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Quantifying growth losses induced by *Nectria* fungus in a natural beech stand situated at the eastern limit of the European area

Ana-Maria Roibu, Cătălin-Constantin Roibu, Bogdan Mihai Negrea

"Stefan cel Mare" University, Suceava, Romania, EU.
Corresponding author: C.-C. Roibu, catalin_roibu@yahoo.com

Abstract. This paper aims to briefly present the results of a study conducted on a sample surface located inside the reserve "secular Fagetul Humosu". The study highlights the growth losses occurred due to *Nectria* fungus attack. Statistics study was conducted on age and diameter classes. Thus it has been shown that growth losses due to attack of the fungus *Nectria* on big diameters are less significant than small diameters. This is a logical conclusion due to the large developpement of the foliar apparatus of the older trees.

Key Words: Growth, *Nectria*, cancer attack, growth losses.

Rezumat. Acestă lucrare are scopul de a prezenta succint rezultatele unui studiu realizat într-o suprafaţă de probă amplasată în interiorul rezervaţiei "Făgetul Secular Humosu". Studiul scoate în evidenţă pierderile de creştere survenite datorită atacului ciupercii *Nectria*. Statistica studiului s-a realizat pe clase de vârsta şi diametre. Astfel s-a demonstrat că pierderile de creştere datorate atacului ciupercii *Nectria* sânt mai însemnate în cazul diametrelor mici decât în cazul arborilor ce prezintă vârste înaintate, lucru explicabil datorită aparatului foliar mai dezvoltat al celor din urmă.

Cuvinte cheie: Creşteri, *Nectria*, atacul cancerului, pierderi de creştere.

Introduction. Beech is a characteristic species of the European continent, occupying about 10% of central, northern and south-east of it and can form pure or mixed stands. In Suceava Plateau, *Fagus sylvatica* is the main species, covering an area of 20,598.1 ha (hectares) and offering a volume of 3,464,715 m^3 (cube meters).

Although beech is a robust species considered by many research papers a climax species, it can present some serious damage. In this category we have taken into analysis pest *Nectria ditissima* Tul. f.c. *Cylindrocarpon willkommii* (Lind.) Wr. form which produces beech cancer.

Until now it is known that attack caused by *Nectria* fungus causes qualitative depreciation of beech wood. In addition to this depreciation there is a question that still has no a firm answer: can beech cancer cause decrease in growth to the beech trees?

To this question we will try to offer a relevant response based on growth samples levied from all trees of the permanent area. This is a dendrochronological research paper based on measured growth samples.

Material and Method. “Oldgrowth beech forest of Humosu” has the status of natural reserve (Giurgiu et al 2001; Paşcovschi & Leandru 1958). This forest is located in Hârlău Forest District of Iaşi Forest Administration, with an area of 73.3 ha (see Figure 1).

Table 1

Main parameters of the investigated stand

Forest District UP ua Area	*Relief Configuration Slope Altitude Exposition*	*Type of site* Type of forest Type of soil*	*Composition Origin Consistency The average age Class production Type of structure*	*Elements measured Size of experimental area*
Hârlău III Humosu 64 41.2 ha	Slope Waved 12 degrees 410-470 m Eastern	5243 4211 2409	10 FA Seed 0.7 300 Uneven age	295 trees Succesive inventories Permanent area (100m x 100m) 1.0 ha

[1]Code from the Romanian classification of soil, forest and site.

