THE INFLUENCE OF ENVIRONMENTAL CONDITIONS ON PHENOTYPIC TRAITS OF SPRUCE (*Picea abies* [L.] Karst)

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Abstract. Norway spruce (*Picea abies* L. Karst.) is one of the most important species among conifers in Europe, which provide valuable raw material for forest industries and also plays an important role in the society and economy. Therefore, the main objective of this study was to monitor the influence of environmental conditions (climatic and soil conditions) upon diverse phenotypic traits of spruce trees (height, diameter, canopy diameter) from four seed preserves situated in different parts of Romania, including the Counties of Bistrița-Năsăud, Maramureș, Harghita and Suceava. For this purpose, the weather conditions were recorded and four different soil profiles were evaluated.The results show that, when temperature and precipitation values together with soil type and profile thickness are in accordance with spruce growth conditions, the phenotypic traits reach their optimum. Therefore, the highest values for tree height (36,63 m), tree diameter (46,53 cm) and average tree volume (2,57 m^3) were recorded in Măria Mică on Eutricambosol soil type on 92 cm soil profile thickness, followed by Făina location were Districambosol was determined in depth of 105 cm. preserve

Keywords: phenotypic characteristics; soil; thickness, profile, temperature, precipitation, spruce

INTRODUCTION

Biodiversity in a forest ecosystem is influenced by several environmental factors, such as climate and soil, but also by the evolution and changes in the geographical areas of species (Carnus et al., 2006). In soils less rich in nutrients and an altered microclimate have led to changes in the composition of plant species in the herbaceous forest cover and in general, to a lower diversity of plant species in the forest (Stabbetorp & Nygaard, 2005; Barbier et al., 2008).

Characteristics of conifer species sometimes may vary discontinuously in reponse to environmental varation that does not follow smooth gradients, such as differences in parent rocks or soil types (Lesser et al., 2004), mezzo or microclimate (Geburek et al., 2008; Rehfeldt and Jaquish, 2010; Gömöry et al., 2012).

Forest soils are an integral and vital part of the forest ecosystem, as the ecological processes that govern tree survival and growth are concentrated around the soil-root interface (Coder, 2016). In addition to providing anchoring substrate, forest soils also form a reservoir for water and nutrients, while also providing habitat foe a diverse fauna (Schaefer and Schauermann, 1990; Brady and Weil, 1996; Binkley and Fisher, 2013).

Norway spruce (*Picea abies* L. Karst.) is one of the most important conifers in Europe, where it provides valuable raw material for forest industries (Jansson et al., 2013; Edesi, et al., 2021). Norway spruce covers approximately 30 million hectares (Ciocîrlan et al., 2021) and plays an important role for society and the economy. Spruce is one of the most economically important species in Central and Northem Europe (Cermak et al., 2017). The wood is used in construction and cellulose, but a special quality is the resonance wood, which is used for the manufacture of musical instruments (Echard et al., 2008).

Spruce prefers a cold and humid climate, with fertile soils, and a minimum of 600 mm of rainfall per annum, less only on soils with a good water supply. Prefers moist, sandy-loamy sites with a pH-value of 4 to 5, but also tolerate neutral to calcareous soils and shady sites. Therefore, it grows well in mixtures with other tree species (Honkaniemi et al., 2020). It is mainly a species spread in the boreal and temperate regions of Europe (Koski et al., 1997), and in Romania dominates at altitudes between 1200 and 1800 m (Feurdean et al., 2011), but it can also be found at lower altitudes in the mixtures of fir and beech (Sofletea and Curtu, 2007). Intolerant of lasting periods of heat and drought and accelerates the leaf-humus formation thereby lowering the soil quality.

Tree diameters and heights are fundamental measurements in forest inventories and are used as input parameters of models or forest decision support systems (Sharma, 2015). The relationship between height and diameter differs from one stand to another due to differences in site quality, age and applied silvicultural treatments, and even within the same stand due to the different competitive situation between the trees (Trincado et al., 2007; Schmidt et al., 2011).

The objective of our study was to determine the influence of environmental conditions on the phenotypic traits of *Picea abies* L. Karst choosing four different locations across Romania.

MATERIAL AND METHOD

1.1. Biological material

The evaluation of the main phenotypic characteristics and the analysis of soil profiles were performed in four spruce seed preserves from different counties from Romania: Măria Mică (Bistrița-Năsăud County), Făina (Maramureș County), Aluniș (Harghita County), Putnișoara (Suceava County). As presented in Table 1, the climatic conditions from the selected regions are different, which enables a more detailed study of the sites.

