Influence of *Nectria ditissima (Tul.)* canker on wood volume of beech (*Fagus sylvatica*) in Obcinile Humorului (N. E. of Romania)

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Abstract. The present work is the subject of some research carried out on similar stands in terms of composition and age, located in the mountain beech floors, in two forest management units of Gura Humorului Forest District. The purpose of this research is quantification of the losses of wooden mass due to bark disease attack and to show the causes that led to the appearance of infestation. Its development was made on the basis of data collected and recorded during the field campaign. In order to cover the statistics of the investigated areas, circular sample plots (500 m^2) were randomly distributed in the stands. The working method used was observation and measurements. All the trees from these surfaces were inventoried by species and biometric elements, the existing pathogen and the losses of wood mass produced were identified. It has been shown that the pathogen pursued can produce major material and economic losses for the forest district that manages these stands. Research has shown that *Nectria ditissima* is the main pathogen with the strongest attacked form on beech (*Fagus sylvatica).* The main recommendation is to avoid the injury of the trees during the harvesting process, to protect the trees next to the road during the harvest period.
Key Words: pathogen*,* beech canker, xylophage fungi infections.

Introduction. The forest has always impressed by the tree's dimensions, the richness of the component elements, massiveness and complexity of composition (Milescu 1997). Even if, through the biodiversity created and by the expansion of pioneer species in new areas, it manages to survive, it still experience annual massif losses due to natural enemies such as parasitic xylophagous fungi and insects (Tiberi & Ragazzi 1998; Boukerker & Bachir 2000). The forest protection action arose from the desire to identify and prevent external factors that cause damage to the forest (Ehrlich 1934). The timely observation of a disease, its probable evolution prediction and its spread prevention is very important for the preservation of a quality forest material (Carter & Griffith 1989; Stenlid et al 2011). Pests and diseases occur in any ecosystem, either in a state of latency or in small outbreaks that are kept under control by applying appropriate forestry measures to the environment (Grudnicki 2006). The appearance and development of outbreaks above certain limits, considered dangerous, can lead to serious disturbances in the forest ecosystems, making human intervention indispensable (Grudnicki & Barbu 2007; Piticar et al 2015). The deciduous forests, although they have a high variety of species and a certain stability in front of disturbance, when they are studied separately by stands, a multitude of pests can be identified, specific to each species. The beech (*Fagus sylvatica* L.*)* is the species with the widest area of spread at the European level, about 10% of forests (Milescu 1967). European beech plays a central role in the current forest transition strategies (Biriş 2014). As an example, in Romania the species occupies approximately 31% of the national forests (Danila et al 2013). By carrying out this research, it was found that the most affected species of those encountered and studied is the beech, a very important species both by its participation in the composition of the stand and by its use for industrial purposes after harvesting (Geßler et al 2007; Nocentini 2009).

Considering its importance, both ecological and economic research has been carried out on the contribution of the xylophagous mushrooms to the production of these

ecological and economic losses (Houston 1983). The *Nectria* canker of beech is a disease caused by *Nectria ditissima* (Tul.), which in general infects young beech trees or twigs (Metzler et al 2002). The relationship between beech trees, the beech scale and *N. ditissima* is the basic model of bark disease (Houston 1994). Lesions of the bark caused by the fungus are visible as distorted trunks and branches. Although, the disease is not a serious threat to beech trees in Central Europe, its presence in young stands can favor the appearance of poor-quality wood without high economic uses (Metzler et al 2002; Grudnicki 2006). The study provides for the analysis of the spread of the pathogen *N. ditissima* in forests with beech in their composition. The objective of this study was the quantification of the severity of the attack by establishing a number of affected trees and a depreciated volume of wood mass.

Material and Method

Study location. The research was carried out within two forest management units (U.P. administrative division of forest district) belonging to the Suceava Forestry Department and are administered by the Gura Humorului Forest District. This unit of forest production was chosen based on a stands composition of relatively similar age. For every forest management unit (u.a., division of forest management units), two stands have been selected: the stands 22A and 22B for the U.P. 5 Păltinoasa, and the stands 73A and 73B for the U.P. 1 Capu Câmpului (Figure 1).

