COMPARATIVE ANALYSIS OF NORWAY SPRUCE HEIGHT AND DIAMETER INCREMENT RESPONSE TO CLIMATE VARIATION FROM THE MOLDOVIȚA RIVER BASIN

Plaiu Nicolaie*

* University Ștefan cel Mare Suceava, Forestry Faculty, 13 University St., Suceava, Romania, e-mail: nplaiu@yahoo.com

Abstract

For a better understanding of the climate influence on the trees biomass storage the analysis of height increment and radial growth response of Norway spruce from the Moldovita River Basin to climate variation was done. In this paper is presented the first study of the influence of climate on trees height increment and radial growth in Romania. The comparative analysis between diameter and height growth indices series was done separately for each sample area and at regional level. In the case of both diameters and heights, a negative influence of temperature from previous July-September was highlighted. Temperature from current January negatively influence height increment, but precipitation from January negatively influence diameter increment, statistically significant being only precipitation. Precipitation during the current summer positively influence both diameter and height increment, excepting July which has a negative influence on height increment. A dendroclimatic analysis accomplished for a certain area and species displays bigger advantages when it relies on the study of both radial growth and height increment.

Key words: Norway spruce, Moldovița River Basin, radial growth, height growth, climate.

INTRODUCTION

Studies in the field of dendroclimatology, most of them, are based on the information given by different characteristics of tree-ring radial growth, such as total width, earlywood width, latewood width, latewood maximum density (Hughes, 2002), number of cells (Panyushkina et al., 2003), etc.

Nevertheless, total width of annual tree-rings, which is the most classical source of information in dendrochronology, has some disadvantages as a source indicator of trees response to climate variation. In comparison with height increment, annual tree-ring width of light nature species is more sensitive to spatial competition changes. In the case of light competition, strategically, height increment is more important in comparison with diameter increment due to the fact that a higher rate of height increment increases access to light (Falster, Webstoby, 2003).

On the other hand, elaborating height increment series requires practicing heavier techniques, requiring chopping down the sample trees and accurate identification of whorls in order for these to match the year they were formed. Likewise, the influence of some disruptive factors such as snow-break, windthrow, etc., have a more powerful and frequent influence on height increment. These are the main reasons why dendrochronology studies based on height increment are much fewer (Pensa et al., 2005; Lindholm et al., 2009).

Norway spruce is, economically speaking, one of the most important resinous species from Europe, having, at the same time, a significant ecological role (Skrøppa, 2003). Likewise, due to shaded areas, productivity and high quality of wood, Norway spruce is one of the most important species from Romania (Ichim, 1990).

In the Carpathian Mountains from Romania, although Norway spruce forest ecosystems have a major economical and ecological value, there are no studies referring to comparative analysis of climate influence on resinous trees diameter and height increment.

Therefore, this study has as main purpose the knowledge and comparative analysis of height and diameter increment response of Norway spruce from the Moldovița River Basin.

MATERIAL AND METHOD

In order to achieve the main purpose of this study, the research place is represented by four ecosystems of Norway spruce from the Moldovița River Basin (fig. 1). There were identified and seen on the field Norway spruces stands, younger than 60 years old, in which the tree whorls could be seen better. Four stands have been selected in which an experimental sample area has been located. Also, diameter increment samples had been taken from the selected trees for measuring in these four areas. The experimental areas that concern this study are presented in table 1 and figure 1.

Table 1

Geographical characteristics of experimental sample areas

No	Code series	u.a.	Forestry District	Species	Altitude (m)- Exposition	Latitude	Longitude
Height increment series							
1	mo1	241c	Moldovița	Mo	1150-1250 - S	47°48'	25°28'
2	mo2	243a	Moldovița	Mo	850-1150 - NW	47°47'	25°27'
3	mo3	245b	Moldovița	Mo	810-970 - NW	47°46'	25°26'
4	mo4	232a	Moldovița	Mo	880-1050 - S	47°48'	25°25'
Diameter increment series							
1	mo1	241c	Moldovița	Mo	1150-1250 - S	47°48'	25°28'
2	mo2	243a	Moldovița	Mo	850-1150 – NW	47°47'	25°27'
3	mo3	245b	Moldovița	Mo	810-970 - NW	47°46'	25°26'
4	mo4	232a	Moldovița	Mo	880-1050 - S	47°48'	25°25'

There were chosen in each experimental area, according to dendrochronological criteria (Fritts, 1976; Popa, 2004), 20-25 healthy trees, from Kraft 1 class, prevalent (the impact of competition is minimal), with straight and unharmed stem, avoiding trees with distorted, asymmetric crown.

