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RELATIONSHIP BETWEEN MORPHOLOGICAL AND PHYSIOLOGICAL ATTRIBUTES OF HOP HORNBEAM SEEDLINGS

Abstract: Most commonly used morphological attributes were correlated with nutrient concentration in order to standardize quality assessment of two-year-old hop hornbeam (*Ostrya carpinifolia* Scop.) seedlings. Diameter has proven to be the best single morphological indicator of seedling quality given its strong positive correlation with all other observed morphological attributes. Seedling dry mass (shoot and root dry mass) and Dickson Quality Index can be considered the most comprehensive indicators of hop hornbeam seedling quality. However, the measuring of mass is destructive and requires a certain amount of time. The absence of strong correlations between physiological and morphological attributes of two-year old seedlings of hop hornbeam suggests the need for further research. The only significant correlation between physiological and morphological attributes (weak and positive) was recorded between the potassium concentration in root and root collar diameter after the second growing season.

Key words: seedling quality, correlation, nutrient concentration, *Ostrya carpinifolia*, morphological attributes

ОДНОС МОРФОЛОШКИХ И ФИЗИОЛОШКИХ ПАРАМЕТАРА КВАЛИТЕТА САДНИЦА ЦРНОГ ГРАБА (*Ostrya carpinifolija* Scop.)

Извод: У овом раду је установљена корелација између морфолошких особина које се најчешће користе и концентрације хранљивих материја како би се стандардизовала процена квалитета двогодишњих садница црног граба (*Ostria carpinifolia* Scop.). Пречник се показао као најбољи јединствени морфолошки показатељ квалитета садница с обзиром на његову јаку позитивну корелацију

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са свим осталим посматраним морфолошким карактеристикама. Маса садница у сувом стању (маса корена и изданка) и Диксонов индекс квалитета могу се сматрати најсвеобухватнијим показатељима квалитета садница црног граба, али мерење масе је деструктивно и захтева одређено време. Одсуство јаке корелације између физиолошких и морфолошких карактеристика двогодишњих садница црног граба указује на потребу за даљим истраживањима. Једина значајна корелација између физиолошких и морфолошких карактеристика (слаба и позитивна) била је забележена између концентрације калијума у корену и пречника кореновог врата после друге вегетације.

Кључне речи: квалитет садница, корелација, концентрација хранљивих материја, *Ostria carpinifolia*, морфолошке особине

1. INTRODUCTION

Assessment of seedling quality is more important for afforestation planning than for the pricing of seedlings. Further, during the selection of methods and interpretation of the results of seedling quality testing, assessment of performance should be clearly separated from the assessment of field survival (Grossnickle, Folk, 1993). The choice of parameters to measure when assessing seedling quality, in addition to the use of results should be based on the efficiency in terms of time, cost and destructiveness of the chosen method. The measuring of dry mass of seedlings and the mass of individual parts of fresh plants is certainly destructive. In addition, the measurement of most parameters of root development is destructive and time consuming. The measuring of height and root collar diameter is quick, easy and non-destructive. However, used individually, these parameters are not sufficient to assess seedling quality (Haase, 2008). Because of that, many derived indicators have been proposed, such as sturdiness quotient (Roller, 1977) which includes height and diameter or quality index (Dickson *et al*., 1960), which includes height and diameter combined with biomass. Grossnickle and Folk (1993) reported that the measurement of four variables (diameter, height, shoot water potential at planting and root growth capacity) is sufficient to evaluate the morphological and physiological condition of seedlings.

The analysis of nutrient concentration for the assessment of seedling quality has been mainly focused on nitrogen, phosphorus and potassium, or stored nutrients, usually in the form of sugars and starches (Mattsson, 1996).

In Serbia, there are no certified seed sources of hop hornbeam (Ivetić *et al*., 2010), as well as organized production of reproductive material, despite recommendations by many authors on its use as the main or associated species in a number of sites (Jović *et al*., 1998, Isajev *et al*., 2006, 2010, Tomić *et al*., 2011). Testing of the relationship between different morphological attributes, as well as between nutrient concentrations, will contribute to the defining of the quality standards of this and other species.