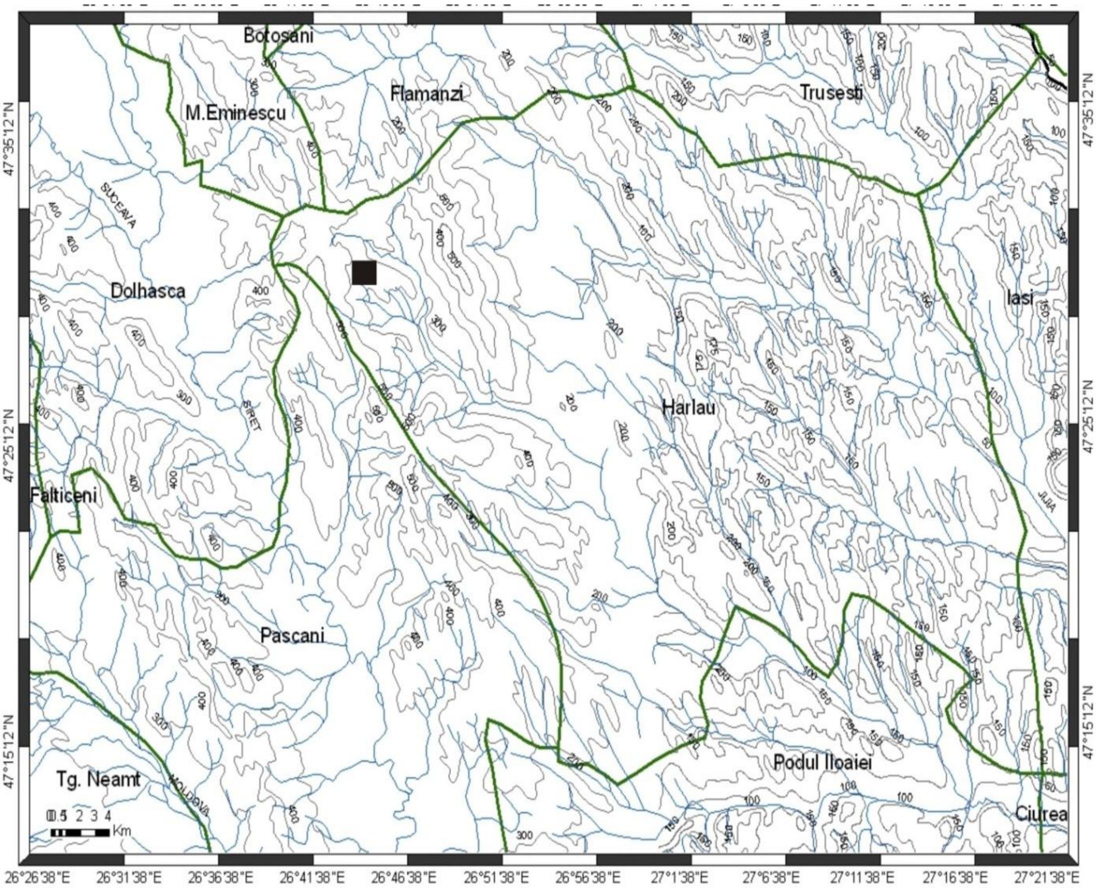

Figure 1. The map of study area.

Method of study is based on observation and experiment. As a modern method of analysis was used simulation in order to grasp the spatial structure. To fulfil its proposed objectives we adopted an experimental method based on successive biometric measurements in a natural beech stand.

The practical part of this study was a general recognition of terrain where the stand was chosen (Table 1). Inside the stand was placed, randomly, in 2006 a permanent experimental sample plot, rectangular, of 1.0 ha. In 2011 the same area was re-inventoried on the purpose of study the spatial evolution of cancer attacks produced by *Nectria* fungus.

Location, demarcation, inventory and re-inventory of trees in the experimental area was put in accordance with established methodology for studying the structure of forest ecosystems through structural profiles (Giurgiu 1979; Cenuşă 1986; Bândiu & Smejkal 1995; Nelson et al 2011).

At successive inventory of stands were registered some characteristics:

- species;
- diameter of 1.30 (cm) - were measured two perpendicular diameters;
- increasing samples (2006);
- total height (m);
- prune height (m);
- positional class (lower floor, middle, upper);
- quality class (grades I-IV);
- crown shape (broom, bucket, flag);
- diameter crown (m);
- presence of cancer in the crown (6 classes, percentage of trunk surface): K0: 0 (no cancer), K1: 1-20%, K2: 21-40%; K3: 41-60% K4: 60-85%, K5: >85%;
- branch angle insertion (degrees) (0-90^{o});
- rhytidome presence (4 classes, percentage of trunk surface): R1: <25%, R2: 26-50%, R3:51-75%, R4: >76%;
- cartesian coordinates (x, y) for each tree.