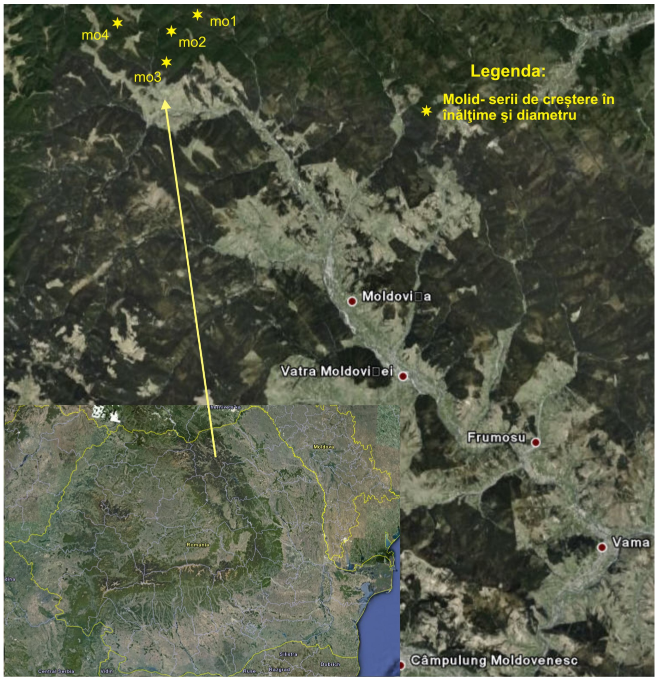

Fig. 1. Study sites

The method of elaborating series of height increment is, in general, similar to the one used to elaborate dendrochronological series in diameter, with some characteristics. Each selected tree was chopped down and height increment was measured between whorls from the stem, starting from top to bottom, in order to know the year since when the measuring of height increment begins. The measure was done with a measuring tape in centimeters. The values of measured height increment were written in a notebook, afterwards, at the office, being transferred into computer in order to be analyzed.

There were taken two increment samples at 1.30 meters form each of these trees, on perpendicular direction to the line of the highest gradient, in order to reduce the negative effects of compression wood. The increment cores were taken using Pressler drill. These cores were carried and preserved in special paper tubes, so that they would dry slowly. After drying, increment samples were fixed on special wood holders by adhesive gluing, subsequently being ground with abrasive tape with granulation of 200-800 in order to highlight annual rings. In next stage, the increment samples were scanned at 1200 pixels resolution so that the annual growth rings could be seen better when they were measured. The measuring of annual rings width was done with CooRecorder 7.4 software.

The increment series were dated through graphical representation of annual growth and through individual growth series compared to average growth series, to characteristic years identification and to series synchronizing. This method was applied with TsapWin software, which allows graphical view of growth curve. The correctness and reliability control of dating was done with COFECHA software (Holmes, 1983).

All individual height growth series were standardized to eliminate non-climatic influence and to obtain the maximum of climatic information from dendrochronological series. For that, negative exponential function was used, because this one is maximizing the climatic response in the strongest way. It was used ARSTANwin software (Cook, Krusic, 2006). The residual dendrochronological series were used due to the fact that autocorrelation is cut out from the obtained indices series.

In order to use a unitary set of climatic data for the entire studied site, with time series for the last century, it appealed to climatic database with resolution of 0.5°x0.5° CRU T.S. 3.0 (Mitchell, Jones, 2005).

The reaction of trees to climate variation is analyzed through correlation indices of Pearson type. To this purpose, it was used DENDROCLIM 2002 software (Biondi, Waikul, 2004). The analysis was accomplished for years between 1967 and 2009, this period of time being dealt for all analyzed series. Concerning the meteorological data, for the studied site, the set of meteorological data (average monthly temperature and monthly precipitation) were taken from CRU T.S. 3.0. database, from 1967-2009.