1.2. Determination of phenotypic traits

For the analysis of phenotypic characters, a number of 30 trees from each seed preserve were selected and evaluated. The characters analysed were: (i) tree height (m) – which was determined using the forest log; (ii) trunk diameter at 1,30 m an at 0,50 m –which were measured with the VERTEX V dendrometer and (iii) canopy diameter (m). Based on these data recorded , the average volume of the tree was later calculated, determining the average diameter and establishing the series of volume. This calculation was made according to the protocol of Biometry of Trees a from Romania described by Giurgiu,1972. Soil profiles were sampled on representative sites identified and described according to the instructions of the Bucharest National Research-Development Institute for Pedology, Agrochemistry And Environmental Protection (I.C.P.A., 1987).

Table 1

Romanian provenances of *Picea abies*

Provenance/Population	County	Administrative Location[1]	Latitude/ Longitude	Average Yearly Temperature (°C)	Average Anuual Precipitation (mm)	Altitude (m)	Soil type
Măria Mică	Bistrița-Năsăud	Primăria Șanț OS. Izvorul Someșului	47°25'N/24°50'E	4,9	960	770 – 1000	Eutricambosol
Făina	Maramureș	RNP – ROMSILVA OS .Vișeu	47°50'N/24°38'E	9,4	1100	820 – 1220	Districambosol
Aluniș	Harghita	RNP – ROMSILVA OS. Borsec	46°45'N/25°20'E	7,0	705	1000 – 1285	Districambosol
Putnișoara	Suceava	RNP – ROMSILVA OS. Pojorâta	47°27'N/25°22'E	4,9	1045	985 – 1200	Rendzina

1.3. Data analysis

The data recorded was averaged to calculate the means for each trait. Analysis of variance (ANOVA) was applied to analyse the data, and when the null hypothesis was rejected, Duncan's Multiple Range Test (Duncan's MRT, $p<0.05$) was performed as a post hoc test to determine significant differences between the means. Regressions and correlations were also performed to check the relationships between the analysed traits.

RESULTS AND DISCUSSION

1.1. Phenotypic characteristics

Based on the data recorded regarding the phenotypic characteristics of the trees from the four spruce reservations taken into study the results show significant differences between the means between the location within the traits. Therefore, the height of the trees in the four reservation was different. The highest value being recorded in in the Măria Mică reservation (35.63 m) as compared to other reservations (Fig. 1). Tree height is the most representative trait of tree growth and development. The height of trees depends not only on age, diameter, species, but also on the site conditions wherever they grow (Petrás, 2014).

The diameter of the trees at breast height was commensurable to their height, following the same variation pattern as in their height. The highest value for this phenotypic trait was recorded in trees grown at Măria Mică (46,53 cm) followed by Făina (44,40 cm). The smallest diameter being recorded in Putnișoara with an average value of 38,00 m. base diameters of the spruce trees varied between 58,97 and 66,80 cm, values that followed the same variation pattern as in previous characters. Thus, the smallest base diameter was recorded in Aluniș, while the greatest in Măria Mică.

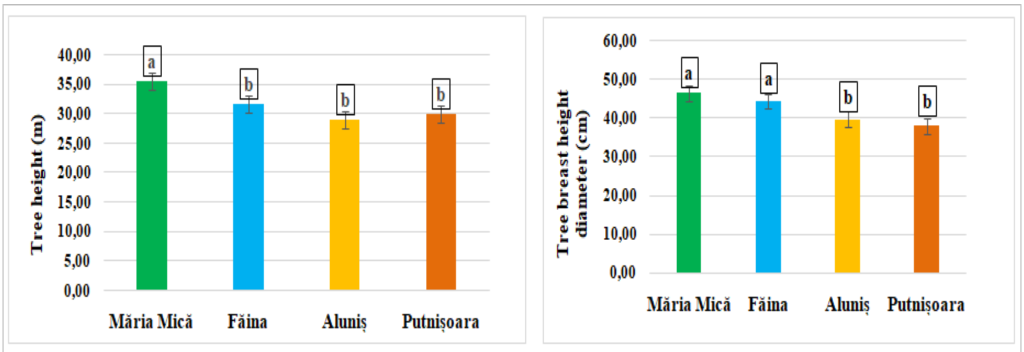

Fig.1. Height and diameter of spruce trees from the four seed preserves uder study Different lowercase letters above the bars indicate significant differences between the means, according to the Duncan's multiple range test at p= 0.05.

