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Effects of altitude on some seedling quality characteristics of Carpinus betulus L. (Common Hornbeam) and Carpinus orientalis Mill. (Oriental Hornbeam)

Carpinus betulus L. (Adi Gürgen) ve Carpinus orientalis Mill. (Doğu Gürgeni) fidanlarının bazı kalite özellikleri üzerine yükseltinin etkisi

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Abstract

This study aims to determine some morphological characteristics of two-year-old common hornbeam (*Carpinus betulus* L.) and oriental hornbeam (*Carpinus orientalis* Mill.) seedling and to determine the quality classes of the seedlings according to Turkish Standards Institute's (TSI) seedling quality standards and sturdiness quotient values. As a study material, two-year-old common hornbeam and oriental hornbeam seedlings, grown from seed obtained from three different altitudes as lower (0-400 m), mid (400-800 m) and upper (800-1200 m) in the Trabzon-Maçka watershed were used. The seedlings were grown in seedbeds in open nursery conditions of Karadeniz Technical University Forestry Faculty Research and Application Greenhouse. Seedling length and root collar diameter were measured in two-year-old seedlings. The sturdiness quotient was calculated with the data of the measured seedling morphological characteristics. Quality classes were classified according to TSI seedling quality standards determined for hornbeam seedlings. The highest mean seedling length for common hornbeam was determined as 48.76 cm at the 3rd altitude level, while the highest mean seedling length for oriental hornbeam was found as 38.90 cm at the 2nd altitude level. The mean root collar diameters for were varied between 4.97-5.23 mm in common hornbeam and 4.62-5.09 mm in oriental hornbeam. As a result of variance analysis, statistically significant differences (p<0.05) among altitudes regarding seedling length and sturdiness quotient of common hornbeam. As for the oriental hornbeam, it was found that statistically significant differences on 95% confidence level in terms of seedling length and root collar diameter. In addition, significant differences between the two seedling quality assessments and consistent results were not obtained. This shows that both TSI seedling quality standards and the sturdiness quotient criteria are not sufficient by themselves to determine the quality of common hornbeam and oriental hornbeam.

Özet

Çalışmada iki yaşındaki adi gürgen (*Carpinus betulus* L.) ve doğu gürgeni (*Carpinus orientalis* Mill.) fidanlarının bazı morfolojik özelliklerinin belirlenmesi ve fidanların TSE fidan kalite standartları ve gürbüzlük indisi değerlerine göre kalite sınıflarının tespit edilmesi amaçlamaktadır. Çalışma materyali olarak, Trabzon-Maçka havzasının üç farklı yükseltisinden (0-400 m, 400-800 m, 800-1200 m) toplanan tohumlardan yetiştirilmiş 2+0 yaşındaki Adi gürgen ve doğu gürgeni fidanları kullanılmıştır. Fidanlar Karadeniz Teknik Üniversitesi Orman Fakültesi Araştırma ve Uygulama Serası açık alan fidanlık koşullarında yetiştirilmiştir. İki yaşındaki fidanlarda fidan boyu ve kök boğaz çapı değerleri ölçülmüştür. Ölçümü yapılan fidan morfolojik karakterine ait veriler ile gürbüzlük indisi değeri hesaplanmıştır. Ayrıca, gürgen fidanı için belirlenmiş Türk Standartları Enstitüsü (TSE) fidan kalite standartlarına göre kalite sınıfları tasnifi yapılmıştır. Çalışma sonucunda, yükseltiler arasında en yüksek ortalama fidan boyu adi gürgende 48.76 cm ile 3. yükseltide, doğu gürgeninde 38.90 cm ile 2. yükseltide elde edilmiştir. Ortalama KBÇ değerleri adi gürgende 4.97-5.23 mm, doğu gürgeninde 4.62-5.09 mm arasında değişmektedir. Varyans analizi sonucunda, yükseltiler arasında fidan boyu ve gürbüzlük indisi açısından %95 güven düzeyinde istatistiksel olarak anlamlı farklılıklar (p<0.05) tespit edilmiştir. Doğu gürgeninde ise fidan boyu ve kök boğazı çapı bakımından %95 güven düzeyinde istatistiksel olarak anlamlı farklılıklar olduğu belirlenmiştir. Ayrıca, her iki fidan kalite değerlendirmesi arasında önemli farklılıklar meydana gelmiş ve tutarlı sonuçlar elde edilmemiştir. Buda gerek TSE fidan kalite standartlarının gerekse gürbüzlük indisi kriterlerinin adi gürgen ve doğu gürgeninin fidan kalitesini belirlemede tek başlarına yeterli olamadığını göstermektedir.

