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Beech (*Fagus sylvatica* L.) bark necrotic damage as a serious phytopathological problem in Central and Southeastern Europe

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ABSTRACT: The results of long-term monitoring of beech bark necrotic damage in a mature stands in Czech Republic, Slovakia, Poland, Hungary, Romania, Serbia and Bulgaria are presented in paper. Overall, 10,863 beech trees were evaluated at 121 localities. The majority of trees (6,679) were evaluated at 55 localities in Slovakia and the remaining 2,684 trees at 50 localities in Bulgaria. In each country, we noted a wide interval of the values of beech stem necrotization index (I_{SN}) – e.g. in Bulgaria from 0.22 to 1.50 and in Slovakia from 0.53 to 1.97. The average value of I_{SN} in Slovakia (1.22) was higher than the value in all other countries except for the Czech Republic (1.35). Overall, in Bulgaria, we found a more favourable state of beech bark necrotic damage than in Slovakia. As much as 80% of the Bulgarian localities had I_{SN} values < 1.1 compared to only 49.1% of the Slovakian localities. At the same time, 12.7% of the Slovakian localities had I_{SN} values > 1.5, whilst there was no Bulgarian locality recorded in this interval. We consider Slovakia and Bulgaria as the countries where the issue of beech bark necrotic damage is relatively well established.

Keywords: Bulgaria; index of necrotization; Slovakia

European beech (*Fagus sylvatica* L.) belongs amongst the most significant tree species throughout its natural range in Europe and is of great forestry, commercial, ecological and countryside importance. However, as observed in almost all tree species, European beech also suffers from a number of various mycotic diseases. We can undoubtedly include the beech bark necrotic damage that has become increasing significantly in recent years in almost all European countries with beech occurrence, amongst the most remarkable fungal diseases of beech. In connection with this, we need to emphasize the negative impact of this damage on health, vitality and ecological stability of beech stands, which apart from other things, has serious consequences in forestry and in the use of wood in the timber industry (Jančařík 2000a, 2000b).

The most frequent symptom of the beech necrotic damage is the formation of typical necrotic wounds on the bark of the bole, branches and stems – from small unnoticeable lesions to large areas of necrosis that result in deformities. Stems and branches often break at the place of necrotization where the solidity of wood is considerably weakened. This damage is caused by a fungal infection, e.g. by fungi *Anthostoma* Nitschke, *Diatrype* Fr., *Fusarium* Link., *Nectria* (Fr.) Fr., *Neonectria* Wollenw., *Ophiostoma* Syd., fungal-like organisms *Phytophthora* de Bary, *Phomopsis* Sacc., *Valsa* Fr., *Verticillium* Nees. and other fungal species (Perrin 1984; Merezhko et al. 1994; Jančařík 2000b; Jung 2009).

In several European countries, as well as in North America, the beech bark necrotic damage reaches the state of mycotic epiphytosis in some places and a serious phytopathological complex is known as the beech bark disease (BBD) (Surovec 1990; Houston 1994; Jančařík 2000a). Currently, we

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can say that beech bark necrotic damage levels vary among European countries, which is confirmed by the results of our long-term monitoring of this disease in selected countries of Central and Southeastern Europe. Previous reports of the beech bark necrotic damage in these countries have been published by e.g. Procházková (1990), Jančařík (1992, 2000a, 2000b), Mrkva (2004) in the Czech Republic, Rykowski et al. (1989) and Mańka (1997) in Poland, Surovec (1992), Cicák and Mihál (1997, 1998), Leontovyč et al. (1999), Zúbrik et al. (1999), Kunca et al. (2000) and Mihál et al. (2009a) in Slovakia, Standovár and Kenderes (2003) and Mihál and Cicák (2005) in Hungary, Chira and Chira (1997, 1998), Chira et al. (1996, 2003), Mihalciuc et al. (2001), Mihál and Cicák (2007b) in Romania, Rosnev and Petkov (1996), Tsakov et al. (2006, 2008) and Cicák et al. (2007) in Bulgaria, Marinković and Karadžić (1985), Karadžić et al. (2003), Mihál et al. (2009b) in Serbia.

The aim of this contribution is to assess the current state of beech bark necrotic disease in selected countries of Central and Southeastern Europe, quantified in the form of necrotization indexes. Currently available information on this disease is varied among the European countries with natural occurrence of beech, and is often only descriptive and lacks quantification of the beech necrotization process.

MATERIAL AND METHODS

Research on the degree of the beech bark necrotic disease was carried out at selected localities in the Czech Republic, Poland, Slovakia, Hungary, Romania, Bulgaria and Serbia between 1995 and 2013. The density of beech, the average age of stands, the altitude and aspect of the stands evaluated were varied at selected localities (Tables 1 and 2). We determined the necrotization index according to methods described in Cicák and Mihál (1997) Table 3. Each individual tree from a particular locality was included in a category describing the degree of bark necrotization – from degree 0 (without necroses) to the worst degree 4 (the occurrence of large and so called "breakthrough" necroses – the necrotization place where the beech stem can break down). For each locality, data from individual trees was averaged to provide an overall average degree of necrotic damage to beech stems at a given locality.