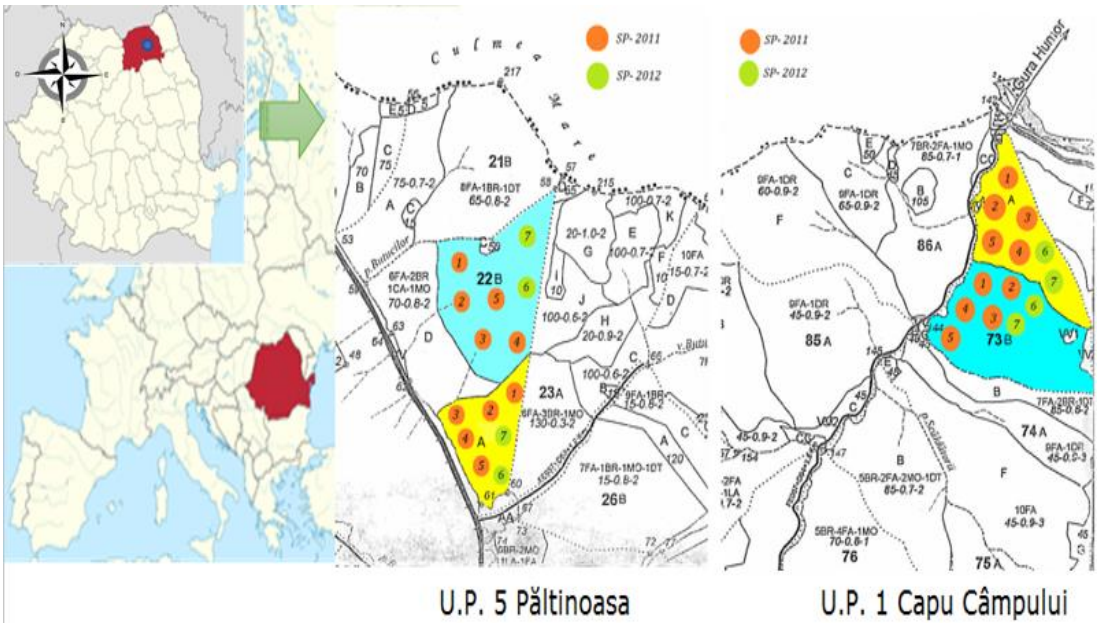

Figure 1. Study area location in N.E. part of Romania (Suceava county). Positions of sample plots at the forest management unit and stand level.

The forest surface of the U.P. 5 is 2,296.5 ha and for the U.P. 1 it is 4,352.3 ha, with 62% of beech in composition (Amenajament 2008, 2009). The studied stands are geographically located in the central part of Suceava County, in the hydrographic basin of the Moldova River. U.P. 5 Păltinoasa is located near the Păltinoasa village and the U.P. 1 Capu Câmpului is near to the Gura Humorului town.

Stationary conditions. The thermal regime specific to this area is characterized by an average annual temperature of 5°C, with monthly average values ranging from -5°C to 17°C (Sandu et al 2008; Tănasă 2011). The atmospheric precipitation regime is characterized by an annual average of 814.6 mm, with variations between 38.6 and 120.4 mm (Pătru et al 2006).

The composition of stands from U.P. 5 Păltinoasa is a mixture of beech (*Fagus sylvatica),* fir (*Abies alba)* and hornbeam (*Carpinus betulus*) in a proportion of 30:20:50

(%) in the stand 22A and 20:60:20 (%) in the stand 22B. In U.P. 1 Capu Câmpului, the composition of the stands is a mixture of beech, fir, spruce (*Picea abies*) and hardwood species in proportion of 40:40:10:10 (%) in the 73B stand and only beech with fir in proportion of 90:10 (%) in the 73A stand (Table 1 From a geomorphological aspect, within about 78% of the U.P. 5 Păltinoasa, we encounter fast slopes, ranging from 16 to 30 degrees, with partially sunny exposures. In U.P. 1 Capu Câmpului, the slope inclination reaches up to 40 degrees, the minimum being about 15 degrees, with a dominance of shaded and partially sunny slopes. The selected forest stands are situated at altitudes between 470 and 750 m above the sea level, and the main soil type is *Eutric cambisol* (Table 1).