2. MATERIAL AND METHOD OF RESEARCH

The fruit was harvested immediately after maturation, at three sites northeast of Gazivodsko Lake. The fruit was dried in a thin layer at room temperature. After drying, the seed was extracted by thrashing in small sacks, and then separated from the mixture by wind blowing. In order to break dormancy, the seed was stratified in moist sand at a temperature of 0° to 5° C for 140 days. The stratified seeds were sown in large containers in a mixture of sand and peat with the 2: 1 ratio. The first germinants appeared on the fifth day after sowing. By the end of the growing season, manual weeding was performed every four weeks. Irrigation was performed at least twice a week. After the first growing season, 945 seedlings were transplanted into three seedbeds (315 per seedbed). During the second growing season, manual weeding was performed every 15 days.

Before transplanting, all 945 one-year-old seedlings were measured for height (H_1), root collar diameter (D_1) and the number of developed buds (NBd). After the second growing season, all seedlings were measured for height (H_2), root collar diameter (D_2), number of branches (NBr) and dry mass, as total seedling mass (Msd), shoot mass (Msh) and root mass (Mro). Seedling dry mass was measured after drying the plant material in the thermostat cabinet at a temperature of 68° C for 48 hours.

The quality index (QI) was calculated (Dickson *et al*., 1960) from the measured morphological parameters after the second growing season:

$$QI = \frac{\text{Msd } (g)}{\left[\frac{\text{H } (cm)}{\text{D } (mm)}\right] + \left[\frac{\text{Msh } (g)}{\text{Mro } (g)}\right]} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Concentration of nitrogen, phosphorus and potassium in shoots and roots was measured at the end of the second growing season. Sample preparation for the determination of P and K was performed using wet combustion of plant material in nitric acid and hydrogen peroxide. From the obtained extract, phosphorus was determined colorimetric with the use tin chloride and ammonium molybdate. Potassium was determined by flame photometry. Nitrogen content was determined by the Kjeldahl method.

The relationship between individual morphological attributes and physiological attributes of the seedlings was measured by simple linear correlation (Pearson R). The correlation coefficients were calculated in the statistical program STATISTICA 7.

3. RESULTS

The calculated Pearson coefficient of a sample of 907 (after casewise deletion of missing data) showed a significant positive correlation between all morphological attributes, table 1.

Table 1. Correlation coefficients between the morphological attributes: height after the first (H_1) and second (H_2) growing seasons, diameter after the first (D_1) and second (D_2) growing seasons, number of buds (NBd), number of branches (NBr), total dry mass (Msd), shoot dry mass (Msh), root dry mass (Mro) and quality index (QI)

Табела 1. Коефицијенти корелације између морфолошких показатеља: висине након прве (H_1) и друге (H_2) године, пречника након прве (D_1) и друге (D_2) године, броја пупољака (NBd), броја грана (NBr), масе садница у сувом стању (Msd), масе изданка у сувом стању (Msh), масе корена у сувом стању (Mro) и индекса квалитета (QI)

	H_1	**D_1**	**Nbd**	**H_2**	**D_2**	**Nbr**	**Msd**	**Msh**	**Mro**	**QI**
H_1	1,0000									
D_1	0,6773	1,0000								
Nbd	0,6610	0,6027	1,0000							
H_2	0,7529	0,8635	0,5766	1,0000						
D_2	0,6647	0,9809	0,6064	0,8700	1,0000					
Nbr	0,6277	0,6145	0,9707	0,5893	0,6250	1,0000				
Msd	0,7233	0,8483	0,6098	0,8837	0,8571	0,6169	1,0000			
Msh	0,7322	0,8415	0,6066	0,8877	0,8502	0,6115	0,9908	1,0000		
Mro	0,6769	0,8243	0,5884	0,8392	0,8328	0,5991	0,9726	0,9324	1,0000	
QI	0,6513	0,8509	0,5880	0,7619	0,8618	0,5941	0,9309	0,9085	0,9330	1,0000

Marked correlations are significant at $p < 0.01$.