The evaluation was carried out in spring or autumn months prior to beech bud break or after leaf fall in autumn. This made the evaluation simpler because of better lighting and visibility of tree crowns. Beech trees in managed as well as in virgin forests were visually evaluated for the presence and degree of bark necrosis along the circumference of the stem from the buttress to the crown. Binoculars were used to evaluate the upper part of the bole and crown of tall trees. Mainly in surveyed mature stands in Slovakia, we mostly evaluated 100 trees of the 1st to the 5th tree class (according to Kraft). In the case of some stands in Slovakia, Serbia and Bulgaria with the status of permanent research area, we adjusted the number of surveyed trees to the amount of numbered trees; in recent years in Bulgaria, we surveyed 50 trees at each locality.

In the absence of fruiting bodies of the genus *Nectria* and *Neonectria* on the beech bark, the precise identification of fungal species responsible for necroses would require laborious and time-consuming laboratory cultivations of bark samples and wood from necrotic wounds. The subject of our article is not the identification of fungal agents of the beech bark necrotic damage but only the quantification of the external demonstration of necrotic damage, i.e. of the degree of succession development of necrotic wounds (Table 3).

To improve the overview and comparability of individual degrees of necrotization, we simplified the interpretation of results when we expressed the necrotization degrees by a single figure representing the whole evaluated stand. For this we used the so-called necrotization index of beech stem bark (I_{SN}), the use and point of which were described by Cicák and Mihál (1998). For the calculation of the necrotization index it is suitable to use the formula for the calculation of the tree health state index (I_{HS}), which aids the interpretation of the evaluation results of the tree defoliation according to the international monitoring ICP Forests (UN-ECE 2008). From the obtained values at each locality, we calculated the I_{SN}, which is the average value of the necrotization degree of stems of the examined trees.

RESULTS AND DISCUSSION

Overall, from 1995 to 2013, we evaluated 10,863 beech trees in mature stands located in 121 localities in 7 different countries across Central and Southeastern Europe. The majority of the trees (6,679) evaluated were in Slovakia (55 localities, 6,679 trees) and Bulgaria (50 localities, 2,684 ones). The two localities in Serbia had the

Table 1. Basic characteristics of the research localities in the individual countries of Central and Southeastern Europe

Country	Orographic unit	Locality	Altitude (m a.s.l.)	Exp.	Beech structure (%) /age of stand (yr)
Czech Republic	Moravsko-sliezske Beskydy Mts.	Hukvaldy	450	E	38/90
		Šance	650	SW	90/60
		Pustevny	680	SE	74/115
Poland	Beskid Sądecki Mts.	Kiczera	600	W	80/65
	Bieszczady Mts.	Przysłop	610	S	80/70
	Beskid Nizki Mts.	Przełecz Zebrak	825	W	95/100
Slovakia*	33 in total	55 in total	300–1,250	all	25–100/40–250
Hungary	Zempéni-Hegység Mts.	Telkibánya	300	SE	50/65
	Börzöny Mts.	Diosjenö	500	N	80/100
	Mátra Mts.	Parád	600	E	100/90
	Bükk Mts.	Öserdö	800	SW	92/200
Romania	Munții Tibleș Mts.	Telciu	420	E	90/70
	Munții Bistriței Mts.	Holda	660	NE	95/120
	Munții Stânișoarei Mts.	Crucea	690	SW	90/100
	Munții Bârgau Mts.	Piatra Fântânele	1,020	E	98/80
Serbia	Kucheyske planine plain	Yavorak	720	NW	100/55
		Velka Brezovitsa	900	N	100/70
Bulgaria	Stara planina Mts.	Prolaz	300	N	90/60
		Shumen	450	E	90/100
		Boaza	450	N	100/70
		Troyan	480	N	100/80
		Vrbitsa	500	W	90/80
		Shipkovo	650	NE	100/70
		Ichera	700	NW	100/80
		Pravets	700	N	100/50
		Kotel	700	N	100/120
		Etropole	720	NE	99/125
		Ticha	750	SW	90/70
		Vitinya	970	NE	97/90
		Karandila	1,000	SE	100/135
		Ribaritsa	1,100	NW	100/70
		Shipka	1,100	NE	90/65
		Barzia	1,150	NW	100/110
		Balkanets	1,250	N	100/110
		Govezhda	1,250	N	100/70
		Beklemeto	1,300	NE	100/60
		Petrohan	1,400	NE	100/110
		Dlgi Del	1,450	S	100/130
	Rodopi Mts.	Debravitsa	550	N	50/65
		Semchinovo	700	NW	100/75
		Fotinski vodopadi	750	N	100/70
		Eleshnitsa	900	NW	100/65
		Rozovo	900	NE	100/65
		Dobra Voda	950	NW	100/80
		Chepino	1,100	E	98/90
		Grashevo	1,100	N	100/80
		Marino	1,150	E	100/100
		Ravnogor	1,200	N	100/90
		Ossenovo	1,220	NW	100/140
		Velingrad	1,250	E	100/75
		Rakitovo	1,380	SW	100/80
		Aposlovtchark	1,400	E	60/50
	Pirin Mts.	Razlog	1,150	NW	100/70
		Yane Sandanski	1,200	NW	100/120
		Popovi livadi	1,350	N	95/35
	Rila Mts	Rilski monastir	975	S	100/90
		Raduil	1,060	E	100/90
		Chaira	1,150	N	100/90
		Borovets	1,500	NE	90/90
	Sredna Gora Mts.	Oborishte	750	W	100/80
		Panagyurishte	1,000	S	100/90
	Strandzha Mts.	Silkosia I	305	NE	90/56
		Silkosia II	305	N	98/100
	Kraisthe planina Mts.	Breznik	975	S	100/70
	Ljulin planina Mts.	Gorna Bania	900	NW	80/70
	Osogovo planina Mts.	Tri Buki	1,550	NW	100/160
	Vitosha Mts.	Dragalevski monastir	1,080	NE	100/130