Table 1

Description of the stands selected

Forest management units	*Stand*	*Area (ha)*	*Altitude (m)*	*Soil type*	*Stand composition (%)**
U.P. 5 Păltinoasa	22A	14.0	500-560	Eutric cambisol	30Fs20Aa50Cb
U.P. 5 Păltinoasa	22B	28.1	540-590	Eutric cambisol	20Fs60Aa20Cb
U.P. 1 Capu Câmpului	73A	20.7	470-750	Eutric cambisol	90Fs10Aa
U.P.1 Capu Câmpului	73B	30.8	500-750	Eutric cambisol	40Fs40Aa10Pa10Hs

* Stand composition percentage, where: Fs-*Fagus sylvatica*; Aa-*Abies alba*; Cb-*Carpinus betulus*; Pa-*Picea abies*; Hs-hardwood species.

Data collection. The study was conducted between 2010 and 2012. In the period 2010–2011, in all selected stands were placed 20 sample plots (circular areas with a size of 500 m^2) with 5 plots per stand (from Sp 1 to 5). From each stand a sample plot was installed as a control sample, in the absence of a pathogen, which denoted the normality of the stand production. In the next year (2011-2012), the number of sample areas was increased with two other sample plots in each stand (with 8 new sample plots in total, from Sp 6 and 7). During this period, the focus was turned to a single pathogen (*N. ditissima*).

From each sample plot all the trees were inventoried (Figure 2), determining the species and the dendrometric characteristics. The signs of infestation with different pathogens were followed, in particular the distance from the portions of the shaft spindle visibly affected by the sporifer form, to the base of the tree were measured.

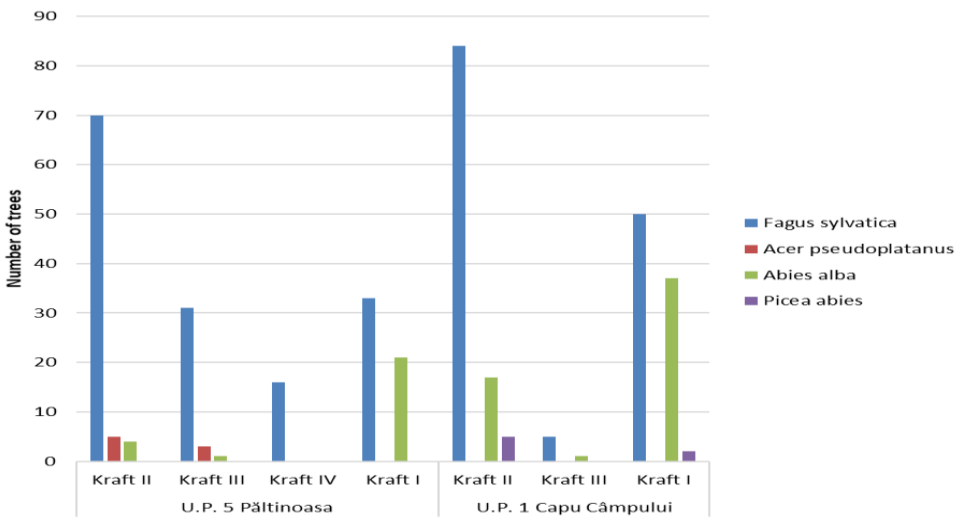

Figure 2. General info regarding the data collected.

For this paper, only the trees of *F. sylvatica* were analyzed, species predisposed to infestations of *N. ditissima*. The methods used were observation and dendrometric measurements in circular sample plots with a radius of 12.62 m for 500 m^2 each. In the sample plots, the following dendrometric characteristics were determined:
- dbh (cm) - diameter at a height of 1.30 m, measured with a forester caliper at an accuracy of 1 mm;
- tree height - H (m), measured with a Haglof 4 hypsometer, accuracy of 10 cm;
- the distance on the trunk of the tree from the wound to the sporiferous form in the case of attacked trees - L_{Af} (m);
- Kraft class (1 - pre-dominant trees; 2 – dominant; 3 - co-dominant; 4 - dominated trees; 5 - overshadowed trees);
- percentage of attacked trunk from the total tree height - P_{Af} (%).

