Mass Mortality of Beech (*Fagus sylvatica* L.) in South-West Hungary

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Abstract – The mass mortality of beech (*Fagus sylvatica* L.) in Hungary, which started in 2003 and went on through 2004, is the result of a typical damage chain. Mortality appeared first of all in beech forests close or outside of its native distribution area. The most significant reason was the drought period from 2000 to 2004, which weakened the trees, and favoured the development of different pests and pathogens. Characteristic symptoms were frequent at stand margins and in stands thinned for regeneration. The direct causes of the mortality were insects, the green jewel beetle (*Agrilus viridis*) and the beech bark beetle (*Taphrorychus bicolor*) as well as the fungus species *Biscogniauxia nummularia*. With the improvement of weather conditions a continuous recovery of the stands has been observed since 2005.

Fagus sylvatica* / *Agrilus viridis* /*Taphrorychus bicolor* / *Biscogniauxia nummularia

Kivonat – A bükk (*Fagus sylvatica* L.) tömeges pusztulása Délnyugat-Magyarországon. A zalai bükkösökben 2003-ban kezdődött, majd 2004 során jelentős mértékben jelentkező pusztulás egy tipikus kárláncolat eredménye. A megjelenő tünetek jellegzetesek, különösen a napsütötte állományszegélyeken és a bontóvágással érintett faállományokban gyakoriak.

A pusztulás elsősorban az extrazonális bükkösökben jelent meg. A legfőbb kiváltó ok a 2000-ben kezdődött, öt évig tartó aszályos időszak, melynek következtében az állományok legyengültek, különböző kártevő és kórokozó fajok elszaporodtak. A pusztulás közvetlen kiváltó tényezői a zöld karcsúdíszbogár (*Agrilus viridis*) és a bóbitás bükkszú (*Taphrorychus bicolor*) rovarfajok valamint a *Biscogniauxia nummularia* gombafaj voltak.

Az időjárási tényezők javulásával 2005-óta az erdőállományok egészségi állapotának fokozatos javulása figyelhető meg.

Fagus sylvatica* / *Agrilus viridis* /*Taphrorychus bicolor* / *Biscogniauxia nummularia

1 INTRODUCTION

Starting from 2003 mass mortality of beech was observed in several parts of Hungary. Health conditions of beech stands were objectives of several investigations in Hungary (Tuzson 1931, Szántó 1948, Szontagh 1989, Leskó 1993, Tóth et al. 1995, Molnár – Lakatos 2007). However, similar symptoms were recorded only once in the eastern part of the Carpatian basin (Máramaros county) in the 1880s. A short description of the event was published at that

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time, however no detailed investigation was made (Piso, 1886). Similar decay of beech has been recently reported from the southern part Germany too (Delb 2005).

The recent mortality appeared with different intensity in beech forests of several parts of Hungary. Symptoms were first observed in Balaton highlands and Bakony mountains, but the most serious damage occurred in the south-western part of Hungary (Zala county). In this area approximately 120,000 cubic meter of damaged or dead timber had to be cut between 2003-2006, which caused approximately 400 million HUF (1.6M EUR) direct loss (Góber 2005) for the forest owner.

The effect of change in the climatic conditions on forest stands have been studied intensively in the recent years (for review see Strelcova et al (2009) and Mátyás (2006)). The aim of our investigation in the present study was to determine the role and importance of the biotic factors, like insects and fungi in these processes.

2 MATERIALS AND METHODS

Field studies were carried out in order to assess the correlations between the climatic characteristics of the affected area and the damages & symptoms. The investigation sites were at the eastern border of Zalaegerszeg, where the heaviest mortality was observed.

2.1 Site characteristics/features

The elevation of the study sites were between 196-302 m above see level. Due to the hilly terrain, shallow and deep tilths alternate with each other in short distances. Soils are of medium and at some places very good fertility.

The macroclimate of the area is typical for the hornbeam-sessile oak zone (*Querco petreae-Carpinetum*). Owing to the prevailing wind direction and the features of the terrain, this area is characterized by cooler and rainier conditions than expected based on the general climatic data.