1. INTRODUCTION

Turkey carries out important activities such as to increase the forest areas and sustainability from the past to present. While the forest area of Turkey was 20.199.296 ha in 1973, it reached 22.342.935 ha in 2015 and covers 28.6% of the country's surface area. However, 57% of these forests are productive and 43% are degraded. Rehabilitating degraded forest areas into productive is extremely important for the continuity of various functional benefits provided by forest ecosystems (Anonymous 2015). Forestation works with natural deciduous broadleaf species have become importance both in Europe and in Turkey (Kahveci and Tüfekçioğlu 1998, Huss and Kahveci 2009).

Since deciduous broadleaf forests provide multiple-use forest functions, protect biodiversity and serve recreational purposes, it is recommended to increase these areas (Löf et al. 2004). On the other hand, it is expected that the log prices of deciduous broadleaf forest trees will increase in the coming years (Abildtrup et al. 1997, Löf et al. 2004) and it is predicted that their growth rate will increase as the deciduous broadleaf forest trees will perform more photosynthesis as a result of global climate change (Sykes and Prentice 1996, Löf et al. 2004).

Biological and economical success of forestations, as well as the habitat conditions, it depends on the land preparation, appropriate planting technique, planting time and the use of quality seedling (Ayan 2002, Gezer and Yücedağ 2006). The quality seedlings are defined as those that meet the desired level of growth and survival after planting (Duryea 1985, Mattsson 1997). Johnson and Cline (1991) defined high quality seedlings as those that have the physical and physiological attributes that enhance their survival and produce vigorous growth after field establishment. The morphological characteristics of seedling such as length, diameter, dry weight and stem-root ratios are significantly effective in the quality of seedling planted in forestation areas (Şevik et al. 2003). Planting success can be increased by using quality seedling in forestation works, and more quantity and quality wood raw materials can be produced in a shorter time from unit areas (Bilgin 2019).

Morphological traits are the most commonly measured in seedling quality assessment as they are cheap and easy to measure (Ritchie 1984, Mexal and Landis 1990, Yahyaoğlu and Genç 2007). Unlike physiological traits, advanced equipment and advanced training are not needed to evaluate morphological traits. Among the morphological traits, seedling length and root collar diameter are the easiest to measure (Haase 2008). There are various studies in which morphological parameters are used to determine the quality of seedling of many species (Yılmaz 1995, Donahue and Upton 1996, Üçler et al. 2000, Apholo and Rikala 2003, Jacobs et al. 2005, South et al. 2005, Ayan and Tilki 2007, Manas et al. 2009, Yer and Ayan 2011, Çiçek et al. 2011, Aksu and Tilki 2015, Ivetić et al. 2016, Bilgin 2019, Ayan et al. 2020). However, there are a limited number of studies in the literature on seedling characteristics of common hornbeam and oriental hornbeam, them of our important tree species and having a wide distribution in Turkey.

The genus Carpinus includes 35-60 species with tree or shrub forms and is widely distributed in the temperate regions of the northern hemisphere (Hora 1981, Krüssman 1984). *Carpinus orientalis* Mill. and *Carpinus betulus* L. species spreads naturally in Turkey. *Carpinus orientalis* has a wide natural distribution area from southeast of Europe to the north of Iran (Babrov 1970). In Turkey, it spreads in North Anatolia, Eastern Anatolia, Aegean and Marmara Regions. (Yaltırık 1982, Demirci 2006). *Carpinus betulus* distrubuted in the Black Sea region. It also spreads locally in the Amanos Mountains (Yaltırık 1982, Anşin and Özkan 2006). Oriental hornbeam has a high drought tolerance and usually grows in dry, shallow and stony soils. Thick bark structure that reduces mortality is characteristic for this species (Shafiei et al. 2010). Due to its resistance to drought stress, it is a suitable species for rehabilitation of degraded areas (Pipinis et al. 2012). Common hornbeam is a shade tolerant species that grows best in forests with deep rich and moist soils. However, it also develops in dry and shallow soils (Browicz 1982). Oriental hornbeam wood is used extensively for local needs, in the production of tourist ornaments and as firewood (Anşin and Özkan

2006). The common hornbeam tree form, leaf color and decorative fruits have the potential to be used as an ornamental plant (Dirr 1998). It is used as sled and timber in the lathe industry, in the construction of vehicle bodies, shipbuilding and wood fuel (Anşin and Özkan 2006).

The research aims to determine some morphological characteristics of two-year-old common hornbeam and oriental hornbeam seedlings which grown from seeds obtained from different altitudes and to decide the quality classes of the seedling according to the Turkish Standards Institute seedling standards and sturdiness quotient.