The tree volume - V_a (m^3) was calculated using the production tables for every species (Giurgiu et al 1972). The same method was used for the estimation of the volume of wood mass affected by the phytopathogenic agent - V_{Af}.

Data analysis. The difference testing was done using the Anova test (Tukey HSD, $P \leq 0.05$) for normal distributions (aspect verified with the Shapiro-Wilk test). Otherwise, the Kruskal-Wallis non-parametric test (Dunn test, $P \leq 0.05$) was applied. The significance testing was carried out on the basis of the Pearson or Spearman coefficients (for data not following a normal distribution). Data processing and analysis was done with the application R and XLStat 2012 (Fahmy 2003; Team & Studio 2015).

Results and Discussion

Intensity of the attack by Nectria ditissima. Following the debilitated tree information of the *Nectria* pathogen, it was noticed that numerically most of the injuries were produced in the stands 22B of U.P. 5 Păltinoasa and 73A from U.P. 1 Capul Câmpului (Figure 3). The volume of unaffected wood mass is the difference between the volume of the whole tree and the volume of wood mass attacked by the watched phytopathogenic agent. The least affected by the agent was the stand 22A, where the presence of canker was observed in only four sample plots analyzed compared to the other stands where it was identified in almost all the plots (forms of the *Nectria* pathogen can be seen in Figure 4). This is also due to the low participation of the *F. sylvatica* species in the composition of the stand.

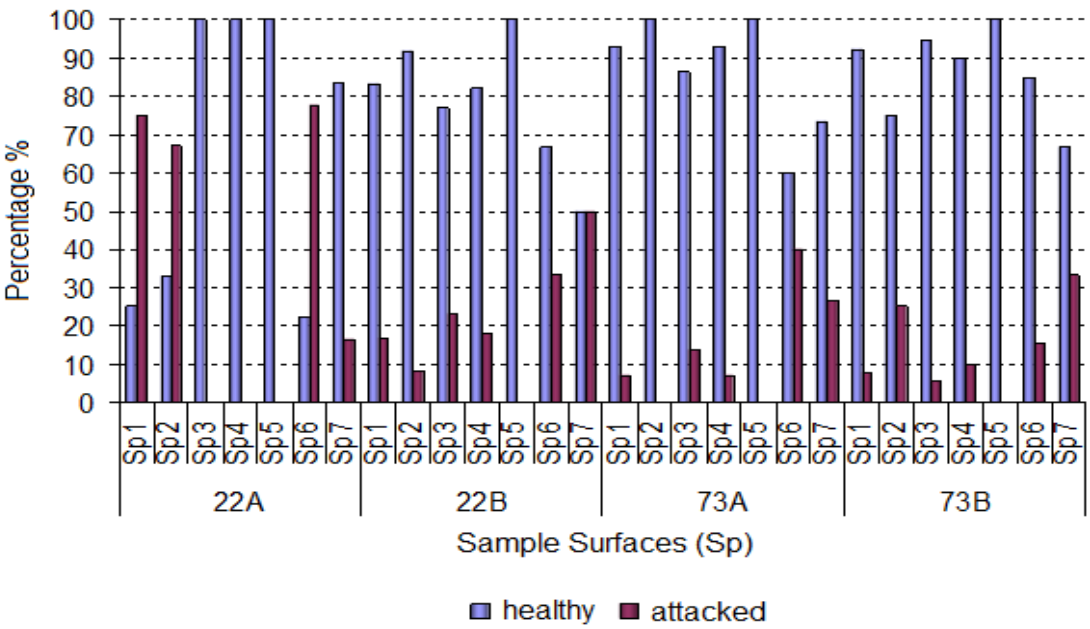

Figure 3. Proportion of trees affected by *Nectria ditissima*.

Attack of *Nectria ditissima* observed in U.P 5 Păltinoasa, stand 22B

Attack of *Nectria ditissima* observed in U.P 1 Capu Câmpului, stand 73A

Attack of *Nectria ditissima* observed in U.P 1 Capu Câmpului, stand 73B

Harvesting wounds observed in U.P 5 Păltinoasa, stand 22A

Figure 4. Different aspects of the attack produced by *Nectria ditissima* (original photos).