*nomenclature of the basic characteristics of the localities of Slovakia is given also in Table 2, Exp. – exposition

Table 2. Basic characteristics of the research localities in Slovakia

Orographic unit	Locality	Altitude (m a.s.l.)	Exp.	Beech structure (%)/ age of stand (yr)
Bukovské vrchy Mts.	Havešová	520	SE	100/120
	Rožok	540	NW	100/150
	Udava	620	W	60/120
	Stužica	800	N	95/180
	Riaba skala	980	S	45/160
Kremnické vrchy Mts.	Boky	370	NE	55/120
	Kováčová	480	W	87/100
	Štagiar	620	W	100/55
	Badínsky prales	760	N	95/150
	Mláčik	850	SE	60/140
Muránska planina plain	Javorníčková	580	SE	30/90
	Pod Veľkou Stožkou	880	NE	90/65
	Nemecké lúčky	950	SE	70/80
	Červená Skala	1,050	NE	60/70
Poľana Mts.	Iviny	750	SW	100/100
	Hrončecký grúň	950	SE	40/150
	Kozí chrbát	1,025	SW	100/80
	Drábovka	1,250	SW	100/60
Štiavnické vrchy Mts.	Žiar nad Hronom	470	NW	95/70
	Jalná	610	W	100/75
	Sitno	900	NW	70/90
Malá Fatra Mts.	Valčianska dolina	680	NE	90/100
	Šlahorka	1,100	S	60/120
Malé Karpaty Mts.	Kačín	320	NE	100/90
	Havrania skala	400	N	98/100
Nízke Tatry Mts.	Korytnická dolina	960	SW	90/120
	Lomnistá dolina	1,200	SE	50/150
Slanské vrchy	Dargov	500	SE	100/50
	Oblík	700	SW	95/250
Stolické vrchy Mts.	Hiencovo	480	NW	100/90
	Kohút	680	W	95/100
Vihorlatské vrchy Mts.	Pod Sninským kameňom	560	N	100/100
	Kyjovský prales	800	N	100/250
Biele Karpaty Mts.	Veľká Javorina	940	E	80/80
Cerová vrchovina Mts.	Pohanský hrad	500	NE	100/100
Čierna Hora Mts.	Vysoký vrch	780	NE	100/90
Krupinská planina plain	Litava	300	NW	80/90
Laborecká vrchovina Mts.	Výrava	550	SW	100/100
Moravsko-Sliezske Beskydy Mts.	Malý Polom	1,060	NW	45/100
Ondavská vrchovina Mts.	Kačalová	640	SW	60/60
Ostrôžky Mts.	Bralce	790	E	100/90
Pieniny Mts.	Bukový les	660	NW	100/100
Pohronský Inovec Mts.	Veľký Inovec	720	NE	100/45
Považský Inovec Mts.	Hrádocká dolina	460	NE	100/60
Revúcka vrchovina Mts.	Železník	660	NW	98/60
Slovenský kras karst	Brzotínske skaly	450	NW	65/70
Slovenský raj Mts.	Vyšná Roveň	1,000	NE	95/105
Starohorské vrchy Mts.	Stará Píla	700	W	47/40
Strážovské vrchy Mts.	Strážov	950	SW	100/80
Tatry Mts.	Belianska jaskyňa	780	NE	55/40
Tríbeč Mts.	Veľký Tríbeč	770	SW	50/80
Veľká Fatra Mts.	Veľká Skalná	950	S	80/80
Veporské vrchy Mts.	Dobročský prales	950	NW	25/250
Volovské vrchy Mts.	Volovec	540	S	55/70
Vtáčnik Mts.	Škurátka	1,025	SE	95/110

Table 3. Classification scale for bark necrosis evaluation on beech stems (according to Cicák, Mihál 1997)

Degree	Characteristics*
0	without any necrotic wounds on the bark
1	small necrotic wounds (bark fissures, cracks) occurring singularly or in individual groups, visible only with the closer examination of the stem
2	small necrotic wounds (like for degree 1) accompanied by the occurrence of larger necrotic wounds (larger fissures, rugged bark) visible under the ordinary examination of the stem
3	larger necrotic wounds denuding the xylem and partly deforming the stem, bark cracking and shedding, visible already from a larger distance
4	large necrotic wounds deforming the stem heavily or leading to "bark necrosis", rugged bark and bark shedding, visible also from a greater distance

*the stem, an evaluated part of the tree, is understood to be the tree part from the buttresses to the crown setting. In the process of evaluation, it is necessary to distinguish consistently between occlusions after bark injury due to logging, game browsing and frost cracks and necrosis of tracheomycotic type; neither the number of necrotic lesions nor the size of the stem bark area covered with necroses can be taken as the main evaluation indicator; destructive effects of necrotic damage are externally manifested namely on the stages of necrosis development specified in the classification scale description

fewest trees (100) evaluated (Fig. 1). We present the actual values of the necrotization index of beech bark at selected localities in the countries of Central and Southeastern Europe in Tables 4–7. The I_{SN} values varied at each locality in each country. Apart from Slovakia and Bulgaria, only a minimum number of beech trees were evaluated in other countries, which affects the ability to accurately compare values between countries.