H_1 shows strong correlation with H_2, as well as with Msh and Msd. D_1 shows a very strong correlation with D_2, as well as with other measured morphological attributes, except with Nbd and Nbr. Nbd shows very strong correlation with Nbr. H_2 shows very strong correlation with Msh, Msd and D_2, and moderate correlation with Nbd and Nbr. The strongest correlation of D_2 is with D_1, but is very strong with all the other measured morphological attributes, except with Nbd and Nbr. Interestingly, D_2 shows moderate correlation with H_1, but very strong correlation with H_2. In addition to very strong correlation with Nbd, Nbr shows a moderate correlation with other measured morphological attributes. As expected, Msd showed an extremely strong correlation with Msh, and a very strong correlation with Mro and QI and a moderate correlation with Nbd and Nbr. Except the extremely strong correlation with Msd, Msh shows a very strong correlation with Mro and QI. Mro shows a very strong correlation with Msd, Msh and QI and strong correlation with H_1. QI shows a very strong correlation with Mro, Msd and Msh and moderate correlations with Nbd, Nbr (0.5941) and H_1, figure 1.

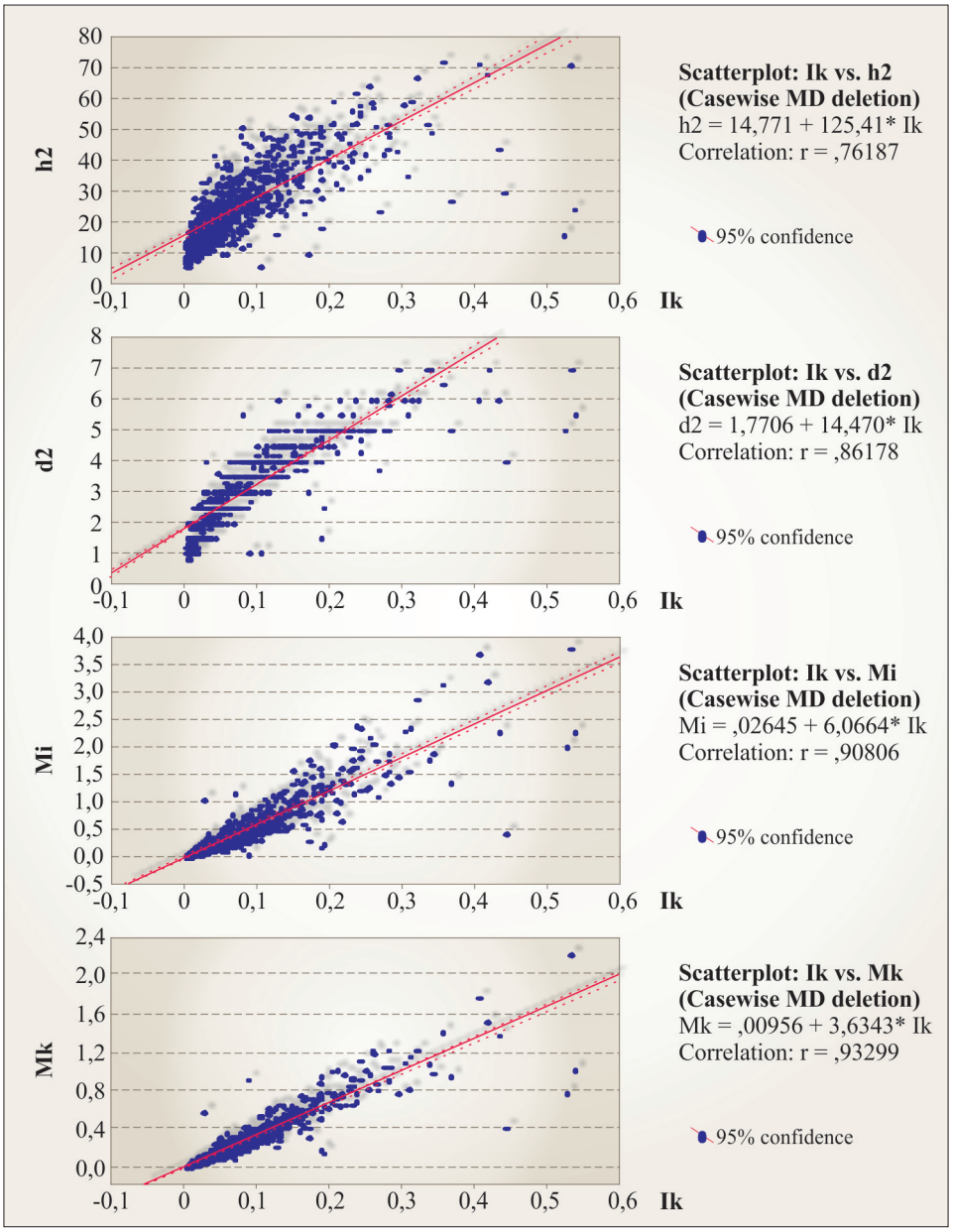

Diagram 1. Regression line of quality index (QI) relationship with height (H_2) and diameter (D_2) after second growing season and shoot (Msh) and root (Mro) dry mass

Графикон 1. Регресиона линија односа индекса квалитета (QI) са висином (H_2) и пречником (D_2) након друге године и масом изданка (Msh) и корена (Mro) у сувом стању

Table 2. Correlation coefficients between nitrogen concentration in shoot (Ns) and root (Nr), phosphorus concentration in shoot (Ps) and root (Pr), potassium concentration in shoot (Ks) and root (Kr), height (H_2) and diameter (D_2) after the second growing season, dry mass of seedlings (Msd) and quality index (QI) in a sample of 135 seedlings