Losses of quality wood resulting from the attack produced by Nectria ditissima. From a volume estimation of the trees inventoried, variations are observed between the analyzed stands, from one forest management unit to another. In stand 22A the volume of wood mass affected by *N. ditissima* is approx. 2.16 m^3 (Table 2). The total volume of trees resulting is 17.6 m^3, which means a volume of wood degraded by *N. ditissima* of about 13% from the total trees inventoried. The highest percentage was found for tree number 2 of Sp 1, about 20%. The most affected sample plot was the Sp 6, where tree diameters range from 30 to 56 cm and mean tree heights are approx. 26 m (Figure 4). In this sample plot we found the highest volume of stem affected, about 0.49 m^3 for tree number 1. The smallest trees affected by *N. ditissima* are found in the Sp 7, with a total volume of 0.11 m^3. A number of 142 trees were inventoried, of which 13 were attacked by *N. ditissima*. We found that out of the 14 ha of 22A, 0.35 ha were analyzed (2.5%). If we reported the volume of wood mass degraded by *N. ditissima* from the analyzed areas to the total area of the stand, we would find that the loss at the level of wood mass attacked only by the phytopathogenic agent pursued would be of 86.4 m^3.

In stand 22B the losses of wood mass due to the attack produced by *N. ditissima* are 3.18 m^3 out of a total of 23.96 m^3 (Table 3). The highest percentage of affected stems is found in tree number 2 of SP 4 and the lowest in tree number 1 of SP 6. Although in the stand 22B the number of trees affected was smaller than in the stand 22A, the volume of wood mass degraded by the pathogen fungus is higher, due to the much larger diameters measured here as well as to the spread of the agent on the surface of the trees' bark. In this stand (22B) there were inventoried a number of 109 trees of different species. Out of this total, *Nectria* damaged the wood of a number of 9 trees, for a total volume of 3.18 m^3 of qualitatively impaired wood. If we reported this loss to the surface of the stand, we would find that, from a statistical viewpoint, there would be losses totalizing a volume of 255.3 m^3 only caused by *N. ditissima*.

Table 2

Estimation of wood mass volume affected from the stand 22A

Tree no.	*Sample plots*	*Species*	*Dbh (cm)*	*H (m)*	V_A (m^3)	L_{Af} (m)	P_{Af} (%)	V_{AF} (m^3)
1	I	beech	30	24	0.84	3.0	12.50	0.11
2		beech	34	25	1.12	5.0	20.00	0.22
3		beech	32	26	1.04	2.0	7.69	0.08
	Total Sp I		-	-	3.00	-	-	0.41
1	II	beech	44	28	2.10	3.0	10.71	0.22
	Total Sp II		-	-	2.10	-	-	0.22
1	VI	beech	56	28	3.44	4.0	14.29	0.49
2		beech	36	26	1.30	3.0	11.54	0.15
3		beech	40	26	1.60	1.8	6.92	0.11
4		beech	36	28	1.41	1.0	3.57	0.05
5		beech	44	28	2.10	1.0	3.57	0.07
6		beech	30	24	0.84	1.7	7.08	0.40
7		beech	30	24	0.84	4.0	16.67	0.14
	Total Sp VI		-	-	11.53	-	-	1.42
1	VII	beech	20	15	0.34	1.2	8.00	0.02
2		beech	28	21	0.64	2.5	11.90	0.09
	Total Sp VII		-	-	0.97	-	-	0.11
	Total stand 22A		-	-	17.60	-	-	2.16

Table 3

Estimation of wood mass volume affected from the stand 22B

Tree no.	*Sample plots*	*Species*	*D (cm)*	*H (m)*	V_A (m^3)	L_{Af} (m)	P_{Af} (%)	V_{AF} (m^3)
1	I	beech	62	31	4.75	3.0	9.677	0.46
	Total Sp I		-	-	4.75	-	-	0.46
1	II	beech	26	21	0.56	4.0	19.05	0.11
	Total Sp II		-	-	0.56	-	-	0.11
1	III	beech	58	27	3.57	5.0	18.52	0.66
2		beech	46	28	2.29	2.0	7.143	0.16
3		beech	44	27	2.02	3.0	11.11	0.22
	Total Sp III		-	-	7.87	-	-	1.05
1	IV	beech	54	28	3.19	4.0	14.29	0.46
2		beech	64	31	5.08	6.0	19.35	0.98
	Total Sp IV		-	-	8.28	-	-	1.44
1	VI	beech	28	26	0.81	1.1	4.231	0.03
	Total Sp VI		-	-	0.81	-	-	0.03
1	VII	beech	34	26	1.70	2.0	7.692	0.10
	Total Sp VII		-	-	1.70	-	-	0.10
	Total stand 22B		-	-	23.96	-	-	3.18