Generally, the I_{SN} values in each country moved up and down, for example in the Czech Republic from 0.98 to 1.92 only at three localities, in Romania from 0.83 to 1.31 at four localities (Table 4). In Slovakia and Bulgaria we evaluated 55 and/or 50 localities, respectively, whilst we noted a wide interval of I_{SN} values – for example in Bulgaria from 0.22 to 1.50 and in Slovakia from 0.53 to 1.97 (Tables 4 and 5). If we compared the average value of I_{SN} found in Slovakia (1.22) with other countries, we would see that a higher average value of I_{SN} than that recorded in Slovakia was found out only in the Czech Republic.

From the aspect of the sufficient set of evaluated localities in Slovakia and Bulgaria (Tables 4 and 5), it is possible to carry out a comparison of the I_{SN} values presented in Tables 6 and 7. After the differentiation of index values into three intervals in Table 6 we can see that the values recorded in Bulgarian localities were far more favourable that the values at Slovakian localities. In the case of I_{SN} interval < 1.1 we can see that in Bulgaria these favourable values were reached at 80% of the localities. On the other hand, in the case of unfavourable values of I_{SN} > 1.5 we can see that no such localities were recorded in Bulgaria, whilst in Slovakia 12.7% of the evaluated localities belonged to this interval of values. It is worth noting that at all localities in Slovakia, there were lower or higher numbers of trees recorded in the worst necrotization degrees 3 and 4 (100% representation of Slovakian localities in Table 6). On the contrary in Bulgaria, we noted only 54% of the localities with the occurrence of trees in the worst necrotization degrees 3 and 4, which means that as much as 46% of Bulgarian localities did not have any representation in the worst necrotization degree.

Similarly, in Table 7, we present the lowest and the highest values of I_{SN} at the first five localities from the set of all evaluated localities in Slovakia and in Bulgaria. Here we can see that even in the

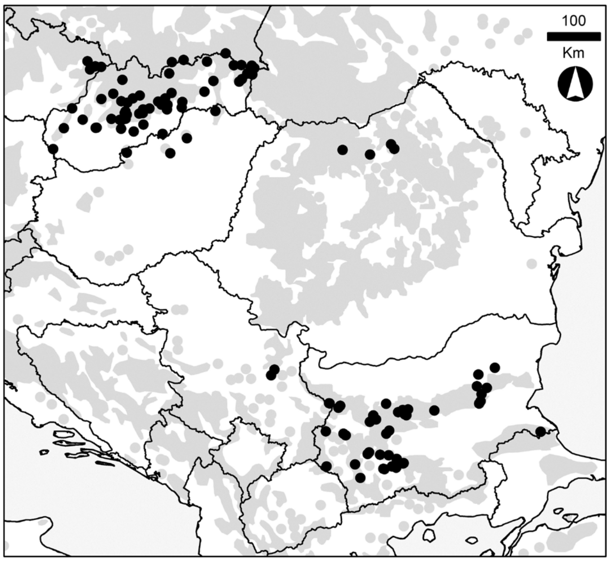

Fig. 1. Schematic location of the studied localities in Central and South-eastern Europe. [Modern distribution of common beech (*Fagus sylvatica* L.) is displayed in the map of source: EUFORGEN, http://www.euforgen.org]

Table 4. Values of beech stem necrotization index (I_{SN}) and frequency of degrees of necrotization (DN) in selected localities of the individual countries of Central and South-eastern Europe

