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Five-Year Impacts of Swiss Needle Cast on Douglas-fir in Interior Forests of Oregon, USA

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Abstract – In 2001 and 2006, we examined 590 Douglas-firs in 59 stands age 10-23 years in the northern Cascade Mountain foothills in Oregon, USA. Mean 5-year-dbh growth was 6.1 cm and total-height growth was 3.6 m. Mean needle-retention index increased by 3.4 over 5 years, and mid-crown retention increased by 1.2 years. Mean percentages of stomata occluded by pseudothecia of *Phaeocryptopus gaeumannii* were 13.6% for 2000-(2-year-old) needles and 1.7% for 2001-(1-year-old) needles sampled in 2002, and 13.3% for 2004 (2-year-old) needles sampled in 2006. Mean crown-length to sapwood-area ratio was 5.2 cm/cm^2 in 2006. There were poor correlations (R^2 <0.3) among all variables except for a moderate correlation between stand elevation and either 2000-stomata occluded (R^2 = 0.43) or 2004-stomata occluded (R^2 = 0.50), where there were fewer pseudothecia at the higher elevations. Either 5 years is not enough time to evaluate the affects of Swiss needle cast on Douglas-fir growth in the Oregon Cascades or there was no significant effect of Swiss needle cast during the latest outbreak on Douglas-fir growth. Based on our results and their interpretation, forest managers may need not alter their current practices in the northern Oregon Cascades, and managing a mix of Douglas-fir and western hemlock at lower elevations and noble fir at higher elevations will help offset any future stand-growth declines due to Swiss needle cast.

***Phaeocrytopus gaeumannii / Pseudotsuga menziesii /* tree growth loss**

Kivonat – A svájci tűhullás ötéves hatása a duglászfenyőre Oregon belső erdeiben. 2001-ben és 2006-ban 590 darab duglászfenyőt vizsgáltunk 59, 10-23 éves állományban, az északi Cascade-hegység lábainál, az USA Oregon államában. Az ötéves mellmagassági átmérő növedékátlaga 6,1 cm, az összes magassági növedék pedig 3,6 m volt. Az átlagos tű-megtartási mutató 3,4-re emelkedett az öt év alatt, és a közép korona-megtartás 1,2 évvel nőtt. A *Phaeocryptopus gaeumannii* pszeudotéciumai által eltömött sztómák átlagos aránya 2002-ben 13,6 % volt a 2000 évi (két éves) tűknél és 1,7% a 2001 évi (1 éves) tűknél. A 2006-ban gyűjtött tűknél ez az arány 13,3% volt a 2004-es (két éves) tűk esetében. A koronahossz és a szíjácsterület átlagos aránya 5,2 cm/cm^2 volt 2006-ban. A változók közötti korreláció gyenge volt (R^2 <0,3), kivéve az állományok tengerszint feletti magassága és a 2000 évi eltömött sztómák (R^2 = 0,43), illetve 2004 évi eltömött sztómák (R^2 = 0,50) közötti mérsékelt korrelációt, amely szerint magasabb helyeken kevesebb volt a pseudotéciumok száma. Vagy az 5 év kevés volt a svájci tűhullás duglászfenyő növekedésére való hatásának

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kimutatására, vagy a betegség legutóbbi kitörésének nem volt szignifikáns hatása a fafaj növekedésére az oregoni Cascade-hegységben. Eredményeink alapján az erdőgazdálkodóknak nem kell megváltoztatniuk az eddigi gyakorlatot, vagyis az alacsonyabb helyeken duglászfenyőt nyugati hemlokfenyővel elegyesen, a magasabb helyeken *Abies procera*-t termesztve kivédhető az állományok svájci tűhullás okozta jövőbeni növedékcsökkenése.

***Phaeocrytopus gaeumannii / Pseudotsuga menziesii /* növedékvesztés**

1 INTRODUCTION

Swiss needle cast (SNC), caused by the fungus, *Phaeocryptopus gaeumannii*, is one of the most damaging diseases affecting Douglas-fir (*Pseudotsuga menziesii*) in the Pacific Northwest, USA (Hansen et al. 2000). Biological impact is particularly acute on the Oregon and Washington Coast, one of the most productive regions for forest growth in the temperate world. In 2006, aerial-detection surveyors mapped 131,360 ha of Douglas-fir forest with obvious symptoms of SNC. Annual Douglas-fir volume-growth losses from SNC are estimated at about 23% over 75,680 ha with some losses as high as 52% in northwest Oregon (Maguire et al. 2002).