For the stand 73A, the distance on the trunk of the trees from the wound to the sporiferous form varies in the range of 0.9-7 m. The wounds were encountered at the base of the trunk, generally produced by anthropogenic causes (harvesting non-compliant with the wood conditions), up to the last observed sporiferous form (Table 4). The highest percentage of affected stems was found in tree number 1 of SP 3, exceeding 25% of the length of the trunk, being also the highest percentage found in this study. The average height within this SP was 29 m. A number of 133 trees were inventoried in stand 73A, on the same area of 0.32 ha. The volume of corresponding wood mass depreciated by *N. ditissima* was 3.2 m^3, almost identical to stand 22B, but on an inferior total area. In this case, the volume of wood mass degraded by *Nectria* would be of 189.26 m^3.

Table 4

Estimation of wood mass volume affected from the stand 73A

Tree no.	*Sample plots*	*Species*	*D (cm)*	*H (m)*	V_A *(m^3)*	L_{Af} *(m)*	P_{Af} *(%)*	V_{AF} *(m^3)*
1	I	beech	40	26	1.60	3.5	13.46	0.21
	Total Sp I		-	-	1.60	-	-	0.21
1	III	beech	40	27	1.67	7.0	25.93	0.43
2		beech	52	32	3.42	5.0	15.63	0.53
3		beech	52	29	3.07	7.0	24.14	0.74
	Total Sp III		-	-	8.16	-	-	1.70
1	IV	beech	40	29	1.80	2.5	8.621	0.16
	Total Sp IV		-	-	1.80	-	-	0.16
1	VI	beech	42	28	1.91	4.0	14.29	0.27
2		beech	32	28	1.13	6.0	21.43	0.24
3		beech	16	24	0.25	5.2	21.67	0.05
4		beech	36	30	1.52	1.4	4.67	0.07
5		beech	40	30	1.87	2.5	8.33	0.16
6		beech	34	26	1.17	0.9	3.46	0.04
7		beech	26	22	0.59	1.2	5.45	0.03
8		beech	24	28	0.66	3.0	10.71	0.07
	Total Sp VI		-	-	9.10	-	-	0.94
1	VII	beech	18	16	0.20	4.0	25.00	0.05
2		beech	20	20	0.32	2.5	12.50	0.04
3		beech	30	22	0.77	2.0	9.09	0.07
4		beech	24	20	0.45	1.3	6.50	0.03
	Total Sp VII		-	-	1.75	-	-	0.19
	Total stand 73A		-	-	22.41	-	-	3.20

In the stand 73B, the volume affected by *N. ditissima* for the period 2011-2012 was about 1.17 m^3, being also the stand with the lowest loss of wood material, compared to the others (Table 5).

Table 5

Estimation of wood mass volume affected from the stand 73B

Tree no.	*Sample plots*	*Species*	*D (cm)*	*H (m)*	V_A *(m^3)*	L_{Af} *(m)*	P_{Af} *(%)*	V_{AF} *(m^3)*
1	I	beech	40	26	1.60	2.0	7.69	0.12
	Total Sp I		-	-	1.60	-	-	0.12
1	II	beech	44	28	2.10	3.0	10.71	0.22
2		beech	36	28	1.41	2.5	8.93	0.13
	Total Sp II		-	-	3.50	-	-	0.35
1	III	beech	48	26	2.31	2.5	9.62	0.22
	Total Sp III		-	-	2.31	-	-	0.22
1	IV	beech	44	28	2.10	3.0	10.71	0.22
	Total Sp IV		-	-	2.10	-	-	0.22
1	VI	beech	42	26	1.76	1.0	3.85	0.07
2		beech	24	24	0.55	1.8	7.50	0.04
	Total Sp VI		-	-		-	-	0.11
1	VII	beech	38	28	1.57	2.0	7.14	0.11
2		beech	22	26	0.51	1.7	6.54	0.03
	Total Sp VII		-	-	2.08	-	-	0.15
	Total stand 73B		-	-	13.91	-	-	1.17