Табела 2. Коефицијенти корелације између садржаја азота у изданку (Ns) и корену (Nr), садржаја фосфора у изданку (Ps) и корену (Pr), садржаја калијума у изданку (Ks) и корену (Kr), висине (H_2) и пречника (D_2) након друге године, масе садница у сувом стању (Msd) и индекса квалитета (QI) на узорку од 135 садница

	Ns	Nr	Ps	Pr	Ks	Kr	H_2	D_2	Msd	QI
Ns	1,000									
Nr	0,580	1,000								
Ps	-0,053	-0,202	1,000							
Pr	-0,356	-0,086	0,281	1,000						
Ks	0,296	0,218	-0,320	-0,139	1,000					
Kr	-0,124	-0,032	-0,325	0,222	0,556	1,000				
H_2	-0,323	-0,069	0,162	0,140	0,065	0,145	1,000			
D_2	-0,366	-0,016	0,061	0,059	0,039	0,195	0,890	1,000		
Msd	-0,318	-0,028	0,103	0,135	0,013	0,122	0,771	0,738	1,000	
QI	-0,313	0,005	0,052	0,094	0,034	0,155	0,770	0,879	0,822	1,000

Marked correlations are significant at p <0.05.

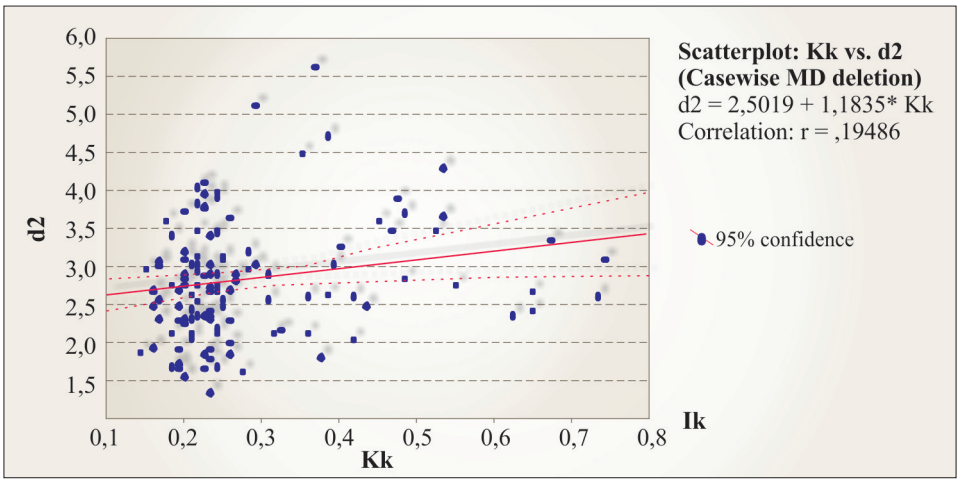

Diagram 2. Regression line of the relationship between potassium concentration in root (Kr) and diameter after the second growing season (D_2)

Графикон 2. Регресиона линија односа садржаја калијума у корену (Kr) и пречника након друге године (D_2)

The calculated Pearson coefficient of a sample of 135 (after casewise deletion of missing data) showed a weak but significant positive correlation between Ps and Pr. There is also a weak but significant negative correlation between Ps and Ks and between Ps and Kr. There is also a weak but significant positive correlation between Pr and Kr. A moderate positive correlation exists between Ks and Kr. The only significant correlation between physiological and morphological attributes (weak and positive) exists between Kr and D_2.