Country	Locality	I_{SN}	Percentage of trees (%)	
			DN 1–4	DN 3–4
Czech Republic	Hukvaldy	1.16 ± 0.05	96.0	1.0
	Šance	1.92 ± 0.11	98.9	24.7
	Pustevny	0.98 ± 0.03	93.0	0.0
Poland	Kiczera	0.84 ± 0.07	69.0	3.0
	Przysłop	0.73 ± 0.08	57.0	5.0
	Przełecz Zebrak	0.80 ± 0.07	69.0	2.0
Hungary	Telkibánya	1.15 ± 0.08	93.0	7.0
	Diosjenö	1.14 ± 0.07	95.0	4.0
	Parád	1.18 ± 0.06	94.0	5.0
	Öserdö	1.11 ± 0.08	86.0	7.0
Romania	Telciu	0.84 ± 0.11	68.0	4.0
	Holda	0.85 ± 0.07	67.0	4.0
	Crucea	0.83 ± 0.08	67.0	3.0
	Piatra Fântânele	1.31 ± 0.09	89.0	10.0
Serbia	Yavorak	0.88 ± 0.13	64.0	8.0
	Velka Brezovitsa	0.80 ± 0.11	64.0	4.0
Bulgaria	Prolaz	1.50 ± 0.14	95.0	12.5
	Silkosia I	0.26 ± 0.13	10.0	6.0
	Silkosia II	0.30 ± 0.10	20.0	4.0
	Shumen	1.34 ± 0.14	82.0	10.0
	Boaza	1.25 ± 0.15	82.5	10.0
	Troyan	0.90 ± 0.12	72.5	10.0
	Vrbitsa	0.82 ± 0.07	76.0	0.0
	Debravitsa	0.22 ± 0.06	22.0	0.0
	Shipkovo	1.03 ± 0.14	75.0	7.5
	Ichera	0.86 ± 0.11	70.0	4.0
	Pravets	1.12 ± 0.10	78.0	12.0
	Kotel	1.05 ± 0.13	80.0	5.0
	Semchinovo	0.46 ± 0.09	34.0	0.0
	Etropole	0.79 ± 0.06	72.0	2.0
	Ticha	0.98 ± 0.13	68.0	8.0
	Fotinski vodopadi	0.56 ± 0.10	46.0	0.0
	Oborishte	0.42 ± 0.09	36.0	0.0
	Eleshnitsa	0.32 ± 0.07	32.0	0.0
	Rozovo	0.26 ± 0.07	24.0	0.0
	Gorna Bania	0.48 ± 0.08	47.5	0.0
	Dobra Voda	0.72 ± 0.12	56.0	4.0
	Vitinya	1.12 ± 0.06	91.0	4.0
	Breznik	0.64 ± 0.10	54.0	4.0
	Rilski monastir	0.38 ± 0.07	38.0	0.0
	Karandila	1.00 ± 0.09	82.5	0.0
	Panagyurishte	0.86 ± 0.10	66.0	0.0
	Raduil	0.40 ± 0.09	34.0	2.0
	Dragalevski monastir	1.00 ± 0.07	81.0	3.0
	Ribaritsa	1.24 ± 0.13	88.0	10.0
	Shipka	0.70 ± 0.10	50.0	10.0
	Chepino	0.32 ± 0.07	30.0	0.0
	Grashevo	0.32 ± 0.07	26.0	0.0
	Chaira	0.64 ± 0.07	64.0	0.0
	Barzia	0.72 ± 0.07	70.0	0.0
	Marino	0.32 ± 0.07	32.0	0.0
	Razlog	0.88 ± 0.09	80.0	2.5
	Ravnogor	0.58 ± 0.08	56.0	0.0
	Yane Sandanski	0.56 ± 0.08	54.0	0.0
	Ossenovo	0.56 ± 0.10	48.0	2.0
	Balkanets	0.90 ± 0.12	70.0	2.5
	Govezhda	0.78 ± 0.10	77.5	10.0
	Velingrad	0.80 ± 0.09	70.0	0.0
	Beklemeto	1.24 ± 0.14	84.0	8.0
	Popovi livadi	0.38 ± 0.07	36.0	0.0
	Rakitovo	0.68 ± 0.08	64.0	4.0
	Aposlovtchark	0.38 ± 0.07	38.0	0.0
	Petrohan	1.08 ± 0.06	93.0	5.0
	Dlgi Del	0.38 ± 0.07	38.0	0.0
	Borovets	0.86 ± 0.09	74.0	2.0
	Tri Buki	0.73 ± 0.09	67.5	0.0

I_{SN} – index of beech stem necrotization, DN 1–4 – degree of necrotization 1–4, DN 3–4 – degree of necrotization 3–4 (according to Cicák, Mihál 1997 – see Table 3)

Table 5. Values of beech stem necrotization index (I_{SN}) and frequency of degrees of necrotization (DN) in selected localities in Slovakia