Although impact from SNC occurs in interior forests in the northern Cascade Mountains of Oregon, it is assumed to be less than damage in the Oregon Coast Range. In 2001, baseline monitoring plots were established in 59 stands covering 809,400 ha in the Cascade Mountains. It was essential that these plots be re-measured in order to determine the 5-year change and biological impact of SNC on Douglas-fir growth in the Oregon Cascades. These plots are the only source of data for SNC impact in the Oregon Cascade Mountains. Therefore, objectives of our study were to determine changes after 5-years (2001 to 2006) in 1) tree diameter and total-height growth and 2) Swiss needle cast severity as estimated by needle retention, stomata occlusion, and crown length/sapwood area ratio in 59 stands in the northern Oregon Cascade Mountains.

2 METHODS

From April to June**,** 2001, prior to Douglas-fir budbreak, transects were installed in 59 stands. Sampled stands were 10- to 23-years old and contained more than 50% Douglas-fir. Stands were systematically located on lands administered by the USDA Forest Service, USDI Bureau of Land Management, Weyerhaeuser Corp., Port Blakely Trees Farms, and Longview Fibre in the northern Oregon Cascade Mountains (Freeman 2001). Each stand has one transect with five sample points located at 15-m intervals. Transects were established in a location representative of the stand. Stand data collected in 2001 included: 1) elevation, 2) slope aspect (8 cardinal points), 3) slope %, and 4) some Global Positioning System (GPS) coordinates at the start of each transect.

At each sample point, the nearest co-dominant or dominant Douglas-fir on each side of the transect was selected for a total of 10 trees per stand. Sample trees were without damage from agents other than SNC. Data collected for each tree in 2001 included: 1) diameter at breast height (dbh at 1.4 m above ground, nearest cm), 2) total height (nearest 0.3 m), 3) height to lowest live branch, 4) ocular estimation of foliage retention in the mid-crown (0 to 6 yrs), and 5) foliage–retention index of a sampled branch. Heights were measured with a clinometer. Live-crown ratios for each year were calculated by subtracting height to lowest live branch from total-tree height for live-crown length, and then dividing crown length by total-tree height and multiplying by 100.

Foliage-retention index was calculated for each sample tree as follows: a live branch at mid-crown was selected on the S side of the sample tree and cut from the stem with the pole pruner, if necessary. From the cut branch, a secondary lateral branch was selected, and the amount of foliage remaining in each needle age class was rated and recorded as: 0 = 0 to10% of full compliment present, 1 = 11 to 20% present, 2 = 21 to 30% present, 9 = 90 to 100% present. Ratings were summed for a minimum score of 0 and a maximum of 36 for each branch. Needle retention has been shown to be the most reliable and efficient variable when estimating SNC severity in terms of tree volume-growth loss (Filip et al. 2000, Hansen et al. 2000, Maguire et al. 2002). Needle retention as estimated from the mid-crown is considered more reliable than upper- or lower-crown estimates, especially for larger trees.

In 2002, 37 of the 59 stands were sampled for pseudothecia density. For 5 sample trees per stand (1 tree per plot pair), a live branch as sampled above was returned to the laboratory for pseudothecia estimates. Pseudothecia density, measured as the percentage of needle stomata occluded, is a direct method of determining the presence and severity of *P. gaeumannii*. Measurements were made on the last 2 years of needles only (1- and 2-year-old needles). Foliage from 10 of 37 stands was sampled for *P. gaeumannii* DNA (Freeman 2002, Winton et al. 2006).

From April 17 to June 17**,** 2006, the 59 stands sampled in 2001 were relocated using reference maps, aerial photos, and, if recorded, GPS coordinates. GPS coordinates were collected for all stands at the start of each transect. The same data as collected in 2001 were collected for each tree in the 59 stands. If a sample tree was dead, the cause was recorded, and a live Douglas-fir tree was selected near the dead tree. Total height, height 5 years ago (to verify past data), and height of the lowest live branch were measured with a laser height measurer (Laser Technology, Inc.). For three sample trees per stand, foliage from severed branches was placed in a sample bag, labeled as to stand number; and processed in the laboratory for pseudothecial counts, which differed from the 2002 sampling. Instead of ocular counts of pseudothecia as done in 2002, sampled needles were placed under an imager connected to a laptop computer, and the percentage of stomata occluded was estimated.