2.2 Field observations

We established a network of 92 study plots with different terrain and age (60-122 years) in mixed forest subcompartments on an area of 102.6 hectares. Each plot was marked by a sample point. We evaluated the condition of the five beech-trunks closest to each point (altogether 460 individuals) every year at the end of the vegetation period from 2003 to 2007. During the experiment, besides the characteristic symptoms of the damage and disease-causing agents like insect and pathogens, we also evaluated the crown conditions.

The following categories were used:

1. The crown of the tree died, epicormic branches may be seen.
2. Several side-branches are infected or died.
3. One side-branch is infected or died.
4. Branch-ends, small branches died, but side-branches are healthy.
5. Totally healthy specimen.

The following criteria were considered for attack and/or infection: blackish chromatism, the existence or lack of bark-loss and the possible drying of the foliage. Other symptoms, like bark beetle attack or early stage fungal infections were not eye-catching at the time of the investigation. Due to the dieback of the trees and the continuous sanitary cuttings, the number of the investigated trunks decreased from year to year.

Xylo- and phloeophagous insects were assessed by felled trees in 2004 and 2006-2007 respectively. We selected trees in the health categories 4 and 3 during autumn and cut them next

February. Altogether 13 trees were cut (3-5-5 in the years 2004, 2006 and 2007 respectively). A total number of 37 cylinders of 35-40 cm length (from the stump, the trunk and the crown each, except two trees, where the crown was missing at the time of cutting). Cylinders were taken after cutting into our lab for insect rearing. Samples from one tree (stump, trunk and crown) were placed into one eclector, and this – unfortunately – does not allow any further differentiation of the tree parts. Hatched insects were collected every week for determination.

Four discs from trunks attacked by insects were cut in October 2005, and were put into a wet incubator to determine the fungi in the early phase of the infection.

We used the last past 46 years' temperature and precipitation data of a meteorological station closest to the examined area. (Zalaegerszeg-Andráshida; courtesy of P. Vig). We analysed the longest available data-set in order to receive the most complete overview about the changes of the climatic factors in the area.

3 RESULTS, STATEMENTS

3.1 Health conditions

The first symptoms of insect attack and fungal infection appeared in 2003 in forest subcompartments relatively far from one another: in old understocked stands on hilltops and in open forest edges exposed to the south. In the following year the mortality increased rapidly and many trees died. We did not find correlation between the social status of the specimens, the exposure of the stands, the site parameters and the health condition of the trees. The mortality was mostly initiated by insolation to the tree trunks.

From the year 2005 fresh symptoms have been observed only on specimens with dying or broken crowns. The spread of the mortality has stopped. Side-branches, which were previously infected, have broken down from the trunks. This was the main reason, why the canopy closure of the stands was still incomplete. A number of trees, having symptoms earlier, have regenerated and developed new crown. Only those side-branches and trunks have broken down where bark became blackish during the years of the decay.

The number of trees in the critical health categories 1-2-3 decreased continuously (*Figure 1*). This shows the loss of side-branches with symptoms as well. A tree classified previously into categories 2 or 3 got into categories 3 or 4 after the loss of certain infected side-branches.

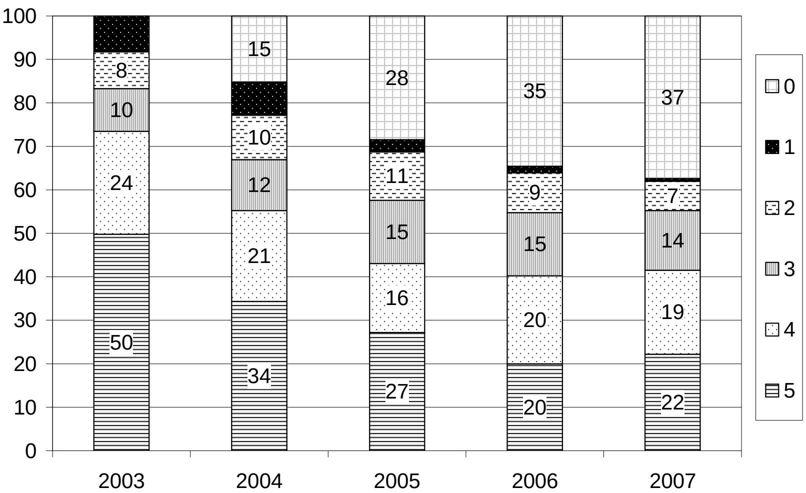

Figure 1. The change of health condition between 2003-2007 (%)
(0: cut/disappeared, 1: dead crown, 2: several dead side-branches,
3: one dead side-branch, 4: dead small branches or branch-ends, 5: healthy)

