetles and other insects protected in the European Union. Nature Conservation 19: 231–243. https://doi.org/10.3897/natureconservation.19.12464