Among the methods used in achieving objectives were applied four punctual processes, Ripley K. In spatial analysis techniques, Ripley K function showed us if we have aggregate, random or regular structure (Ripley 1976).

Ripley K function is a tool for analyzing and quantifying the intensity of second order punctual process. Confidence interval for the theoretical process is obtained by Monte Carlo simulation of a number of 100 punctual processes to a probability of 95% coverage.

Results and Discussion. Successive inventories performed can offer very valuable information about dynamics of cancer attacks, concentration of attacks, the manner of spreading spores, establishing a front of tree mortality and possibilities of restoring the stand. Given the fact that the research has been performed in a natural stand, established as a natural reserve (Roibu et al 2008; Roibu 2010), we are confident that the obtained results are not distorted by human intervention with direct effects on stand structure. In these circumstances were realized three punctual processes composed of healthy trees (H), medium affected trees (M) and severely affected trees (S). First we will analyse the whole common period of the three types of attack (healthy trees, medium affected trees and severely affected trees) (Figure 2).

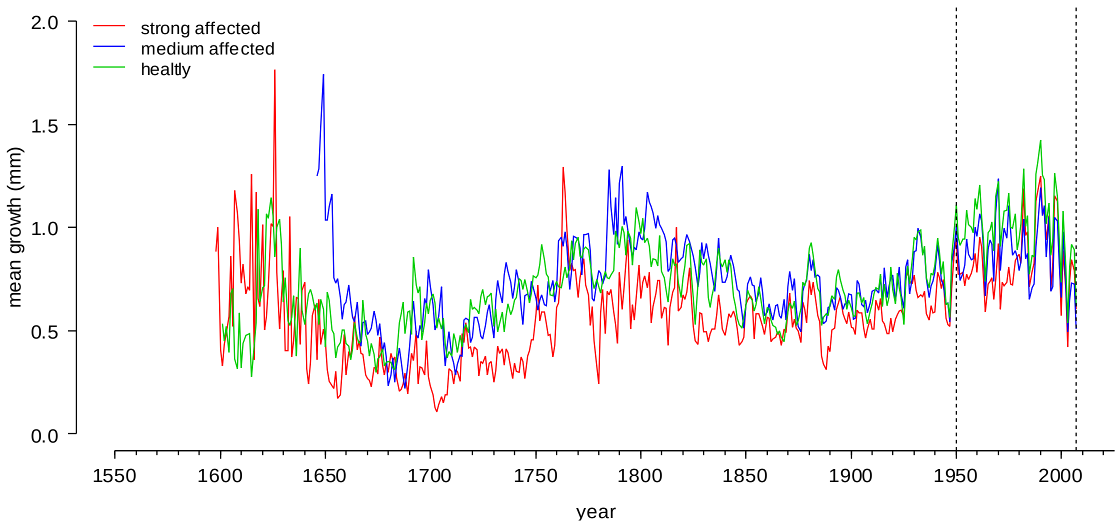

Figure 2. Radial growth dynamics of trees in relation to the attack intensity.

This type of analysis, based on the entire common period does not identify visible growth losses, aspect demonstrated through application of *t* statistics. Undetecting of some growth differences can be explained by the fact that recent trees classified in intensity classes of the attack, were not evenly exposed to *Nectria* fungus infections.

Still, we can observe periods (1650-1850) in which the trees considered ill at present day, had significantly lower growth compared to those healthy. Interesting to note is the fact that in this interval medium affected trees have the most vigorous increases. However, these findings can be quite distorted, primarily due to the reduced number of trees in this period. Secondly, because of a large period of analysis, possible losses of growth cannot be attributed to cancer attack. In this period a variety of endo- and exogenous factors, induces major changes in growth processes. For this reason all analyses of quantification of growth losses have started from the premise that the visible attacks of the *Nectria* fungus currently are older than 50 years. For a better relevance of results were established two study periods 1950-2007, respectively 1990-2007 (see Figure 3).