The analysis of the correlation between dendrochronological series and meteorological parameters was accomplished from July of the previous year of annual growth development until July of the current year height increment development.

RESULTS AND DISSCUSIONS

The comparative analysis between diameter and height growth indices series, separately for each sample area (table 2 and figure 2), highlights the fact that the highest correlation between indices series is in the case of area number 2, and the lowest in the area number 3, being, nevertheless, insignificant.

In the case of both diameter and height increment series, the correlation values between series remain significant, excepting the correlation between height series from area number 2 and height series from area number 3.

Table 2

Pearson correlation between indices series

Variables	mo1d	mo2d	mo3d	mo4d	mo1h	mo2h	mo3h	mo4h
mo1d	**1**	**0,593**	**0,717**	**0,814**	0,125	-0,191	0,257	0,162
mo2d	**0,593**	**1**	**0,663**	**0,673**	0,135	0,156	0,110	0,192
mo3d	**0,717**	**0,663**	**1**	**0,773**	0,099	-0,076	0,041	0,100
mo4d	**0,814**	**0,673**	**0,773**	**1**	0,015	-0,123	0,132	0,104
mo1h	0,125	0,135	0,099	0,015	**1**	**0,407**	**0,555**	**0,738**
mo2h	-0,191	0,156	-0,076	-0,123	**0,407**	**1**	0,193	**0,351**
mo3h	0,257	0,110	0,041	0,132	**0,555**	0,193	**1**	**0,604**
mo4h	0,162	0,192	0,100	0,104	**0,738**	**0,351**	**0,604**	**1**

The correlations between diameter increment indices series are higher as compared with the existing ones between height increment indices series. Considering the fact that in the case of both diameter and height increment series, the elaborated series are significantly correlated between them, there were elaborated regional series of height increment indices (figure 3). These indices series express, both as trend and as values, regional increment in diameter and in height of Norway spruce from the Moldovița River Basin.

Regarding the comparative analysis of dendroclimatological response in relation to height and diameter, regionally, it distinguishes in the case of both diameters and heights, a negative influence of temperature from previous July-September. In the case of precipitation from this period, if they have a positive influence on diameter increment, then on height increment they have a negative influence, excepting precipitation from July.

Temperature from current January negatively influence height increment, but precipitation from January negatively influence diameter increment, statistically significant being only precipitation.

As compared to temperature, precipitation have a stronger positive influence on both diameter and height increment.

Precipitation during the current summer positively influence both diameter and height increment, excepting July which has a negative influence on height increment (figure 4). In Romania, a positive influence of temperature from current March on radial growth was pointed out for Norway spruce also from regions Întorsura Buzăului, Comăneşti, Harghita Băi, Lăpuşna, Oțelul Roşu. Likewise, there were pointed out negative correlations with temperature and positive ones with precipitation from previous July and September for the same regions and for Gârda region (Sidor, 2011).