3.2 Insects and pathogens

Table 1. Insect species emerged from the samples collected in 2004-2007

Family	Species	Number of insect individuals 2004 N of logs: 21	2006 N of logs: 8	2007 N of logs: 8
Staphylinidae	*Staphylinidae*	12	1	
Buprestidae	*Agrilus viridis*	73	3	13
Lymexylidae	*Hylecoetus flabellicornis*		50	
Lymexylidae	*Lymexylon navale*		1	
Cleridae	*Thanasimus formicarius*	3		1
Cucujidae	*Monotoma* sp.	8		
Cucujidae	*Laemophloeus* sp.	6		
Cucujidae	*Laemophloeus testaceus*	5	1	1
Cucujidae	*Silvanus unidentatus*	2	1	2
Bostrichidae	*Lichenophanes varius*	4	2	11
Anobiidae	*Ptilinus pectinicornis*			14
Tenebrionidae	*Tenebrionidae* sp.	49		1
Mycetophagidae	*Litargus connexus*	1		3
Colydiidae	*Cerylon* sp.	434	6	
Cerambycidae	*Cerambyx scopolii*		1	
Cerambycidae	*Xylotrechus antilope*			1
Scolytidae	*Crypturgus* sp.	74	186	26
Scolytidae	*Taphrorychus bicolor*	34	1136	707

Altogether 2,873 individuals of 18 beetle species emerged from the collected wood samples. From every collected trap tree sample we were able to rear the specimens of *Agrilus viridis* and *Taphrorychus bicolor*. However, their ratio has changed during the years. In the intensive dieback phase (2004) *A. viridis*, but in the recovery (2006-07) phase *T. bicolor* prevailed. This might be connected with the different health status of the cut trees in the different years. During the second period the number of emerging insect species hatching from dead or dying trees has increased (*Table 1*). Most of them are connected to dead, discoloured wood (e.g. *Hylecoetus flabellicornis*), or to insects (*Thanasimus formicarius*) and fungi (*Litargus connexus*) living on this wood material. Some of them are even considered as a rare species to Hungary (e.g. *Lichenophanes varius*). We have found insect galleries in the bark usually just around the trunk part with fungal attack. In the bark with healthy xylem we could detect only a few insect galleries. Only the two beetle species *A. viridis*, and *T. bicolor* can be considered as important in the sense of forest protection. While *A. viridis* seems to be able to attack healthy trees and cause tree death, *T. bicolor* attacks felled logs, fallen branches, stressed trees and in some cases healthy looking (but very probably already stressed) trees. Even the pupal chamber of *A. viridis* was different in the different years. While during the intensive mortality phase L-type (one hole) pupation chamber was typical, during the recovery phase the U-type (two holes) pupation chambers.

Fungal species involved in the process couldn't be identified from the sample disks, therefore we did not repeat this examination on the recovering stand. The fungus causing characteristic blackish chromatism on side-branches, was identified as *Biscogniauxia nummularia* (Bull) Kuntze (earlier name: *Hypoxylon nummularium* (Bulliard ex Fries)).

3.3 Climate conditions

The macroclimate of the area is typical for the hornbeam-sessile oak zone (*Querco petreae-Carpinetum*) (*Figure 2*). The values of the Pálfai drought index (*Figure 3*) show, that the mass mortality have been initiated by an unusually heavy and long drought period from 2001 to 2003. Especially the value of 2003 (6.71) is an extreme. The drought period lasted for five years (*Figure 4-7*). Even the average precipitation of the years 2005 and 2006 yet fell behind the average of the previous decades (1961-2007). 2007 showed an average precipitation again (*Table 2*).