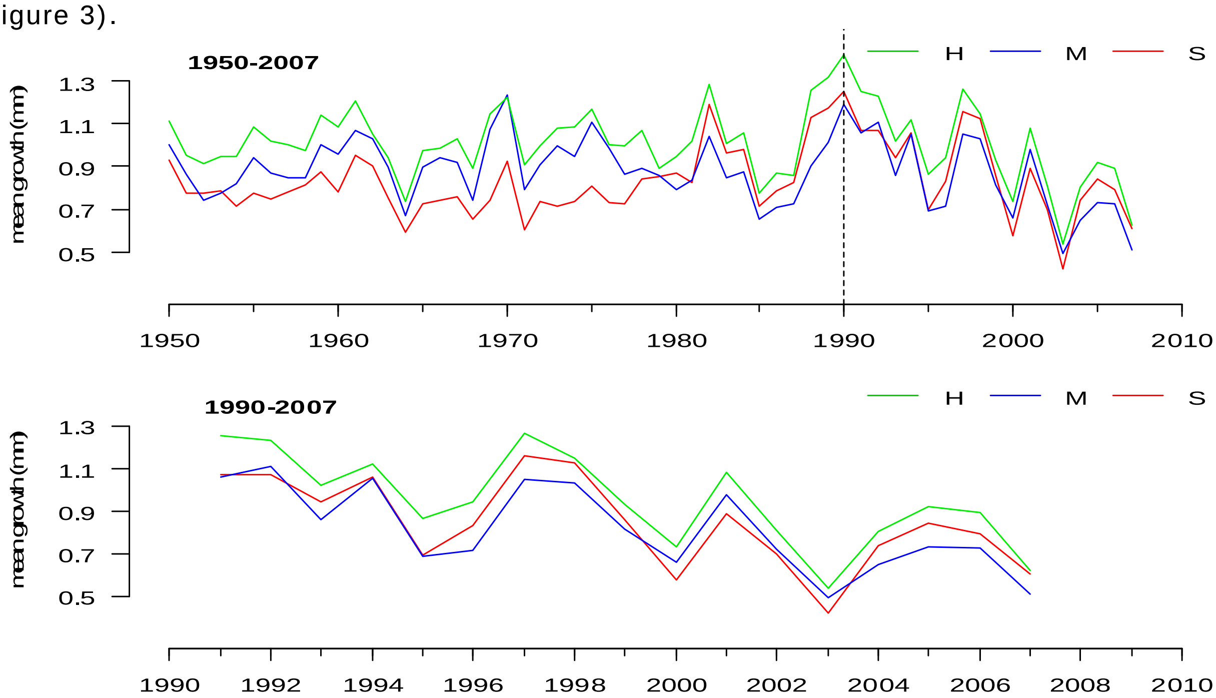

Figure 3. Radial growth dynamics of trees in relation to the intensity of cancer.

In the graphic that reflects the radial growth during 1950-2007 can be observed a clear distinction (as regards growth) between healthy trees and those most affected. This finding is valid between 1990 and 2007 except the fact that gap of differences is reduced. To determine the statistical significance of these differences will be used *t* test (Table 2).

Table 2

Application of *t* statistics for testing significance of growth losses

Variable	Mean *x (mm)*	Mean *y (mm)*	t-value	Df	p	Signification
			1950-2007			
H vs S	0.7281918	0.5626757	10.5922	720.95	0.0000	significant
			1990-2007			
H vs S	0.9516583	0.8457120	1.4563	31.984	0.155	insignificant

Application of *t* test allowed us to emphasize statistically significant differences between radial growths of healthy trees compared to those affected. Growth losses induced by the *Nectria sp*. fungus attacks, registered in the last 57 years, are situated around 22.75%. On these we can draw that cancer attacks cause important reductions of growth processes, reaching up to quarter of healthy tree growth. This conclusion has a novelty character in the Romanian forest research, being demonstrated for the first time the negative impact of *Nectria sp.* cancer on radial growth of beech tree.

When analysis is done on a smaller range (27 years), growth losses persists, but there are statistically insignificant. This reduction can be primarily motivated by the high frequency of dry periods after the 1990's, knowing that the last two decades have been among the warmest of the last century. Therefore, climatic parameters become determinants of annual ring width, cancer having no more a defining influence. For these reasons growth losses in this period are estimated around 11%. A synthetic representation of the variation to average radial growth is presented by box plot graphs (see Figure 4).