Locality	I_{SN}	Percentage of trees	
		DN 1–4	DN 3–4
Badinský prales	1.21 ± 0.09	83.0	10.0
Belianska jaskyňa	0.87 ± 0.09	61,0	6.0
Boky	0.90 ± 0.06	76.0	2.0
Bralce	1.11 ± 0,07	84.0	5.0
Brzotínske skaly	0.70 ± 0.08	56.0	3.0
Bukový les	1.14 ± 0.11	67.0	14.0
Červená skala	1.15 ± 0.09	83.0	10.0
Dargov	1.48 ± 0.10	92.0	13.0
Dobročský prales	0.78 ± 0.08	57.0	3.0
Drábovka	1.74 ± 0.11	96.0	26.0
Havešová	0.83 ± 0.09	60.0	5.0
Havrania skala	0.94 ± 0.08	71.0	6.0
Hiencovo	1.08 ± 0.06	65.9	8.6
Hrádocká dolina	1.18 ± 0.10	80.0	11.0
Hrončecký grúň	1.06 ± 0.10	72.0	11.0
Iviny	1.56 ± 0.10	89.2	20.0
Jalná	1.34 ± 0.05	96.5	24.6
Javorníčková	1.00 ± 0.07	83.0	5.0
Kačalová	1.50 ± 0.11	88.0	21.0
Kačín	1.06 ± 0.06	88.0	3.0
Kohút	0.80 ± 0.08	64.0	3.0
Korytnická dolina	1.12 ± 0.11	65.0	15.0
Kováčová	0.82 ± 0.03	75.7	1.6
Kozí chrbát	1.78 ± 0.11	92.0	23.0
Kyjovský prales	1.46 ± 0.11	88.0	15.0
Litava	0.68 ± 0.07	67.0	2.0
Lomnistá dolina	1.08 ± 0.11	70.0	12.0
Malý Polom	1.42 ± 0.11	84.0	14.0
Mláčik	0.90 ± 0.11	59.0	10.0
Nemecké lúčky	0.53 ± 0.07	44.0	2.0
Oblík	0.76 ± 0.07	62.0	2.0
Pod Sninským kameňom	1.26 ± 0.10	75.0	14.0
Pod Veľkou Stožkou	1.06 ± 0.08	82.0	5.0
Pohanský hrad	1.23 ± 0.10	77.0	12.0
Riaba skala	1.37 ± 0.11	82.0	18.0
Rožok	0.87 ± 0.08	65.0	4.0
Sitno	1.09 ± 0.08	84.0	6.0
Stará píla	1.05 ± 0.08	78.0	5.0
Strážov	1.17 ± 0.09	80.0	9.0
Stužica	0.73 ± 0.08	60.0	3.0
Škurátka	0.94 ± 0.10	60.0	8.0
Šlahorka	1.81 ± 0.13	89.0	29.0
Štagiar	1.97 ± 0.04	97.4	31.0
Udava	0.70 ± 0.10	47.0	7.0
Valčianska dolina	1.12 ± 0.10	74.0	9.0
Veľká Javorina	1.03 ± 0.09	75.0	7.0
Veľká Skalná	1.68 ± 0.14	79.0	29.0
Veľký Inovec	1.49 ± 0.11	85.0	18.0
Veľký Tríbeč	1.16 ± 0.09	83.0	9.0
Volovec	1.11 ± 0.08	85.0	6.0
Vyšná Roveň	0.93 ± 0.11	58.0	11.0
Výrava	0.82 ± 0.09	58.0	6.0
Vysoký vrch	1.15 ± 0.08	83.0	7.0
Železník	1.50 ± 0.11	88.0	19.0
Žiar nad Hronom	1,87 ± 0.15	94.4	31.9
Total	1.22 ± 0.01	77.9	12.8

case of the lowest (i.e. the most favourable) necrotization indexes, the average value of the first five localities in Slovakia is 2.4 times higher than in Bulgaria (0.67:0.28). In the case of the highest (the worst) indexes this value in Slovakia is 1.4 times higher than in Bulgaria (1.83:1.31), this means that at the first five localities in Slovakia, the recorded maximum and minimum I_{SN} results in the given categories were always worse, i.e. higher I_{SN} values. The data mainly from Tables 6 and 7 document that we recorded the much more favourable state of necrotic beech disease in the set of evaluated localities in Bulgaria than in a comparable set of localities in Slovakia. Among the possible explanations of this phenomenon, from our point of view could be for example a difference given by the geographical position of Slovakia and Bulgaria, geomorphological, geological and soil differences, the influence of climate, anthropogenic influences, also the influence of the vertical gradient of beech distribution (for example, we noted higher index values in stands at a higher altitude in Slovakia compared to Bulgaria), also some local and many other factors. At the same time it is to add that the necrotization process is subjected to its successive development, which is affected by a number of ecological, climatic and anthropic factors.

The necrotization process can move in the negative direction – addition of further necroses, enlargement of the existing ones etc., as well as in the positive direction – a healing process is taking place, particularly the healing of small necrotic wounds, which was proved experimentally (Klein 1997; Cicák et al. 2003). Because of this reason, the changes in the necrotization process can take place very slowly and are not necessarily significant even with the gap of several years, which we proved by a comparison of beech stem bark necrotization index at the same locality, nine years after the research (Mihál, Cicák 2007a).

So far, we have found only few scientific works expressing the concrete quantification of necrotic beech disease in the surveyed countries. Several literature sources only state the occurrence of the disease describing the process and symptoms, and/or suggesting sanitary and protection measures. For this reason, we can understand our results in Tables 4–7 as concrete quantification of this disease in a given time and our actual contribution to the recognition of these issues in given countries.

For example in the Czech Republic, Jančařík (1992) described in detail the symptoms of dying back of the beeches infected by ophiostomatoid fungi of the genus *Ophiostoma* Syd. He paid attention

Table 6. Comparison (%) of the values of beech stem necrotization index (I_{SN}) and representation (%) of localities with degrees of necrotization 3–4 (DN) between Slovakia and Bulgaria

Country	I_{SN} < 1.1	I_{SN} = 1.1–1.5	I_{SN} > 1.5	DN 3–4
Slovakia	49.1	38.2	12.7	100
Bulgaria	80.0	20.0	0.0	54.0

Slovakia – 55 studied localities, Bulgaria – 50 localities

to an important symptom of beech bark necrotic disease, to the so-called "T-disease" that devalues timber to a large extent (Jančařík 2000a). Apart from abiotic causes, this disease can be caused by the infection with *Neonectria ditissima* (Tul. & C. Tul.) Samuels & Rossman. Jančařík (2000b) also suggested some possible ways of protection against the necrotic beech disease. A mutual relation between the genesis of bark fissures created by the impact of abiotic factors and their consequential infection by vascular parasitic fungi was studied by Mrkva (2004). The beechnut infection by fungi from the genus *Fusarium* Link., *Graphium* Corda, *Phomopsis* Sacc. and *Verticillium* Nees. was studied by Procházková (1990), when she found out that as much as 15.2% of examined samples were infected by these fungi.