2. MATERIAL AND METHOD

2.1. Material

As a study material, two-year-old common hornbeam and oriental hornbeam seedlings, grown from seeds obtained from three different altitudes (0-400 m, 400-800 m, 800-1200 m) of the Trabzon-Maçka watershed were used (Figure 1). Seeds were collected during the optimum seed maturation period in early October. Seeds were harvested from a total of 90 trees (3 altitude levels × 15 trees × 2 species). The harvested seeds were labeled according to the altitude levels they were collected from by putting them separately into bags. Afterwards, they were separated from the pericarps by hand and empty and rotten seeds were removed. Filled seeds were identified through floatation in 96% alcohol. Seeds were sown using line sowing method (75 seeds in each sowing line), by a randomised sampling design, in nursery seedbeds (using 10.0 cm sowing line spacing across 1.0 m wide seedbeds) in October. All nursery operations were performed as uniformity as possible (i.e. irrigation, shading, weed control, maintenance, etc.). The seedlings were grown in seedbeds in open nursery conditions of Karadeniz Technical University Forestry Faculty Research and Application Greenhouse. According to the climate data between 1927-2019 in the province of Trabzon where the nursery is located, the annual average temperature is 14.7 and the total annual precipitation is 829.6 mm (Table 1).

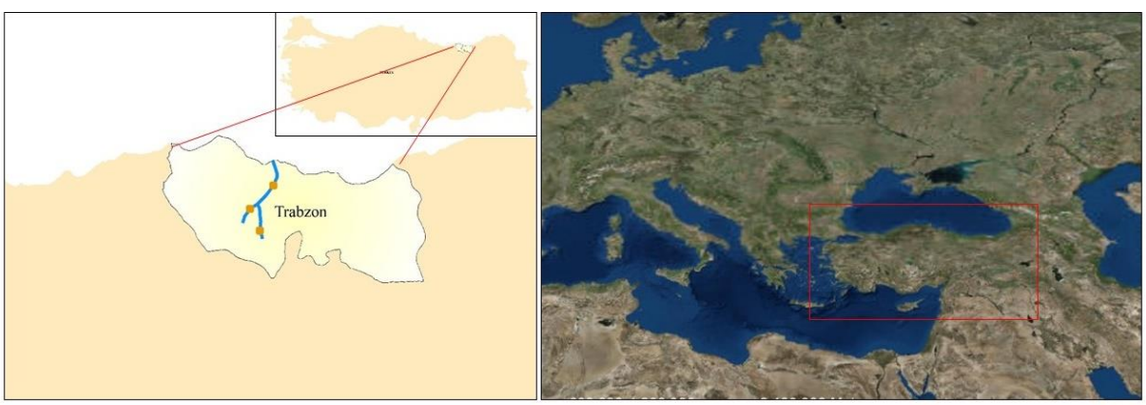

Figure 1. The geographical locations of the altitudes where seeds were collected

Table 1. Meteorological data of the province of study area

	Climate Period (1927-2019)											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	7.4	7.2	8.3	11.7	15.8	20.1	22.9	23.3	20.3	16.6	12.9	9.5
2	10.7	10.7	11.9	15.5	19.1	23.1	25.9	26.5	23.7	20.0	16.5	12.9
3	4.6	4.3	5.4	8.6	12.9	17.0	19.9	20.3	17.3	13.6	10.0	6.7
4	2.6	3.2	3.4	4.3	5.5	7.0	5.9	5.6	4.9	4.5	3.6	2.6
5	11.8	11.7	12.6	12.4	12.3	10.3	7.6	8.3	10.4	11.8	11.3	12.0
6	82.9	64.6	58.4	56.9	52.1	51.8	35.6	48.0	78.6	115.4	99.6	85.7

1. Avg. Temperature (°C); 2. Avg. Highest Temperature (°C); 3. Avg. Lowest Temperature (°C); 4. Avg. Sunshine Time (hour); 5. Avg. Number of Rainy Days; 6. Monthly Total Precipitation Avg. (mm)

2.2. Method

In the study, morphological characteristics were measured on a total of 900 seedlings (2 species × 3 altitudes × 3 replications × 50 seedlings). Seedling length and root collar diameter were measured in two-year-old seedlings. The sturdiness quotient was calculated with the data of the measured seedling morphological characteristics.

Seedling Length (SdL): It is the length value from root collar to the top of the terminal shoot. It was measured by use a meter with precision of ± 0.1 cm.