4. DISCUSSION

The examination of the relationship between the measured morphological and physiological attributes showed a strong positive correlation between all morphological attributes. As expected, H_1 showed the strongest positive correlation with H_2. In addition, H_1 showed a strong positive correlation with Msh and Msd, measured after the second growing season. H_2 showed the strongest positive correlation with Msh, as previously reported for the wild cherry (Stjepanović, Ivetić, 2013). These strong correlations of height and shoot mass are consistent with seedling structure. According to Mattsson (1996), correlation between the initial height and success after planting in the field is often contradictory, while diameter is a useful indicator of survival and growth after planting in the field. Height is a reliable indicator of seedling quality only when used combined with the diameter. Jacobs *et al*. (2005) found significant positive correlation between height, diameter, root volume and fresh mass with height and diameter of red oak seedlings in the first and second year after planting in the field.

There is a strong positive correlation between D_1 and D_2 with all other measured morphological attributes, except with the Nbd and Nbr. Significant correlation between diameter and shoot and root was reported by Ruehle and Kormanik (1986) for red oak seedlings. Binotto *et al.* (2010) reported that the root collar diameter is the best single indicator of seedling quality, given its high-level correlation with the quality index. Stjepanović and Ivetić (2013) also reported on the high level of correlation between the diameter and the quality index. Diameter is a good indicator of root development, such as volume and dry mass (Jacobs *et al*., 2004, Stjepanović, Ivetić, 2013). It seems that the correlation between the diameter and height grows stronger with age because the correlation between D_2 and H_2 is much stronger compared to the correlation between D_1 and H_1.

Dry masses of seedling, shoot and root expected, showed the strongest correlation with each other. In addition, all masses show a very strong correlation with QI.

QI showed the strongest correlation with dry masses (Msd, Msh, Mro), which is consistent with the results reported by Binotto *et al.* (2010), and expected considering the calculation method.

In the case of physiological attributes, a weak positive correlation was recorded between the nutrient concentration in shoot and root; as well as between Pr and Kr. On the other hand, a negative correlation was recorded between Ps with Ks and Kr. Mattsson (1996) states that despite the extensive literature on nutrient concentration in seedlings,

there is no extensive research on their correlation with their success on the field and the results are often contradictory. He also states that nitrogen concentration in the leaves has a certain potential as a predictor of seedling growth after planting in the field. On the other hand, the results obtained in this research indicate a lack of significant correlation between nitrogen concentration in shoot and root, with all measured morphological attributes. Even if it is not significant, there is a negative correlation between Ns with all measured morphological attributes.

The only significant correlation between physiological and morphological parameters (weak and positive) was recorded between Kr and D_2.

The results from this research confirm the statements of a number of authors about the correlations among the morphological attributes of seedling quality (Thompson, 1985, Roller, 1976, Haase, 2007, Ivetić, 2013, Stjepanović, Ivetić 2013).

5. CONCLUSION

The diameter has proven to be the best single morphological indicator of hop hornbeam seedling quality, given its strong correlation with other measured morphological attributes. Seedling height should be used only when combined with the diameter. Assessment based on height is reliable only for shoot development, given the strong correlation with dry mass. However, height is important, because it can refer to seedling survival and success in the field, especially in weedy habitats.

Seedling dry mass (shoot and root mass) and quality index represent the most comprehensive indicators of hop hornbeam seedling quality, but the measuring of mass is destructive and requires a certain amount of time.

The absence of strong correlations between physiological and morphological attributes of the quality of two-year hop hornbeam seedlings suggests the need for further research. The presence of strong correlations among the measured morphological attributes can simplify common methods of seedling quality assessment for practical purposes. However, standardization of quick, easy, inexpensive and non-destructive methods of seedling quality assessment requires a much more extensive research.