Crown-length to sapwood-area ratio (CL:SA) was estimated for one tree in a plot pair (5 trees per stand). CL:SA has been shown to effectively discriminate among stands with varying degrees of SNC (Maguire – Kanaskie 2002). Variables measured to estimate 2006 CL:SA were: 1) live-crown length (as calculated above) and 2) sapwood radius at dbh. Sapwood radius (nearest mm) and tree age at dbh were measured from an increment core taken on the side of the tree facing the transect for one tree in a plot pair (5 trees per stand).

Because some stands were thinned and stand density can influence tree growth, total basal area/ha and basal area/ha of Douglas-fir were calculated around one sample tree at each of the five sample points. Total plot basal area was measured around each sample tree by counting all in-trees with a prism and multiplying by the basal area factor (BAF=10). Only trees $\geq$2.5 cm dbh and all tree species including hardwoods were counted. All data were entered into an Excel spreadsheet where R^2 values were calculated from selected graphed data.

3 RESULTS AND DISCUSSION

We sampled 590 Douglas-firs in 59 stands from April 17 to June 17, 2006. Stands ranged in elevation from 150 to 1300 m and % slope from 0 to 60. Total basal area (m^2) per ha averaged 18.2 with a range of 4.6 to 36.3. Some stands had been precommercially thinned either before or after initial plot establishment in 2001. Some plot trees were accidentally felled, and these were replaced with other trees in 2006. Douglas-fir basal area (m^2) per ha averaged 16.1 with a range of 4.6 to 36.3. Other stand species included western hemlock (*Tsuga heterophylla*) at the lower elevations and noble fir (*Abies procera*) at the upper elevations.

Mean 5-year-dbh growth was 6.1 cm (range = 3.0 to 8.6) and total-height growth was 3.6 m (range = 2.3 to 4.7). Mean live-crown ratio (LCR) decreased by 9.1% (range = 3.7 to -28.0) over 5 years, but 7 of 43 (16%) stands increased in mean LCR. Although the trend was for tree growth to increase with decreasing stand density, correlations were poor for both 5-year-dbh growth (R^2 = 0.05) and total-height growth (R^2 = 0.02). Recently thinned stands (lower basal areas) may not have had enough time to show any density-reducing effect. Also, diameter growth has been shown to substantially increase with precommercial thinning, but height growth of young Douglas-fir was independent of stand density for the ranges tested (11.5-63.3 m^2/ha) (Tappeiner et al. 1982).

Mean needle-retention index increased by 3.4 (range = -3.4 to 11.8) over 5 years, and mid-crown–foliage retention increased by 1.2 years (range 0.2 to 2.3). In 2006, many trees had a partial fifth-year and some a partial sixth-year complement of needles, but these were not reflected in retention indexes that score only the last 4 years of needles. Mid-crown-retention ratings, however, did capture 5 and 6-year needles. Needle retention in healthy Douglas-fir does not increase with tree age, at least over a relatively short period (5 years), so the observed increase is probably due to decreasing defoliation by SNC.

Mean percentages of stomata occluded by pseudothecia were 13.6% for 2000-(2-year-old) needles and 1.7% for 2001-(1-year-old) needles sampled in 2002, and 13.3% for 2004-(2-year-old) needles sampled in 2006. There was a poor correlation between the 2001-foliage retention and percentage of 2000-needle (2-year-old) stomata occluded (R^2 = 0.15, *Figure 1*) and 2001-needle (1-year-old) stomata occluded (R^2 = 0.03). Correlation between 2006-foliage retention and 2004-(2-year-old) needle stomata occlusion was slightly better (R^2 = 0.22). In the Oregon Coast Mountains, Hansen et al. (2000) showed that increasing proportions of stomata occupied by pseudothecia were associated with increasing defoliation. They recorded, however, mean pseudothecia densities up to 50% in 1-year-old foliage and foliage retention as low as 1 year, whereas our highest mean pseudothecia density was 11% in 1-year-old needles and our lowest mean foliage retention was 2.3 years. All pseudothecia collected in the Cascade Mountains in 2002 were from lineage 1 (Winton et al. 2006).