In Poland, we can find the beech bark necrotic disease in the works of Rykowski et al. (1989), who found out that in the original stands of Bieszczad in south-eastern Poland, as much as 57% of examined trees were affected by various mycoses. The occurrence of *Cryptococcus fagisuga* Lindinger, as a biotic vector of necrotic disease ranged from 18% to 48%, whilst in 1% to 3% of evaluated beeches they found the occurrence of fruiting bodies of the parasitic fungi *Neonectria coccinea* (Pers.:Fr.) Rossman & Samuels. Mańka (1997) reported the increase of deciduous tree dieback in western and north-western Poland, where the necrotic disease of bark and rot was observed. The parasitic fungus *Cylindrocarpon destructans* (Zins.) Scholten [teleomorph: *Neonectria radicicola* (Gerlach & L. Nilsson) P. Chaverri & C. Saldago] was also included amongst the significant originators of this dieback Mańka (1.c.). Cicák and Mihál (2008) presented the actual state of the beech necrotic disease at three localities in south-eastern Poland. They found that compared to the average necrotization index noted in Slovakia (I_{SN} =1.22), the values of I_{SN} noted in Poland were lower − from 0.73 to 0.84. For the first time in Poland, also the necrotization index of beech crowns was evaluated, with values ranging between 0.12 and 0.51.

In Slovakia, besides our research, there were other authors dealing with the issue of beech necroses. For example Kunca et al. (2000) examined the correlation between the necrotic disease and biotic vectors of the disease (*Cryptococcus fagisuga* and *Ectoedemia liebwerdella* Zim.), as well as selected abiotic conditions at examined localities. They discovered that the presence of *C. fagisuga* and *E. liebwerdella* did not statistically affect the occurrence of necroses. A statistically significant correlation was revealed between the occurrence of necroses and unsuitable abiotic conditions of the stands (for example shallow soil, steep slopes, southern and eastern exposition of the stands). The issue of biotic vectors of the necrotic disease was studied by Zúbrik et al. (1999), who found out a positive relation between the occurrence of *C. fagisuga* and the degree of necrotic damage to beeches. In the whole set of 550 trees, the occurrence of *C. fagisuga* was found on 74% of the trees and necroses were present on 52% of the trees. Concrete values of the necrotization index of beech were presented by Leontovyč et al. (1999), who found out that in the set of 400 beeches during 1996 to 1999, the aver-

Table 7. Comparison of the highest and the lowest values of I_{SN} in selected localities between Slovakia and Bulgaria

Slovakia*				Bulgaria*			
highest I_{SN}		lowest I_{SN}		highest I_{SN}		lowest I_{SN}	
Štagiar	1.97	Nemecké lúčky	0.53	Prolaz	1.50	Debravitsa	0.22
Žiar nad Hronom	1.87	Litava	0.68	Shumen	1.34	Silkosia I	0.26
Šlahorka	1.81	Brzotínske skaly	0.70	Boaza	1.25	Rozovo	0.26
Kozí chrbát	1.78	Udava	0.70	Beklemeto	1.24	Silkosia II	0.30
Drábovka	1.74	Stužica	0.73	Ribaritsa	1.24	Chepino	0.32
mean	1.83	mean	0.67	mean	1.31	mean	0.28

*the first five localities from all studied localities are presented in the table age value of necrotization index grew from 0.75 in 1996 to 0.80 in 1999. The increased degree of necrotization had a negative impact also on the lower girth increment of evaluated trees. The condition of the necrotic disease in younger phases of beech development was studied by SUROVEC (1992), who found on average 17 necrotic wounds on a single individual beech in a young beech stand. On average, there were 5.6 necroses on the main stem and as much as 11.5 necroses on side branches on a single individual tree in a young beech stand.

STANDOVÁR and KENDERES (2003) presented interesting phytopathological data about beech in Hungary stating that in the mixed primeval forest Őserdő in northern Hungary as much as 49 trees (26%) out of 188 examined trees were damaged by abiotic factors. Damaged bark and wounds were often infected by fungal pathogens. Here, the authors determined the occurrence of dangerous parasitic fungi *Neonectria ditissima* and *N. galligena* (Bres.) Rossman & Samuels. Concrete data about the necrotic disease of beech in Hungary was presented by MIHÁL and CICÁK (2005), who carried out the evaluation of beech stem necrotization at four localities in northern Hungary. They found out that I_{SN} reached the values from 1.11 at Őserdő locality to 1.18 at Parád locality, which were more favourable values than average I_{SN} in Slovakia (1.22). Despite the comments of STANDOVÁR and KENDERES (2003) about a strong phytopathological attack on beech stands in the Őserdő primeval forest, at this very locality we noted the lowest value of I_{SN} out of all four localities in northern Hungary.