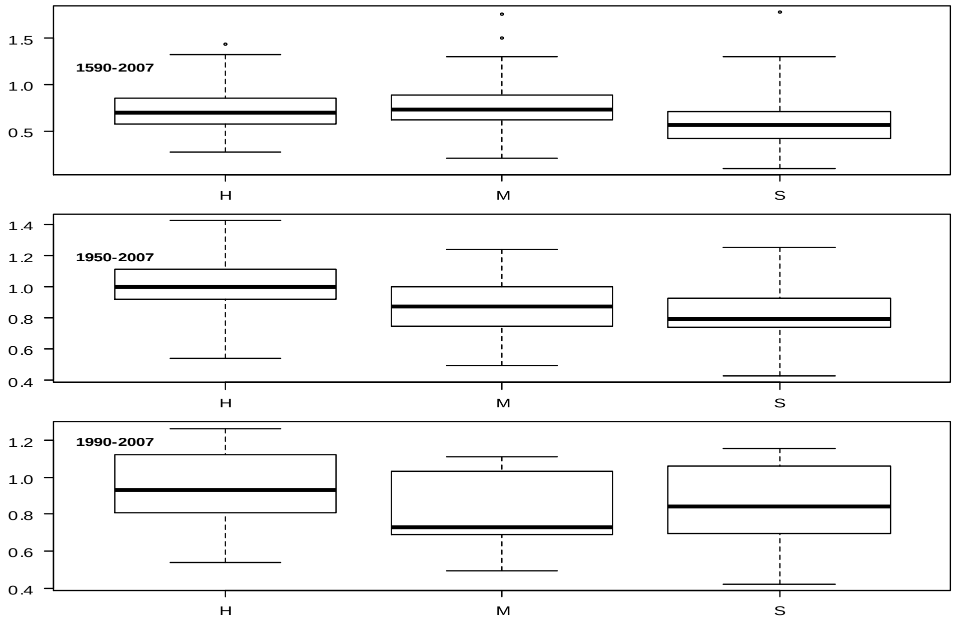

Figure 4. Mean increases of the trees on width categories and classes of cancer intensity.

This type of graph complements *t* test, and once again shows major growth differences between healthy trees and those strongly affected by cancer.

For the first type of analysis samples taken from all trees were stratified only by intensity of attack. There were not taken into account a range of biometric and auxological particularities of trees. For this reason, below, we present the dynamics of radial trees growth in relation to the intensity of cancer attacks, thickness and their cenotic position. In this case, due to the small number of medium and large size trees with strong attacks, we chose to compare the dynamics of radial growth of healthy trees and medium affected trees. To identify growth losses for each cenotic layer in part, were kept the two periods mentioned above (see Figs 5-6).