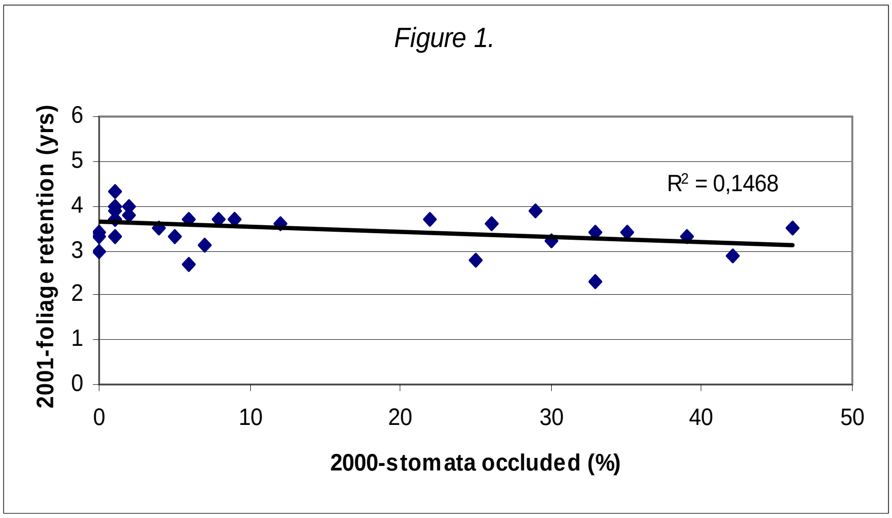

Figure 1. Graph showing correlation between the number of years of 2001-foliage retention at mid-crown and the percentage of 2000-(2-year-old) needles occluded by pseudothecia of Phaeocryptopus gaeumannii.

There was a moderate correlation between stand elevation and 2000-stomata occlusion (R^2 = 0.42) or 2004-stomata occlusion (R^2 = 0.50), where there were fewer pseudothecia at the higher elevations (*Figure 2*). Although correlations were poor (R^2 = 0.14 for 2001 and 0.21 for 2006), the trend was for foliage retention to also increase with elevation. Correlations between slope percent and either 2000-stomata occluded (R^2 = 0.25) or 2004-stomata occluded (R^2 = 0.14) were poor with occlusion decreasing with slope percent. Correlations between slope percent and either 2001-foliage retention (R^2 = 0.14) or 2006-foliage retention (R^2 = 0.05) were also poor with foliage retention increasing slightly with slope percent.

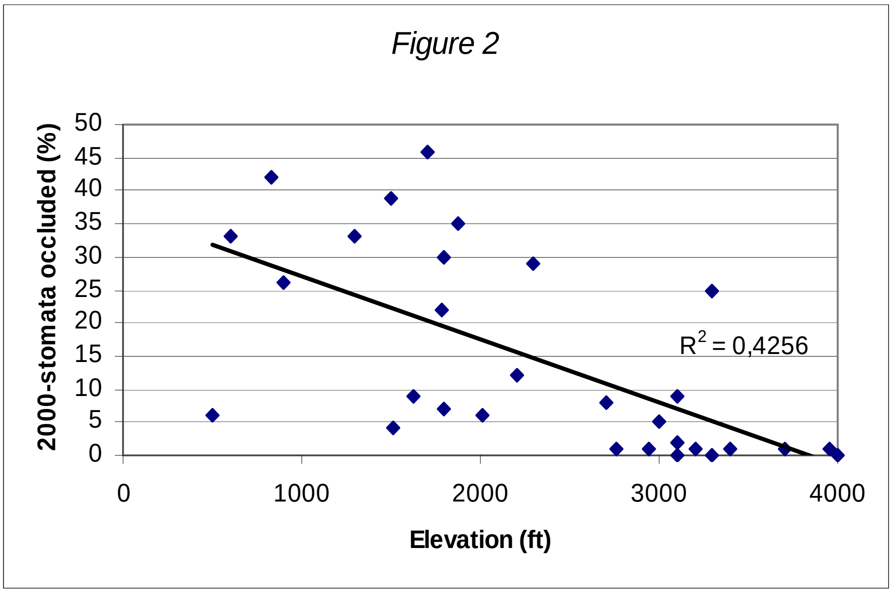

Figure 2. Graph showing correlation between the percentage of 2000-(2-year-old) needles occluded by pseudothecia of Phaeocryptopus gaeumannii and mean stand elevation. Pseudothecia decreased with increasing elevation.