In the case of the stand 73B, a number of 138 trees of different species were analyzed and inventoried. Here, through the attack produced by *N. ditissima*, a volume of 1.17 m^3 from a total area of 0.35 ha was quantified as a loss of wood material. Reporting the degraded volume of the 0.35 ha to the total area of the stand, the loss would be of approximately 102.9 m^3.

Compared to our results, in a study conducted during 2001-2004 in the same conditions of the analyzed area, it was shown that the stands the most affected by diseases, including the infections with *Nectria* spp., are those in which the beech species is dominant or have in their mixture a significant percentage of beech. In this research it was proved that most wood losses are found in arboretums located on partially shaded slopes (Chira et al 2004). Compared to our stands located in U.P. 1 Capul Câmpului, on slopes with North West exposition, and in U.P. 5 Păltinoasa, on slopes with Western exposition, it can be seen that the sample plots located on partially shaded slopes (73A and 73B) present the most infested number of trees.

Comparing the volume from analyzed stands between the affected and unaffected trees by *N. ditissima*, it is noticed that the affected trees do not differ statistically (Table 6). Differences occur only between unaffected trees, where volumes vary within wider limits (Figure 4).

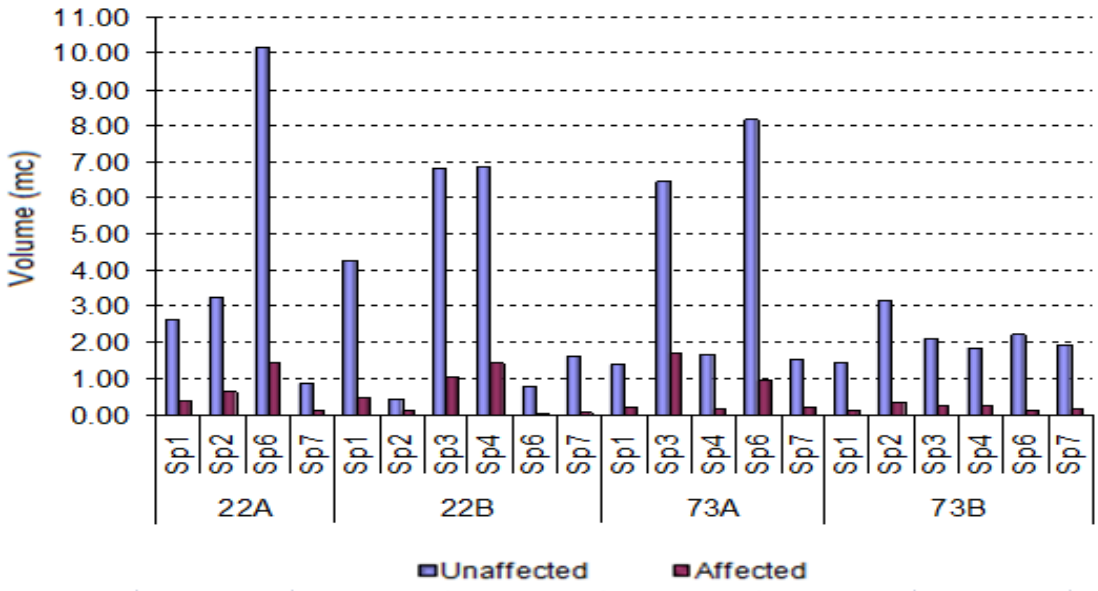

Figure 4. Distribution of volumes at sample plots and stands level.