Data about the state of the beech bark necrotic disease in Romania are also known. For example, CHIRA and CHIRA (1997) described some environmental conditions that limit the occurrence and the degree of beech necrotization (for example soil conditions, climatic conditions, stand structure and others). They indicated the species *Neonectria ditissima* that infects trees through mechanical bark wounds as a significant parasite causing the beech necrotic disease. Also, CHIRA and CHIRA (1998) presented the occurrence and phytopathological importance of the species *N. ditissima* and *N. coccinea* in Romanian beech stands and suggested preventive and control measures against the necrotic disease. Similarly, the issue of fungal pathogens was studied by CHIRA et al. (1996), who reported the enlargement of the area of phytopathogenic fungi *N. ditissima* and *N. galligena* in Romanian beech stands, whilst they consider the impact of drought periods during the last 15 to 30 years as the main reason for this process. The impact of the parasitic fungus *N. ditissima* on the beech health was described by MIHALCIUC et al. (2001), who determined 28.4% defoliation of beech in 1997, whilst as much as 80% of evaluated trees were infected by the pathogenic species *N. ditissima*. The evaluation of the beech stem necrotization at four selected localities in northern Romania was carried out by MIHÁL and CICÁK (2007b). They revealed quite a favourable state of the necrotic damage to beech, whernthe values of I_{SN} ranged between 0.83 and 1.31. The authors simultaneously recorded the occurrence of the genus *Nectria* as well as the occurrence of selected biotic vectors of the beech necrotic disease.

In Bulgaria, the beech bark necrotic disease was studied by ROSNEV and PETKOV (1996), who observed a significant occurrence of beech bark necrotic disease in the Central and Eastern part of Stara Planina in the north of Bulgaria. It follows from their observation that the necrotic disease at examined localities occurred on 5% to 70% of evaluated trees. The authors also revealed the occurrence of the species *Neonectria ditissima* and *N. galligena*, as well as the occurrence of *Cryptococcus fagisuga* in affected stands. They also confirmed the occurrence of so-called "T-disease", as a hidden symptom of beech necrotic damage. TSAKOV et al. (2006) summarized the results of necrotic damage and beech health at selected localities in the mountain region of Stara Planina in the north of Bulgaria. They found out that necrotic damage to beech stem bark ranged from 28.7% to 35.7% of evaluated trees. Similarly, TSAKOV et al. (2008) summarized the results of beech health and beech necrotic damage from 14 localities in Bulgaria. In beech stands aged up to 80, trees damaged by necrosis ranged from 2.2% to 10.4%, whilst in stands aged up to 160, the range was from 2.6% to 35.8% trees. In stands situated up to 500 m above sea level, the values of necrotic damage amounted up to 8.8%, whilst in stands over 1,000 m a.s.l. the values reached up to 16.5%. Values of the actual state of beech necrotic disease in northern Bulgaria expressed by I_{SN} were reported by CICÁK et al. (2007), who found that I_{SN} values of beech bark ranged between 0.72 and 1.12; these were more favourable values than the average I_{SN} value for the whole of Slovakia. At the same time, the values of beech crown index of necrotization ranged from 0.54 to 0.75 and the values of whole tree (stem and crown) necrotization index from 0.80 to 1.42.

The spread, the symptoms of fungi originators and the ecological significance of beech necrotic disease in Serbia were presented by KARADŽIĆ et al. (2003) and MARINKOVIĆ and KARADŽIĆ (1985). According to these authors, the beech bark necrotic disease appeared in Serbia for the first time around the year 1983 and was caused by the synergic action of infectious agents *Cryptococcus fagisuga* + *Neonectria* spp. Marinković and Karadžić (1985) presented the fungus *Neonectria coccinea* as a significant parasitic species on beech. According to Karadžić et al. (2003) in Serbia, higher resistance of *Fagus moesiaca* (Maly) Czeczott to the necrotic disease was observed compared to *Fagus sylvatica* L. At two localities in south-eastern Serbia we found out the I_{SN} values ranging from 0.80 to 0.88, which were lower than the average I_{SN} value for the whole of Slovakia (Mihál et al. 2009b).

Obviously, the knowledge of beech necrotic damage in each of the above-mentioned countries of the European area is at a different qualitative and quantitative level (for example from the aspect of research complexity, the depth of processed issues, as well as the number and make up of scientific teams studying the given issue.)

Within our possibilities in Slovakia, in a long period we dealt with this issue from several points. We have worked out some original methodical ways of the evaluation of beech stem and crown bark necrotization (Cicák, Mihál 1997, 1998; Cicák et al. 2007), we have compared the dynamics of damage at the same locality in the time interval of 9 years (Mihál, Cicák 2007a), we have quantified the occurrence of biotic vectors of the necrotic damage as well as the occurrence of the most serious fungal pathogens of the genus *Nectria* s. l. and other fungal species that can cause this disease (Mihál et al. 2009a). Our activities are mainly connected with the area of Slovakia, where we have been carrying out the research continuously since 1995.

We have gained a lot of new knowledge also in Bulgaria, which, concerning the research of the beech necrotic disease, we can consider a well-researched country within south-eastern Europe. The least amount of concrete and actual data about beech necrotic disease has been recorded so far in Poland, Hungary, Serbia and partially in the Czech Republic. We think that also because of these reasons, it is necessary to pay more attention to the research of the beech bark necrotic damage as a serious phytopathological problem not only in the countries of Central and Southeastern Europe but also in all European countries with natural occurrence of beech.

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