Tree development is also stronly related to its canopy size and foliage, having an effect on the size and efficiency of the assimilation process. Tree canopy dimensions can vary canopydepending on light and nutrient requirements, as well as susceptibility to stress intensity (Klepacki, 2017). Among the four reservations, the diameter of the canopys varied between 5,35 and 5,78 m. The greatest canopy diameter being recorded in Aluniș reservation while the smallest was recorded in Făina location. Intermediate values were recorded in spruce grown in Putnișoara (5,55 m) and Măria Mică (5,50 m) with no sognificant differences between the means.

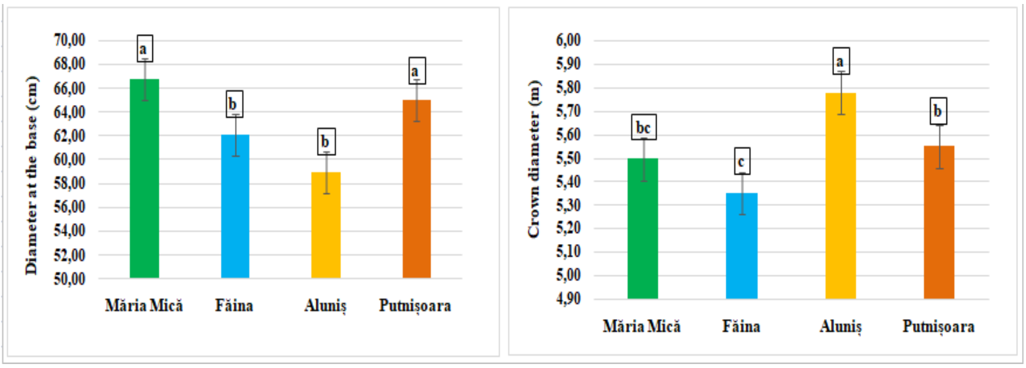

Fig. 2. Base and canopy diameter of trees from the spruce preserves analysed. Different lowercase letters above the bars indicate significant differences between the means, according to the Duncan test (p = 0.05).

1.2. Regressions and correlations between phenotypic characters of the trees

Tree diameter at breast height (1.30 m) and tree height are two fundamental tree attributes with importance for several aspects of forest management (Husch et al., 2003). These two characteristics are key variables, and the relationship between them is essential for improving estimates of forest biomass and carbon storage, but also for describing stand development trajectories (Ducey, 2012; Lam, 2017).

In this study, the relationship between the two characters was estimated by simple linear regression, being illustrated by the following regression formula: $y = 0.1146x + 42.449$, and the value of the coefficient of determination is $R^2 = 0.0023$ (Figure 3). The coefficient of determination illustrates the fact that in the Măria Mică preserve, the height of the trees influences the diameter of the canopy by a percentage of 0.23%.

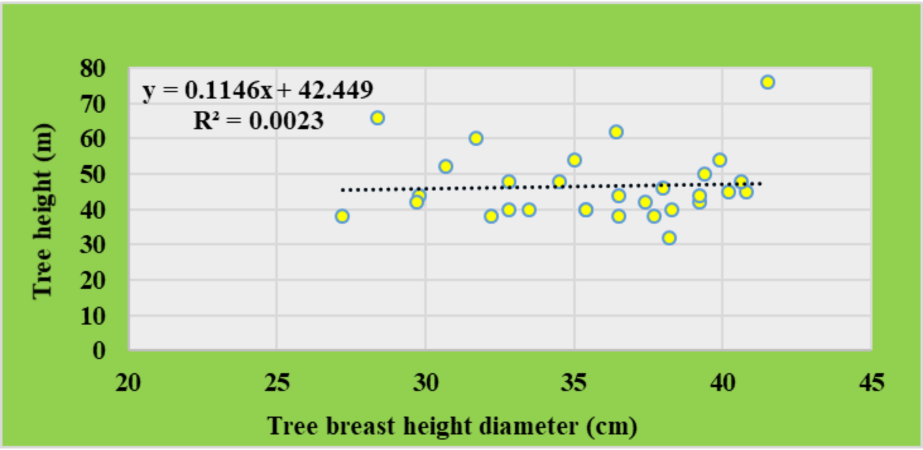

Fig. 3. The regression equation between the tree height (m) and tree breast diameter (cm) from the Măria Mică reservation

In the Făina population, the connection between the two characters is estimated by the simple linear regression, which was illustrated by the following equation: *y = 0,826x +21,19*, and the value of the coefficient of determination is R^2 = *0,389*. The coefficient of determination illustrates that 38% of the height of the trees influences the diameter of trees.