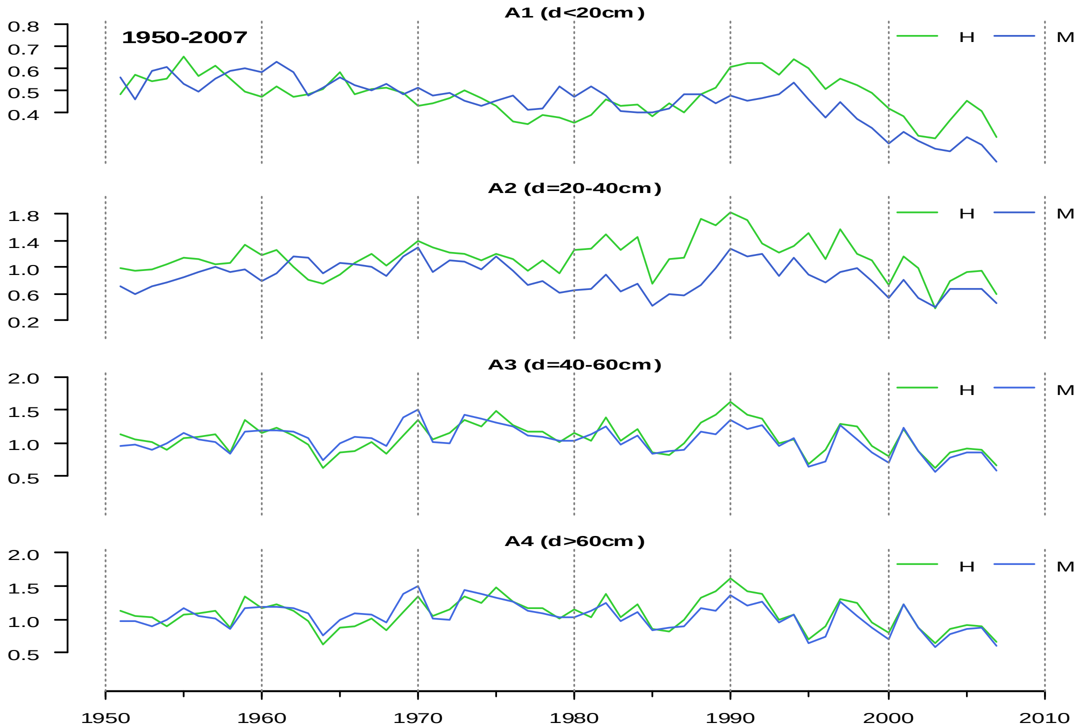

Figure 5. Radial growth dynamics on diameter categories and classes of attack intensity during 1950-2007.

Graphical analysis illustrates the clear differences between healthy tree growths and those who are affected, especially among those in lower and middle layer. This finding was statistically tested by applying the (*t*) Student test (Table 3).

Table 3

Application of *t* statistics for testing losses of growth significance between 1950 and 2007

Variable	Mean *x (mm)*	Mean *y (mm)*	*t*-value	Df	p	Signification
HA1 vs MA1	0.4783900	0.4569304	1.1803	109.9	0.2404	insignificant
HA2 vs MA2	1.1392707	0.8531927	6.1158	107.117	0.0000	significant
HA3 vs MA3	1.076928	1.043127	0.8373	111.482	0.4042	insignificant
HA4 vs MA4	1.765512	1.380462	5.8358	110.736	0.0000	significant

Application of statistical test had confirmed the initial assumptions. In this sense we can conclude that for a period of 57 years, the strongest growth losses caused by the attack of *Nectria* fungus are among trees with diameters between 20 and 40 cm. Growth loss is around 25%. Thick trees (d > 60 cm), in this interval, showed a significant loss of growth, estimated at 21%. Overall, we state that for a longer period, growth processes are affected from cancer attack among medium and large diameter trees.