Table 6

Anova test results for testing differences between affected and unaffected trees

Stands	*Affected trees*		*Unaffected trees*	
	Pr>Diff	*Significant*	*Pr>Diff*	*Significant*
22B vs 22A	0.490	No	<0.0001	Yes
22B vs 73A	0.612	No	<0.0001	Yes
22B vs 73B	0.666	No	<0.0001	Yes
73B vs 22A	0.961	No	<0.0001	Yes
73B vs 73A	0.999	No	0.003	Yes
73A vs 22A	0.982	No	0.005	Yes

The total volume of trees attacked, as well as the volume affected by the fungus, varies from one sample area to another. By summing all these volumes of wood mass degraded related to the total areas of the stands from Gura Humorului forest district, a significant loss of 633.93 m^3 can be observed. It is mainly due to the different diameters as well as the number of trees inventoried in each area. The sample plots the most affected by *N.*

ditissima were Sp 6 from stand 22A, inventoried in 2012, and Sp 4 from stand 22B, installed in 2011. Also, large attacks are recorded in U.P. 1 Capu Câmpului, only in stand 73A, in Sp 3, installed in 2011, and Sp 6, from 2012. It should be noted that stand 22B and 73A have many old tractor roads on which wood material was transported, thus favoring the injury of the nearby trees as well as the spread of the pathogen. The same aspects are noted in the case of crops from New Zealand, were the pathogen penetrates the trunk of the trees (especially in the harvest season when the trees are harvested by mechanized means), where there are scratches at the level of the trunk or branches (Amponsah et al 2015).

By analyzing the total volumes of trees inside each stand, it is observed that statistical differences occur between the trees of the two categories (affected and unaffected) only in the stands of 22A and 73A (Table 7). The other two stands do not significantly differ, statistically. The mean volume of the trees included in the survey varies from 0.550 m^3 in the stand 22A to 2.428 m^3 in stand 22B. Another study conducted in the Region of Elbei (North Germany) describes the attack produced by *Nectria* spp*.*, especially in the autumn period when low temperatures lead to the fall of leaves and the creation of entrance gates through the place of detachment from the branch (Weber 2014). Also, in this research is described the phenomenon of transporting spores with the help of raindrops, that favors the spread of this cancer.

Table 7

Analysis of the differences at stand level between affected and un-affected trees for the total volume of tree (m^3)

Category	*Mean*	*Stand 22A (Pr<0.0001)*	*Mean*	*Stand 22B (Pr 0.2386)*	*Mean*	*Stand 73A (Pr 0.0004)*	*Mean*	*Stand 73B (Pr 0.2133)*
Affected	1.225	A	2.428	A	1.487	A	1.570	A
Un-affected	0.550	B	1.973	A	0.917	B	1.376	A

In Romania there are many studies regarding the attack produced by *Nectria spp.* especially in the eastern areal of beech (Roibu et al 2011). It describes the presence of this type of cancer in the canopy of mature trees and the way of spreading the spores in the young stands, a phenomenon that indicates the extent of an infestation with this pathogen (Roibu et al 2012).

Conclusions. The wood mass volume degraded from Gura Humorului forest district is estimated at about 633.93 m^3. The stands with the largest volume of wood material affected by *N. ditissima* are 73A and 22B. The main factor that led to the expansion of the agent in the stands was the provision of "entrance gates" by creating wounds. Injuries are caused mainly by the anthropogenic factor, in particular by a faulty harvesting of the surrounding trees. The main favoring vector in the transport of ascospores is the wind. The reaction of infected trees is to immediately cover the wound.. In order to prevent the spread of the disease, it is recommended to avoid as much as possible the injury of trees during the forest harvesting, to protect the trees next to the road during the transport of harvested trees and to extract with priority the attacked trees and the non-usable saplings that are very vulnerable to the attack produced by *N. ditissima.*

Acknowledgements. The work of Iulian Constantin Dănilă was supported within the project entitled "DECIDE-Development through entrepreneurial education and innovative doctoral and postdoctoral research", project code POCU/380/6/13/125031, project co-financed from the European Social Fund through the 2014–2020 Operational Program Human Capital.

Conflict of interest. The authors declare no conflict of interest.

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Received: 09 July 2021. Accepted: 18 August 2021. Published online: 30 August 2021.
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How to cite this article:
Mititelu C., Ceornea C., Danila I. C., 2021 Influence of *Nectria ditissima* (Tul.) canker on wood volume of beech (*Fagus sylvatica*) in Obcinile Humorului (N. E. of Romania). AAB Bioflux 13(2):52-62.