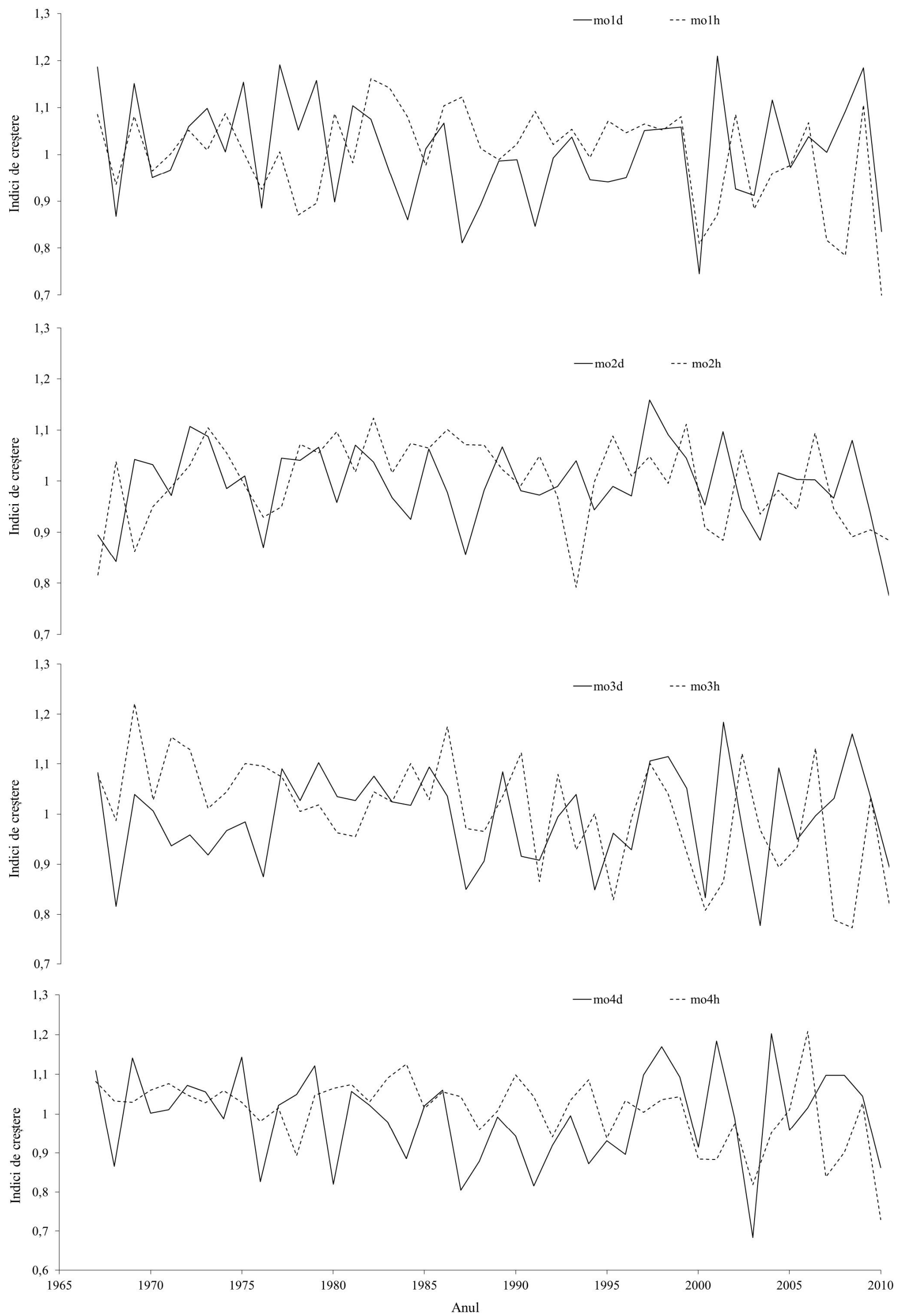

Fig. 2. The elaborated increment indices series

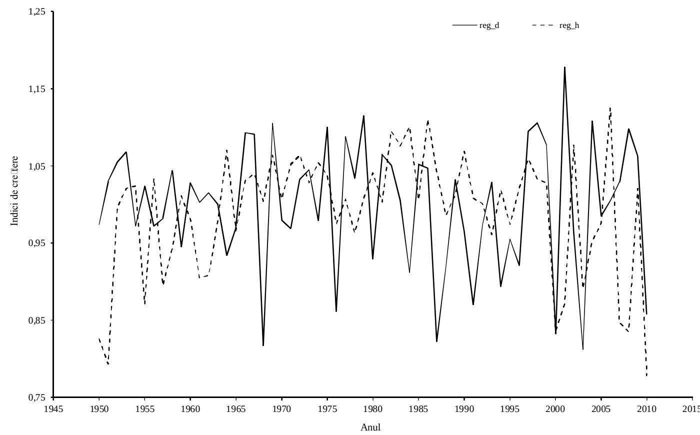

Fig. 3. Diameter and height growth indices series

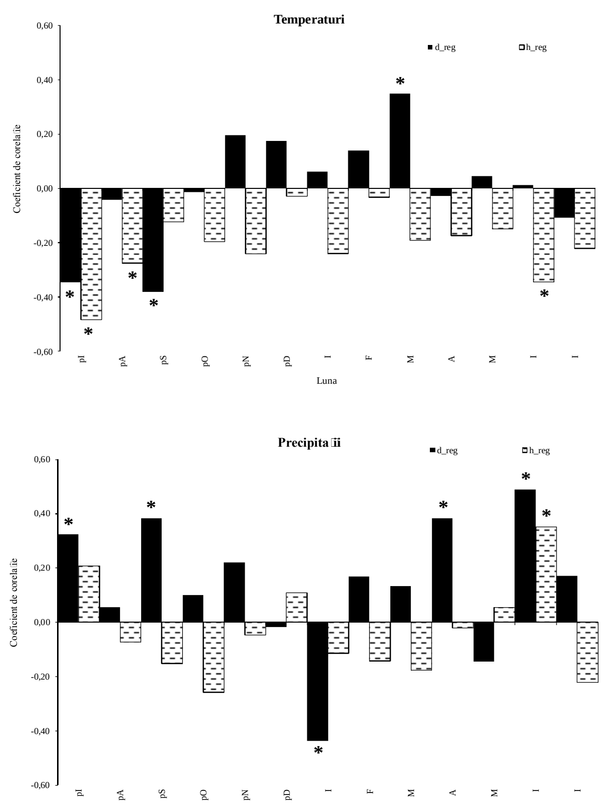

Fig. 4. Comparative correlation between regional growth indices series with climatic parameters (the star symbolizes the months with significant influence on growth)

Negative correlations with the temperature from the previous vegetation season were identified for Norway spruce from the central and west part of the Alps (Buentgen et al., 2006) and from Lithuania (Vitas, 1998). Likewise, for trees from Trockental Valley from Switzerland, from the Alps, it was proved that Norway spruce reacts positively to March temperature (Lingg, 1986).

Concerning height increment, climatic parameters from the previous year of current height increment growth development have influence on terminal bud development, causing storage of reserve substances, while climatic parameters from the current year of current height increment growth development influence the speed and the size extension of twigs (Lanner, 1976). Negative correlation with average temperature from current June were pointed out for height increment of Norway spruce from north-east part of Slovenia, situated at about 350 altitude (Levanic et al., 2009). A negative response of height increment to climatic parameters from July of the previous year height increment growth was relieved as well in other studies for another species. At the northern timberline forest, where temperature during the summer represents the main limitative factor of growth, the height growth of Pinus sylvestris is mainly determined by the average temperature of July from the previous year of growth (Juntila, Heide, 1981; Jalkanen, Tuovinen, 2001; McCarroll et al., 2003; Salminem, Jalkanen, 2004; Lindholm et al., 2009). The same thing was demonstrated in the case of height increment of Pinus sylvestris from the south part of Finland (Makinen, 1998). The correlation between height increment and the average temperature of previous July was positive in all the cases. Also, the strong positive correlation between height increment of Pinus sylvestris and the temperature during the current summer of growth development was highlighted (Jalkanen, Tuovinen, 2001; McCarroll et al., 2003).

In the south part of Finland, Makinen (1998) compared climate variation response of two dendrochronological series with a 75 years length, one for diameter increment and the other for height increment. He pointed out the fact that height increment doesn`t have advantages in relation to diameter increment, concerning both the intensity of response and the average sensitivity.

CONCLUSIONS

A dendroclimatic analysis accomplished for a certain area and species displays bigger advantages when it relies on the study of both radial growth and height increment. It obtains information concerning much more climatic indices that influences the entire growth of trees, not only radial growth or height increment, studied independently.