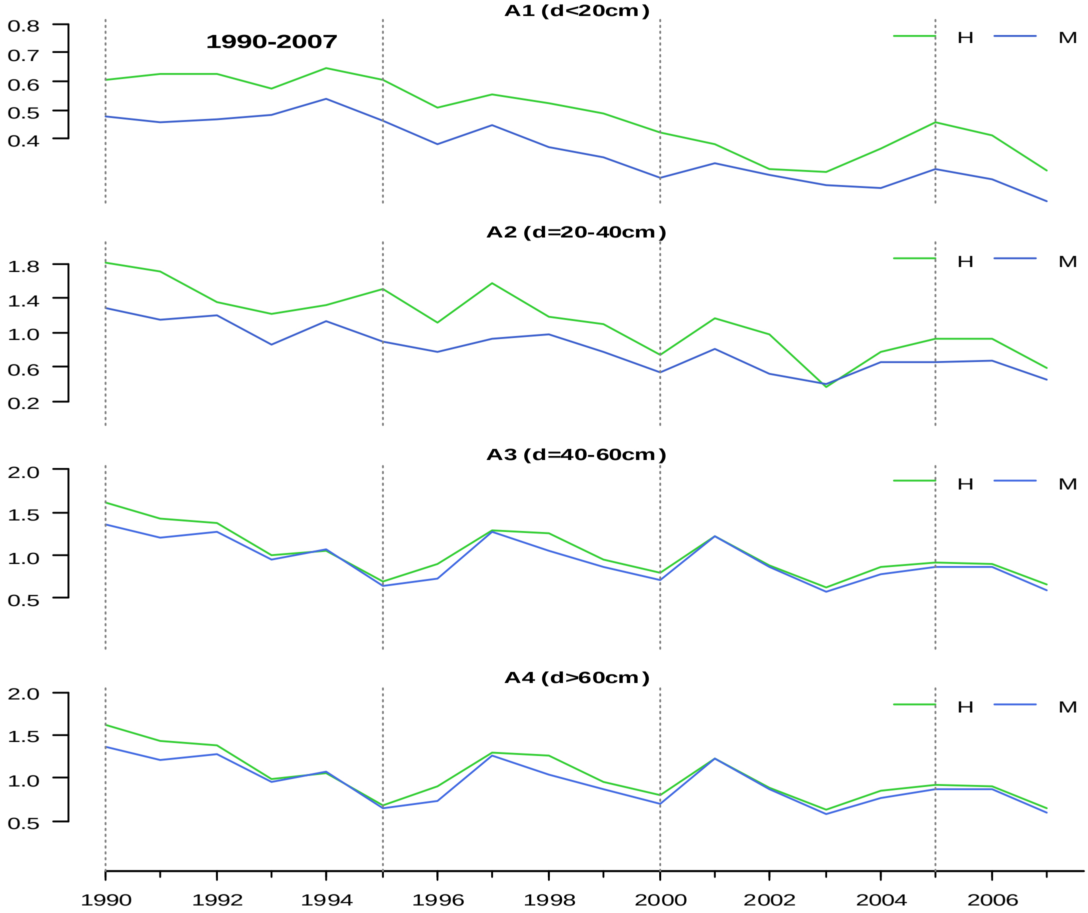

Figure 6. Radial growth dynamics on diameter categories and classes of intensity attack during 1990-2007's.

When the survey period is reduced by half (three decades), negative auxological effects of cancer attacks focus among trees with diameters up to 40 cm, the rest of individuals (diameters over 40 cm) did not had any obvious loss of growth. This finding was confirmed by applying the *t* statistics (see Table 4).

Table 4

Application of *t* statistics for testing significance of growth losses between 1990 and 2007

Variable	Mean *x (mm)*	Mean *y (mm)*	*t*-value	Df	p	Signification
HA1 vs MA1	0.4810874	0.3592063	3.1517	33.449	0.003414	significant
HA2 vs MA2	1.1325476	0.8165938	2.8903	30.059	0.007081	significant
HA3 vs MA3	1.0245385	0.9393824	0.9567	33.556	0.3456	insignificant
HA4 vs MA4	1.652283	1.479070	1.2393	33.359	0.2239	insignificant

t-Test, confirmed the above mentioned, meaning that trees with medium intensity attack with diameters under 40 cm, have significantly reduced radial growth compared with trees with the same dimensions, but healthy. Growth losses in this case are around 27.5%. Regarding trees with diameters over 40 cm, they have also growth losses, but statistically insignificant. General situation related to radial growths is shown by box plot graphs application (see Figure 7).