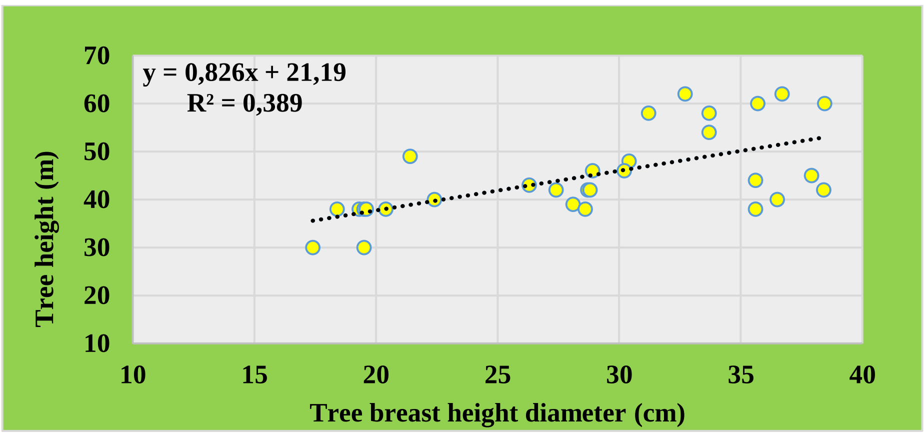

Fig. 4.The regression equation between tree height (m) and tree breast diameter (cm) from the Făina reservation

The simple liniar regression presented below reflect the relationship between tree height and tree breast height diameter in according to the following equation: *y = 0,554x +23,59*, the value of the coefficient of determination was R^2 = *0,187*.

The coefficient of determination illustrates that 88% of the height of the trees influences the diameter of trees.

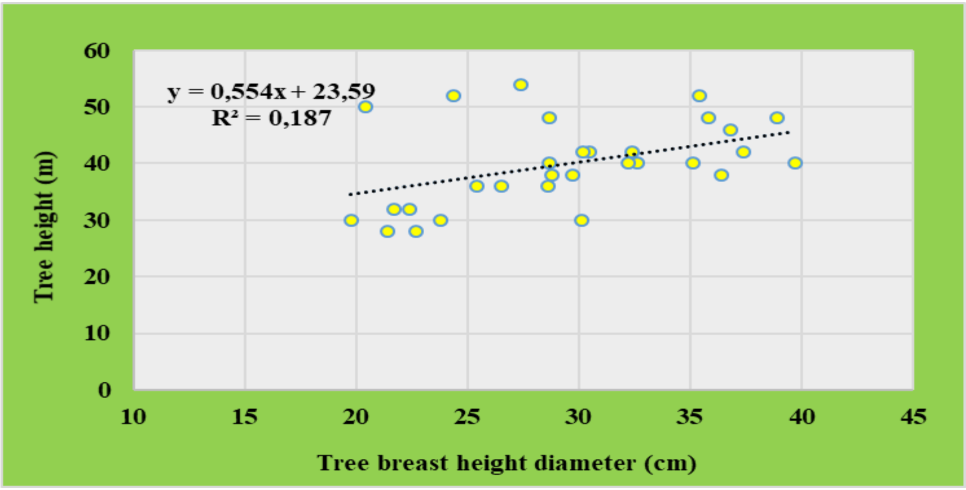

Fig. 5. The regression equation between the tree height (m) and tree breast diameter (cm) from Aluniş reservation

In Putnişoara the relationship between the two phenotypic charaters was illustrated by the following regression formula: *y = 0,093x +35,74*, the value of the coefficient of determination was R^2 = *0,010*. The result indicate that tree height influences the trunk diameter at breast height in 0,10%. (Figura5).