Crown-length to sapwood-area ratio at dbh (CL:SA) averaged 5.2 cm/cm^2 (range 2.3 to 9.0) in 2006. Higher CL:SA values usually indicate poorer-growing stands; however, all of the Cascade stands sampled were in the lower range of CL:SA values for coastal Douglas-fir stands age 3-28 years that range from 3 to 24 CL:SA at crown base (Maguire – Kanaskie 2002) and for commercially thinned coastal Douglas-fir age 28-69 years that ranged from 5-18 CL:SA (Mainwaring et al. 2005). Although the trend was higher CL:SA values with poorer growing Cascade stands, correlations were poor with both 5-year-dbh growth (R^2 = 0.04) and total-height growth (R^2 = 0.05). There were also poor correlations between 2006 CL:SA and 2001-foliage retention (R^2 = 0.003), 2006-foliage retention (R^2 = 0.02), 2000-stomata occluded (R^2 = 0.20), or 2004-stomata occluded (R^2 = 0.18) .

There were poor correlations between 2001-foliage retention and 5-year-dbh growth (R^2 = 0.02, *Figure 3*) and total-height growth (R^2 = 0.01, *Figure 4*), between 2000-stomata occluded and 5-year-dbh growth (R^2 = 0.02) and total-height growth (R^2 = 0.03), and between 2004-stomata occluded and 5-year-dbh growth (R^2 = 0.02) and total-height growth (R^2 = 0.04). Either 5 years is not enough time to evaluate the affects of Swiss needle cast on Douglas-fir dbh growth in the Oregon Cascades, or there was no significant effect of Swiss needle cast on Douglas-fir growth during the latest outbreak.

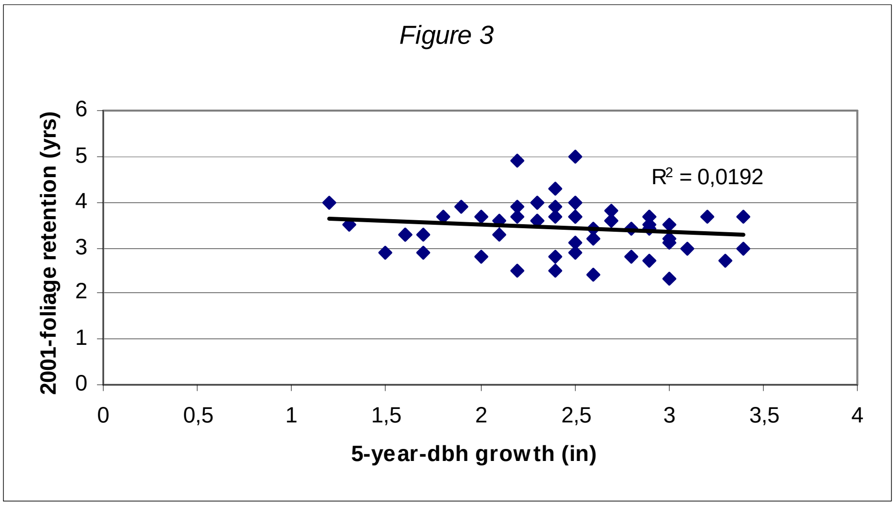

Figure 3. Graph showing correlation between the number of years of 2001-foliage retention at mid-crown and 5-year-dbh growth of Douglas-fir from 2001 to 2006

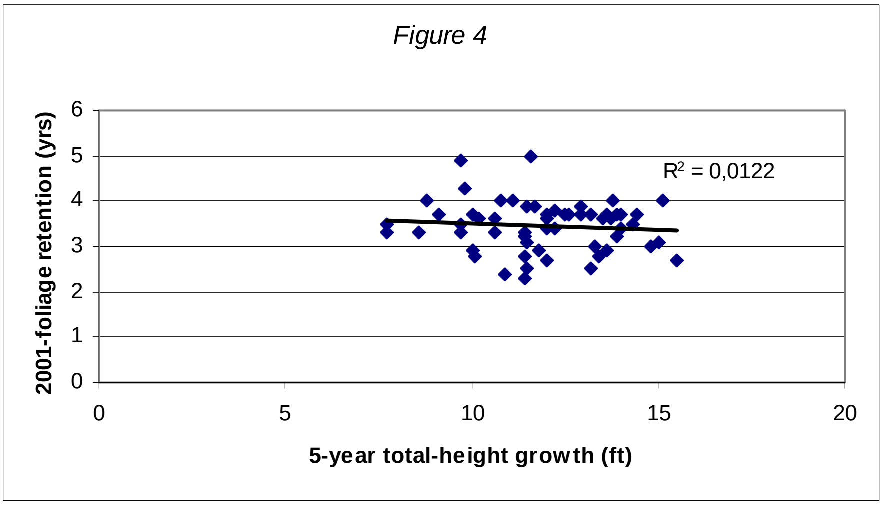

Figure 4. Graph showing correlation between the number of years of 2001-foliage retention at mid-crown and 5-year total-height growth of Douglas-fir from 2001 to 2006