Root Collar Diameter (RCD): It is the value measured just above the uppermost root on the seedling stem. It was measured by use a digital caliper with precision of ± 0.01 mm.

Sturdiness quotient (SQ): The sturdiness quotient refers to the ratio of the height of the seedling to the root collar diameter and expresses the vigour and robustness of the seedling (Thompson 1985, Aldhous 1994, Jaenicke 1999).

$$SQ = SdL\ (mm)/RCD\ (mm) \quad (1)$$

The seedling were classified as quality seedling (SQ<50), medium quality seedling (50<SQ<60) and low quality seedling (SQ>60) by using the SQ values (Yahyaoğlu and Genç 2007). In addition, seedlings were classified according to Turkish Standards Institute's (TSI) deciduous seedling standards (TS 5624/21.03.1988) (Anonymous 1988). TSI quality standards of hornbeam seedlings are given in Table 2.

Table 2. Quality classes of hornbeam according to Turkish Standards Institute

Classes	Minimum length (cm)	Minimum RCD according to seedling lengths (mm)					
		20	30	40	50	75	100
I	30	-	4	5	6	7	8
II	20	3	3	4	5	6	7

The coefficient of variation of seedling morphological characters were also evaluated depending on the altitude. The coefficient of variaton (CV) was calculated as follows:

$$CV\% = \left(\frac{\sigma}{\mu}\right) \times 100 \quad (2)$$

where σ is standard deviation, μ is the overall mean (Bland and Altman 1996).

The data were analysed by SPSS 23.0 statistical package program. In the study, analysis of variance (one-way ANOVA) was performed to reveal the statistical significance of the differences in the morphological characteristics of the seedling depending on the different altitudes. In case of significant differences as a result of variance analysis, groups were determined by Duncan test.

3. RESULTS AND DISCUSSION

Morphological characteristics of common hornbeam and oriental hornbeam seedlings are shown in Table 3. In the common hornbeam, the seedling length was between 6.00 to 132.00 cm with a mean value of 44.03 cm. The value of root collar diameter ranged from 0.95 to 14.05 mm, the mean of seedling length was 5.13 mm. Sturdiness quotient was from 29.52 to 178.95, the mean of sturdiness quotient was 86.40. In the oriental hornbeam, the value of seedling length was from 6.00 to 105.00 cm, the mean value was 36.48 cm. The root collar diameter were between 0.90 to 13.20 mm with a mean value of 4.78 mm. The sturdiness quotient in all altitudes ranged from 17.98 to 266.67, with a mean value of 78.30. The values of the measured morphological characteristics varied in both species depending on the increase in altitude. The seedlings belonging to the 1st altitude level had the lowest seedling length (41.43 cm and 34.77 cm for *Carpinus betulus* and *Carpinus orientalis*, respectively) in both species. The highest seedling length was obtained at the 3rd altitude level with 48.76 cm in common hornbeam and at the 2nd altitude level with 38.90 cm in the oriental hornbeam. It was determined that the sturdiness quotient of common hornbeam increase depending on the increase in altitude.

The changing of coefficients of variation of the measured morphological characteristics depending on the altitude was determined. The CV of most of seedling morphological characteristics was high in the 3rd altitude level (Figure 2).

Table 3. Statistical data regarding the morphological characteristics of the seedlings

		C. betulus			*C. Orientalis*		
		1st Altitude (0-400 m)	2nd Altitude (400-800 m)	3rd Altitude (800-1200 m)	1st Altitude (0-400 m)	2nd Altitude (400-800 m)	3rd Altitude (800-1200 m)
SdL	Mean	41.43	41.90	48.76	34.77	38.90	35.76
	Std. dev.	19.95	20.20	25.50	18.20	17.82	19.06
	Std. error	1.72	2.25	2.56	1.48	1.03	1.57
	Min	12.00	6.00	6.00	7.00	6.00	8.00
	Max	100.00	106.00	132.00	100.00	105.00	102.00
RCD	Mean	5.23	4.97	5.20	4.62	5.09	4.63
	Std. dev.	1.96	2.26	2.51	1.97	1.96	1.91
	Std. error	0.16	0.25	0.26	0.16	0.11	0.15
	Min	1.41	0.95	1.37	0.90	0.96	1.14
	Max	14.05	11.35	13.00	9.96	13.20	11.28
SQ	Mean	79.96	85.02	94.23	77.94	79.02	77.94
	Std. dev.	23.46	20.21	26.50	30.37	27.99	30.12
	Std. error	2.02	2.26	2.66	2.48	1.61	2.48
	Min	34.00	29.52	41.96	26.77	30.36	17.98
	Max	178.95	133.90	169.88	233.96	266.67	260.09