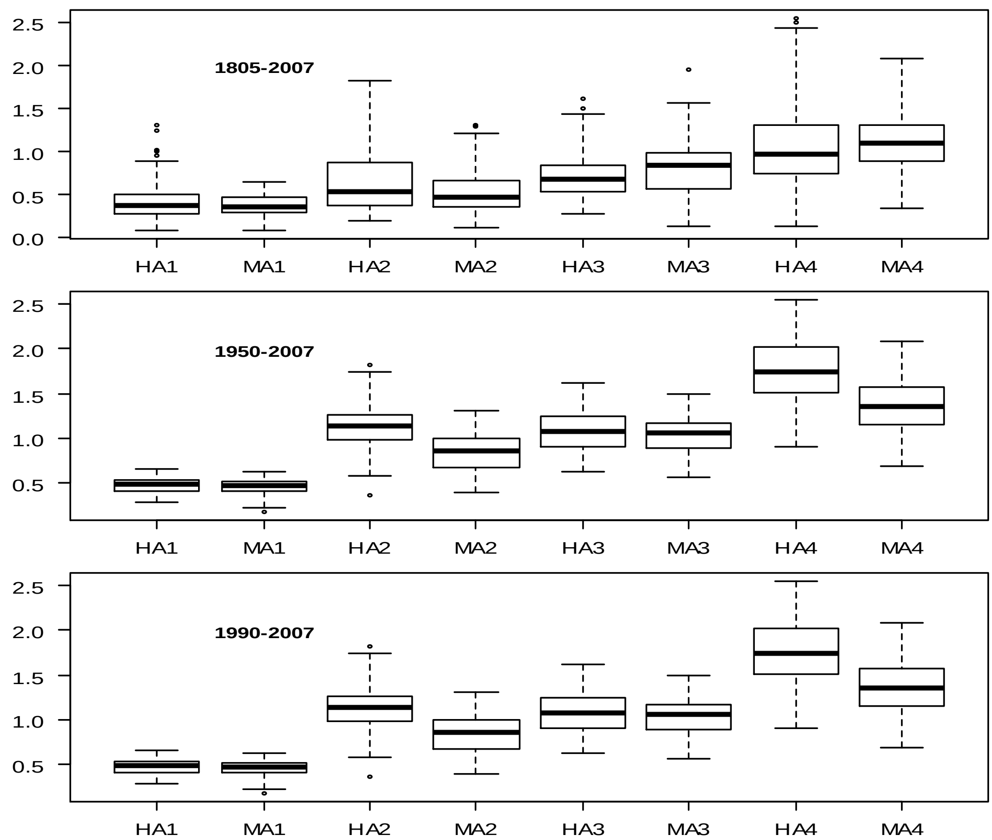

Figure 7. Mean width of the trees on categories and classes of cancer intensity.

This type of chart allows visualization of average and quantile. Also using this representation we confirm the results obtained by applying *t* statistics.

Finally, we appreciate the fact that there is a loss of dynamic growth in relation with trees dimensions. Also, in relation to a short period of time, negative influences affect trees with small dimensions. In this way was observed the initiation point of the fungus attack. When was doubled the reference range, it appears that loss of growth continues, mostly to the trees from medium layer. Surprising are the growth losses recorded at trees with large dimensions. Those trees, for a short period do not show significant growth reduction, but when we refer to a longer time period, negative effects in terms of radial growth are significant. This finding may be attributed to the fungus preferences for young tissues found at the crown level. Due to large amount of vegetative tree apparatus (especially twigs and leaves), physiological processes are not strongly perturbed, and growth losses are evident only over long periods of time.

Conclusions. Growth trees, as we all know, is determined by a complex of factors, including exogenous ones. The main conclusions of this article show how attack caused by *Nectria sp.* fungus affects bioaccumulation processes of beech.

Highlighting such effects was possible only after a stratification of data in relation to thickness of trees, layer vegetation and attack intensity. Because cancer effects on beech growth are not constant during the entire life of trees, were adopted two periods of analysis: 1990-2007, respectively 1950-2007.

In relation to thickness it was found that for a long period of time, auxological effects of cancer attack are visible among medium and large diameter trees, losses of growth hovering around 20-25%. These results, in premiere for Romania, are in accordance with the literature researches. Starting from this premise, results provide the possibility of deeper investigation, based on xylotomy techniques, which will have demonstrated that the cancer produced by *Nectria sp.* fungus induces different rate of cambial activity.

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Authors:
Ana-Maria Roibu, Faculty of Forestry, University "Stefan cel Mare" Suceava, University Street no. 13, 720229, Suceava, Romania, EU; e-mail: ana33cre@yahoo.com;
Cătălin-Constantin Roibu, Faculty of Forestry, University "Stefan cel Mare" Suceava, University Street no. 13, 720229, Suceava, Romania, EU; e-mail: catalin_roibu@yahoo.com;
Bogdan Mihai Negrea, Faculty of Forestry, University "Stefan cel Mare" Suceava, University Street no. 13, 720229, Suceava, Romania, EU, e-mail: bogdannm@yahoo.com
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