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ОДНОС МОРФОЛОШКИХ И ФИЗИОЛОШКИХ ПАРАМЕТАРА КВАЛИТЕТА САДНИЦА ЦРНОГ ГРАБА (*Ostrya carpinifolija* Scop.)

Резиме

Сакупљање плодова црног граба извршено је на три локалитета североисточно од Газиводског језера. Након дораде, стратификовано семе је посејано у посуде, у супстрат од мешавине песка и тресета у односу 2 : 1. Након првог вегетационог периода, у три леје је пресађено по 315, односно укупно 945 садница. На крају прве године, на узорку од 945 садница, измерене су висине и пречници садница и избројани су пупољци. На крају друге године, на узорку од 945 садница, измерене су висине и пречници садница, избројане су гране и измерена је маса садница у сувом стању: укупна маса, маса надземног дела и маса корена. На основу измерених морфолошких показатеља у другој години, израчунат је индекс квалитета. Измерен је садржај азота (N), фосфора (P) и калијума (K) у надземном делу и корену анализираних биљака. Испитивање међусобне зависности посматраних морфолошких и физиолошких показатеља квалитета, показало је јаку позитивну корелацију између свих морфолошких показатеља. Очекивано, најјача позитивна корелација висине једногодишњих је са висином двогодишњих садница. Поред тога, забележена је и јака позитивна корелација једногодишњих садница са масом изданка и укупном масом садница у сувом стању. Најјача позитивна корелација двогодишњих садница је са масом изданка у сувом стању. Присутна је снажна позитивна корелација пречника једногодишњих и двогодишњих садница са свим осталим испитиваним морфолошким параметрима, осим са бројем пупољака и бројем грана. Може се констатовати да веза пречника и висине јача са старошћу садница јер је корелација између пречника и висина двогодишњих садница знатно већа од оне између једногодишњих. Масе у сувом стању очекивано показују најснажнију међусобну корелацију. Поред тога, показују и снажну корелацију са индексом квалитета. Најјача корелација индекса квалитета је управо са масом у сувом стању (масом садница, масом изданка, масом корена). Код физиолошких показатеља забележена је слаба позитивна корелација између садржаја макроелемената у надземном делу и корену; као и између садржаја фосфора и садржаја калијума у корену. Са друге стране, забележена је негативна корелација између садржаја фосфора у изданку и садржаја калијума у изданку и корену. Резултати добијени у овом раду указују на одсуство сигнификантне корелације садржаја азота, како у надземном делу, тако и у корену, са свим испитиваним морфолошким параметрима раста садница. И ако није сигнификантна, постоји изражена негативна корелација садржаја азота у изданку са свим испитиваним морфолошким параметрима. Једина сигнификантна корелација између физиолошких и морфолошких показатеља (слаба и позитивна) забележена је између садржаја

калијума у корену и пречника двогодишњих садница. Пречник се показао као најбољи појединачни морфолошки параметар квалитета садница црног граба јер висока вредност пречника указује на високе вредности осталих испитиваних морфолошких параметара и може их поуздано заменити. Висину садница треба користити само у комбинацији са пречником. Издвојено посматрање висине поуздано указује на развијеност надземног дела садница, исказану кроз масу надземног дела у сувом стању. Ипак, висину треба обавезно мерити, јер може указати на преживљавање и успех садница на терену, нарочито на закоровљеним стаништима. Маса садница у сувом стању (надземног дела и корена) и индекс квалитета представљају најобухватније показатеље квалитета садница црног граба, али је мерење масе деструктивно и захтева одређено време. Одсуство снажних корелација између физиолошких и морфолошких показатеља квалитета двогодишњих садница црног граба наводи на потребу за даљим истраживањима. Присуство снажних корелација између истраживаних морфолошких параметара омогућује поједностављење уобичајених метода процене квалитета садница у практичне сврхе. Ипак, ради стандардизације брзих, лаких, јефтиних и недеструктивних метода процене квалитета садница потребно је извршити знатно обимнија истраживања, која нису била предмет овод рада.