4 CONCLUSIONS

There are at least two possible reasons why there may be no appreciable affect of Swiss needle cast on Douglas-fir 5-year-diameter and height growth during the latest SNC outbreak in the Cascade Mountains:

1) Oregon Cascade site characteristics, including plant associations, soil chemistry and parent material, air temperatures, and monthly precipitation and leaf wetness may not be as conducive to elevated populations of the causal fungus, *Phaeocryptopus gaeumannii*, and subsequent severe defoliation, as in the Coast Range.
2) The genetics (lineage 1) of isolates of the causal fungus in the Oregon Cascade Mountains more closely resemble isolates from New York, Europe, and New Zealand than isolates from the Oregon Coast Mountains (Winton et al. 2006). Also, lineage 2, which is abundant in the Oregon Coast Mountains, has not been reported in interior Oregon (Cascade Mountains) or elsewhere in the world.

Based on our results and their interpretation, forest managers may need not alter their current practices in the northern Oregon Cascades, and managing a mix of Douglas-fir and western hemlock at lower elevations and noble fir at higher elevations will help offset any future stand-growth declines due to Swiss needle cast or other pest outbreaks. On the other hand, we report only 5-year results, and more time may be needed to adequately detect any significant effects from Swiss needle cast in the Cascade Mountains. Plans are to resample Cascade stands in 5 years (2011).

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REFERENCES

FILIP, G.M. – KANASKIE, A. – KAVANAGH, K. – JOHNSON, G. – JOHNSON, R. – MAGUIRE, D. (2000): Silviculture and Swiss needle cast: research and recommendations. Forest Research Lab, Research Contribution 30, Oregon State Univ., Corvallis, USA. 16 p.

FREEMAN, F. (2001): Swiss needle cast monitoring transects in the Oregon Cascades. In: Swiss Needle Cast Cooperative annual report. Filip, G. (ed.), College of Forestry, Oregon State Univ., Corvallis, USA. 11-13 .

FREEMAN, F. (2002): Swiss needle cast monitoring in the Oregon Cascades. In: Swiss Needle Cast Cooperative annual report. Filip, G. (ed.), College of Forestry, Oregon State Univ., Corvallis, USA. 11-14 .

HANSEN, E.M. – STONE, J.K. – CAPITANO, B.R. – ROSSO, P. – SUTTON, W.-WINTON, L. – KANASKIE, A. – MCWILLIAMS, M.G. (2000): Incidence and impact of Swiss needle cast in forest plantations of Douglas-fir in Coastal Oregon. Plant Disease 84: 773-778.

MAGUIRE, D. – KANASKIE, A. (2002): The ratio of live crown length to sapwood area as a measure of crown sparseness. Forest Science 48 (1): 93-100.

MAGUIRE, D. – KANASKIE, A. – VOELKER, W. – JOHNSON, R. – JOHNSON, G. (2002): Growth of young Douglas-fir plantations across a gradient in Swiss needle cast severity. Western Journal of Applied Forestry 17 (2): 86-95.

MAINWARING, D.B. – MAGUIRE, D.A. – KANASKIE, A. – BRANDT, J. (2005): Growth responses to commercial thinning in Douglas-fir stands with varying severity of Swiss needle cast in Oregon, USA. Canadian Journal of Forest Research 35: 2394-2402.

TAPPEINER, J.C. – BELL, J.F. – BRODIE, J.D. (1982): Response of young Douglas-fir to 16 years of intensive thinning. Research Bulletin 38, Forest Research Lab, Oregon State Univ., Corvallis, USA. 17 p.

WINTON, L.M. – HANSEN, E.M. – STONE, J.K. (2006): Population structure suggests reproductively isolated lineages of *Phaeocryptopus gaeumannii.* Mycologia 98(5): 781-791.