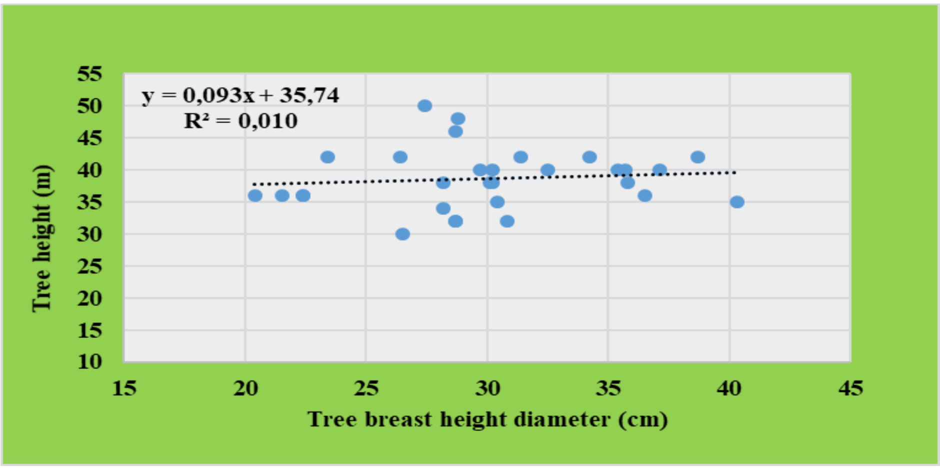

Fig. 6. The regression equation between tree height (m) and tree diameter (cm) at breast height from Punişoara reservation

Regarding the correlations between phenotypic traits of the trees, it was observed that the tree heights in Făina location had a positive correlation with tree diameter and tree canopy diameter (0,625). Similar positive correlation was found between tree diameter and tree heights (0,655). Slightly weaker correlations have been observed between the same characters of the spruce trees in Aluniş as presented in Table 3.

Table 2

Multiple correlation between the phenotypic traits of the spruce trees (tree height, tree and canopy diameter) from the four locations under study

Correlation	Măria Mică	Făina	Aluniș	Putnișoara
Rx.yz=	0,259	0,625***	0,429*	0,136
Ry.xz=	0,049	0,655***	0,449*	0,129
Rz.xy=	0,255	0,293	0,155	0,126

x- tree height; y – tree diameter at breast height; z – canopy diameter

1.3. The influence of soil type and profile thickness on the average volume of the tree

The variability of tree volume is largely conditioned by the ratios between the thickness of the soil profile and its structure, but also by other external factors, such as precipitation fallen during the growing season and temperatures, which might positively or negatively influence biomass accummulation. The influence of soil and microclimate on spruce growth, wood quality or other important parameters were also observed by Voicu and Comeau (2006), Fravolini et al.,2016).

The diameter measurement at 1.30 and the total height of the trees, is commonly used as alternatives to estimate the volume of the tree (Xu et al., 2019; Yang et al., 2020). In our study, the average volume of the tree was calculated according to the diameters and heights of the trees studied from each location, on different soil types and subtypes, with variable thickness of the soil profile. In forest ecosystems, soil thickness can have an important influence on the productivity and characteristics of the stand, as it strongly affects the potential volume of roots, water available from plants and hydrological function (Meyer, 2007).

Table 3

The influence of soil type and profile thickness on the average volume of the tree

Soil type		Thickness of soils profile (cm)	Average tree volume (m^3)
Eutricambosol	tipycal	92	2,57
Districambosol	tipycal	105	2,05
Rendzina	calcaric	37	1,54

Typical Eutricambosol – Măria Mică; Typical Districambosol – Făina and Putnișoara; Calcaric Rendzina – Aluniș

From the data presented in Table 3 it can be concluded that the average volume of the tree varies with the thickness of the soil profile and its structure. The lowest tree volume being recorded on rendzina soil on limestone with a soil profile thickness of 37 cm. The largest volume was recorded on the typical eutricambosol soil type with a thickness of the soil profile of 92 cm in the Măria Mică preserve. This similarity could be explained by the similar soil layers to typical districambosol. The degree of saturation in bases is at the eubasic-mesobasic level in the Ao horizon and eubasic in the Bv horizon. There are moderately and strongly acidic soils on the surface and moderately and weakly acidic in depth. The productivity of stands from this preserve is superior, which reflects very good conditions for the development of spruce, and the amount of precipitation falls between 770-1000 mm, which is also favorable for the development of trees.

CONCLUSIONS

The height and diameter of trees are essential variables that characterise the structure of stands and provide an essential basis for calculating the volume of trees and assessing their quality. Regarding the height of the trees in the four preserves under study, it can be observed that statistically significantly differences ($p = 0.05$) were recorded in the Măria Mică reservation compared to the other preserves, as well as the diameter of the trees followed by the Făina preserve.

In forest ecosystems, the thickness of the soil can have an important influence on the productivity and characteristics of the stand. Therefore, the results of this study reveal that the average volume of the tree was strongly influenced by the soil type and the thickness of the profile.

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