REFERENCES

1. Biondi F., Waikul K., 2004, DENDROCLIM2002: a C++ program for statistical calibration of climate signals in tree-ring chronologies. Computers & Geosciences 30, pp. 303-311.
2. Buntgen U., Frank D., C., Schmidhalter M., Neuwirth B., Seifert M., Esper J., 2006, Growth/climate response shift in a long subalpine spruce chronology. Trees - Structure and Function 20(1), pp. 99-110.
3. Cook E., R., Krusic P., J., 2006, ArstanWin 4.1.b_XP. http://www.Ideo.columbia. edu.
4. Falster D., S., Westoby M., 2003, Plant height and evolutionary games. Trends in Ecology & Evolution, 18, pp. 337-343.
5. Fritts H., C., 1976, Tree Rings and Climate. Academic Press., 567 p.
6. Holmes R., L., 1983, Computer-assisted quality control in tree-ring dating and measurement. Tree Ring Bulletin 43, pp. 69-75.
7. Hughes M., K., 2002, Dendrochronology in climatology-the state of the art. Dendrochronologia, 20, pp. 95-116.
8. Ichim R., 1990, Gospodărirea raţională pe baze ecologice a pădurilor de molid. Editura Ceres Bucureşti, p. 186.
9. Jalkanen R, Tuovinen M., 2001, Annual needle production and height growth: better climate predictors than radial growth at treeline?. Dendrochronologia, 19, pp. 39-44.
10. Junttila O., Heide O., M., 1981, Shoot and needle growth in Pinus sylvestris as related to temperature in northern Fennoscandia. Forest Science, 27, pp. 423-430.
11. Lanner R., M., 1976, Patterns of shoot development in Pinus and their relationship to growth potential. In: Cannell, M.G.R. & Last, F.T. (eds.). Tree Physiology and Yield Improvement. Aca- demic Press, London, UK. pp. 223-243.
12. Levanic T., Gricar J., Gagen M., Jalkanen R., Loader N.J., McCarroll D., Oven P., Robertson I., 2009, The climate sensitivity of Norway spruce (Picea abies) in the southeastern European Alps. Trees, 23, pp. 169-180.
13. Lindholm M., Ogurtsov M., Aalto T., Jalkanen R., Salminen H., 2009, A summer temperature proxy from height increment of Scots pine since 1561 at the northern timberline in Fennoscandia. The Holocene, 19, pp. 1131-1138.
14. Lingg W., 1986, Dendrookologische Studien an Nadelbaumen im alpinen Trockental Wallis (Schweiz). Eidg Anst forstl VersWes 287, pp. 1-81.
15. Makinen H., 1998, The suitability of height and radial increment variation in Pinus sylvestris for expressing environmental signals. Forest Ecology and Management, no. 112, pp. 191-197.
16. McCarrol D., Jalkanen R., Hicks S., Tuovinen M, Gagen M., Pawellek F., Eckstein D., Schmitt U., Autio J., Heikkinen O., 2003, Multiproxy dendroclimatology: a pilot study in northern Finland. The Holocene, 13, pp. 829-838.
17. Mitchell T., D., Jones P., D., 2005, An improved method of constructing a database of monthly climate observations and associated high-resolution grids. International Journal of Climatology 25, pp. 693-712.
18. Panyushkina I., P., Hughes M., K., Vaganov E., A., Munro M., A., R., 2003, Summer temperature in northeastern Siberia since 1642 reconstructed from tracheid dimensions and cell numbers of *Larix cajanderi*. Canadian Journal of Forest Research 33(10), pp. 1905-1914.
19. Pensa M., Salminen H., Jalkanen R., 2005, A 250-year-long height-increment chronology for *Pinus sylvestris* at the northern coniferous timberline: A novel tool

for reconstructing past summer temperatures. Dendrochronologia 22 (2005), pp. 75-81.

20. Popa I., 2004, Fundamente metodologice şi aplicații de dendrocronologie. Editura Tehnică Silvică, Stațiunea Experimentală de Cultura Molidului, Câmpulung Moldovenesc, 200 p.
21. Salminen H., Jalkanen R., 2004, Does current summer temperature contribute to the final shoot length on Pinus sylvestris. A case study at the northern conifer timberline. Dendrochronologia, 21, pp. 79-84.
22. Sidor C., 2011, Relația dintre climat şi creşterea radială a arborilor din zona montană superioară. Editura Silvică, 196 p.
23. Skrøppa T., 2003, EUFORGEN Technical Guidelines for genetic conservation and use for Norway spruce (*Picea abies*). International Plant Genetic Resources Institute, Roma, Italy, p. 6.
24. Vitas A., 1998, Dendroclimatological research of spruce forests in the west and central Lithuania. Mater Thesis. Vytautas Magnus University. Kaunas, 60 p.