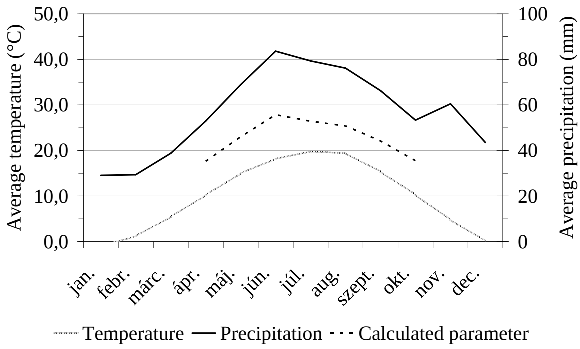

Figure 2. Walter climate diagram of the investigated area (Zalaegerszeg, 1961-2007)

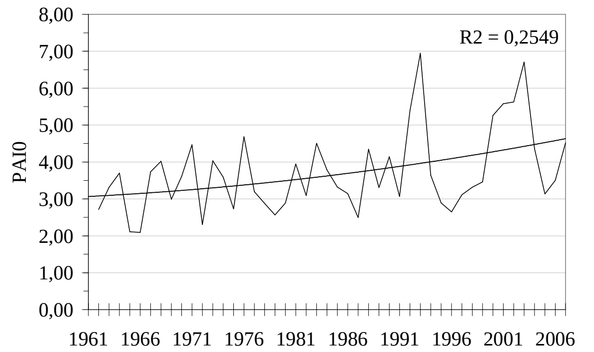

Figure 3. Pálfai drought index and trend for the investigated area (Zalaegerszeg, 1961-2007)

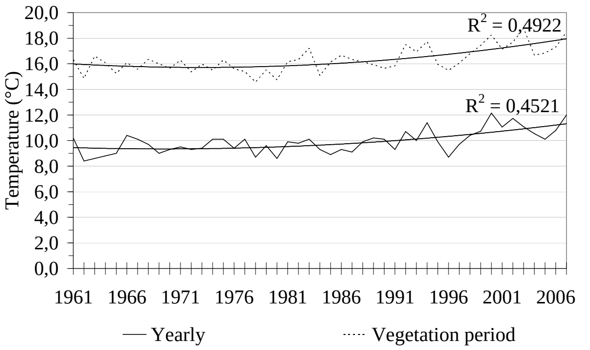

Figure 4. Average temperatures (annual and vegetation period; Zalaegerszeg, 1961-2007)

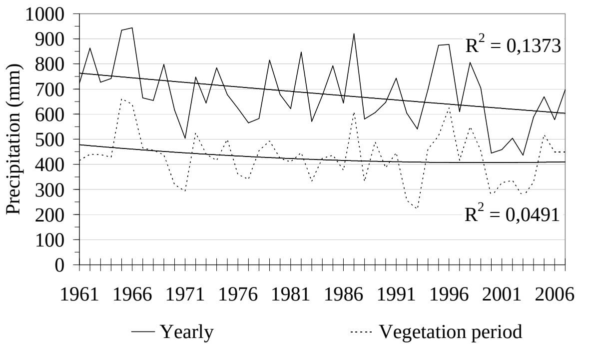

Figure 5. Precipitation (annual and vegetation period; Zalaegerszeg, 1961-2007)

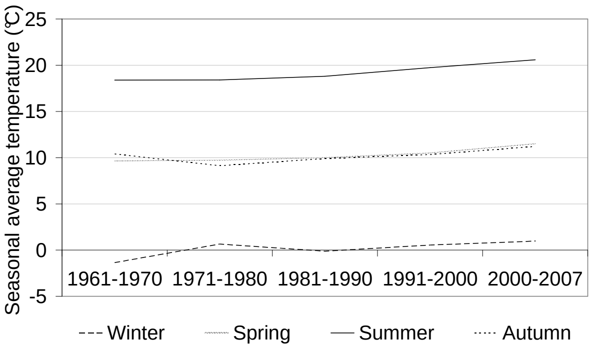

Figure 6. Seasonal average temperature (Zalaegerszeg, 1961-2007))

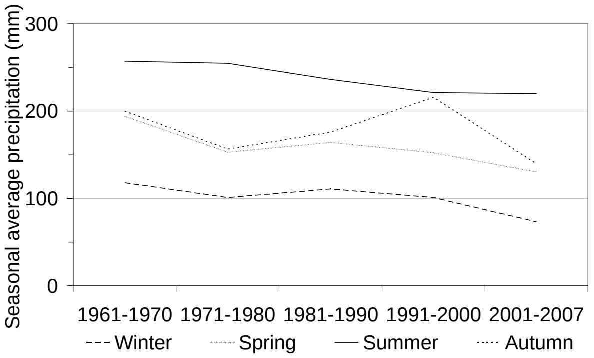

Figure 7. Seasonal precipitation (Zalaegerszeg, 1961-2007)

Table 2. Amount of precipitation and average temperature, and values of the drought index between 1961 and 2007 (Meteorological station, Zalaegerszeg; courtesy of P. Vig)

	Amount of precipitation (mm)			Average temperature (C°)			Pálfai drought index
	Annual	Apr - Sep	Oct - Mar	Annual	Apr - Sep	Oct - Mar	
2000							5,26
2001	459	327	132	11,1	17,1	5,0	5,58
2002	504	336	168	11,7	17,7	5,8	5,63
2003	436	270	166	11,1	18,8	3,4	6,71
2004	588	329	259	10,5	16,7	4,4	4,36
2005	669	518	151	10,1	16,8	3,4	3,13
2006	578	449	129	10,8	17,3	4,2	3,50
2007	697	449	248	12,0	18,5	5,5	4,52
1961-2007	681	427	254	9,9	16,3	3,5	3,71

4 CONCLUSIONS

During the last 50 years there have been unfavourable changes in the weather conditions for the beech forests both in Europe (Jump et al. 2006) and in Hungary (Mátyás et al. 2007). During this period the temperature was increasing while the amount of precipitation was decreasing. Also its dispersion was changing in the unfavourable direction: the relatively abundant rainfall of late autumn can hardly compensate the lack of summer precipitation (Szalai – Mika 2007). To assume, the tendency is ongoing, the natural range of beech will be definitely reduced in Hungary (Berki et al. 2007). The weakened trees are ideal places for mass reproduction of different pests and heavy infestation of pathogens (Csóka et al. 2007, Lakatos – Molnár, 2008).

The analysis of the climatic data showed that there had been dry years earlier, too (*Figure 3*), however without remarkable damage symptoms. This unfavourable periods, however, lasted only for short period, followed by more favourable (humid) years. Although the drought, which started in 2000 and lasted for five years, gave pests and pathogenes the chance to attack the weakened trees. Two beetle species, *A. viridis* and *T. bicolor*, were the major biotic factors. *Agrilus viridis* can be considered as the main pest species in this case, while *T. bicolor* attacks only weakened trees even if they look rather healthy based on our categories (e.g. 4 and 5). The population size of the two insects differs strongly in the intensive and the recovery phase of the dieback. *A. viridis* prefers the still living phloem with sap circulation disorders, mainly in higher altitude of the trunk. Imagines developed in a drying trunk part often do not have the capacity to create exit holes, and they die in the pupation chamber or in the exit hole. Bark beetle adults could be found under the bark of stumps, assortments and side-branches on the ground as well. The importance of *T. bicolor* in the mortality of beech was highlighted in two recent publications from Austria (Steyrer 2008) and Bavaria (Muck 2008). Delb (2005) reported the same insect species involved in the beech mortality in Baden-Württemberg. Other xylo- and phloeophagous species emerged from the trees have no significance in the damage chain. Their presence can be explained by the large amount of dying and dry trees suitable for their development.

We presume that there is a strong relation between insects and fungal damage. Larval galleries and exit holes were found above trunk parts with fungal infection. At the present stage it is hard to give an unambiguous explanation and description of the process. It is very likely, that entrance holes of the different insect species offer a unique opportunity for the fungal attack. However, the phloem, having weakened by the fungal attack, provides optimum conditions for the insect development too. On trunk parts without fungal attack insect galleries and exit holes are rare and the mortality of the larvae is higher too. We can assure, that there is a strong correlation between insects and pathogens, nevertheless their exact role needs further explanation.

The role of the pathogene fungus species, *Biscogniauxia nummularia* is not completely clarified either, however its presence or absence is crucial in the damage chain. The fruiting bodies appear in the first year of the decay. Later the tree loses almost all of the infected branches. If the fruiting bodies appear also on the trunk, the entire crown will die. None of the other symptoms can give an unambiguous forecast about the process of the decline, since spontaneous regeneration was often observed. In the recovery phase the beech stands are losing side-branches infected by *Biscogniauxia nummularia*.

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