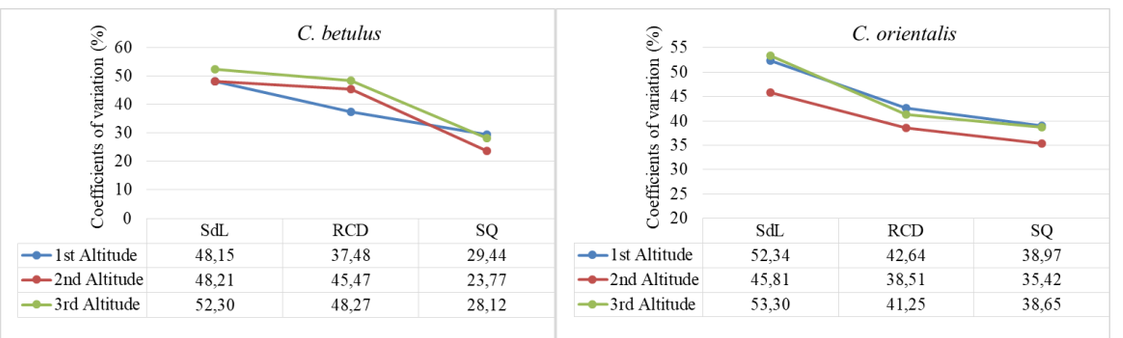

Figure 2. The CV of seedling morphological characteristics

As a result of variance analysis, it was determined that statistically significant differences on 95% confidence level ($p<0.05$) among altitudes regarding seedling length and sturdiness quotient of common hornbeam. As for the oriental hornbeam, it was found that statistically significant differences on 95% confidence level in terms of seedling length and root collar diameter (Table 4). Groups formed by the altitudes for each morphological characteristics were determined by Duncan's test. Accordingly, among the altitudes, there were 2 groups for seedling length and sturdiness quotient in common hornbeam. 3 groups for the seedling length and 2 groups for the root collar diameter occurred in the oriental hornbeam (Figure 3).

Table 4. The results of variance analysis regarding the morphological characteristics

	C. betulus		*C. Orientalis*	
	F	*P*	F	*P*
SdL	3.615	**0.028**	3.075	**0.047**
RCD	0.374	0.688	4.137	**0.016**
SQ	10.746	**0.000**	0.102	0.903

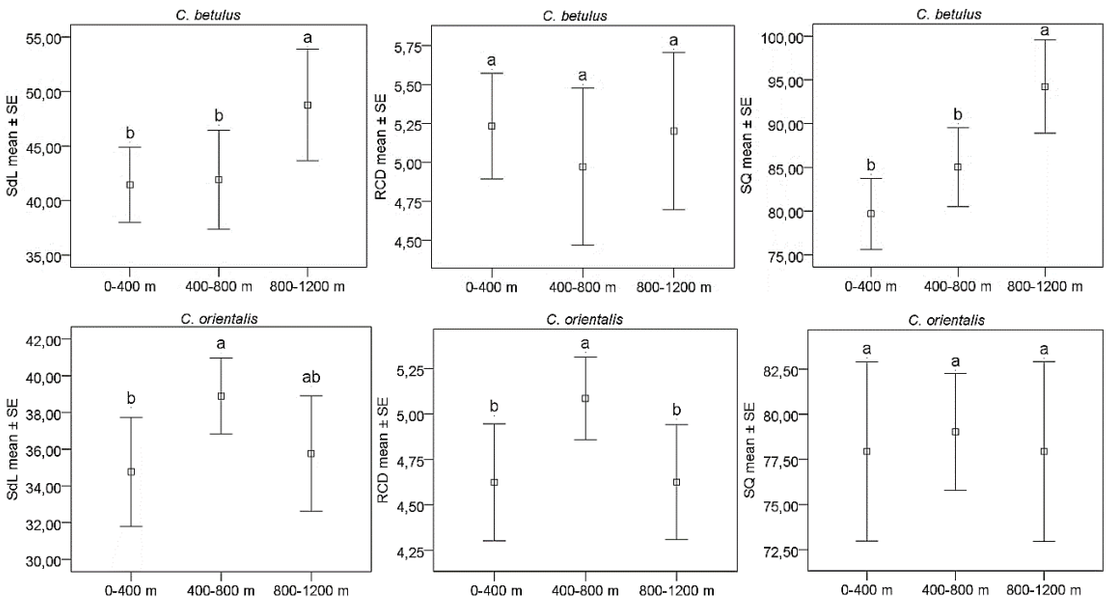

Figure 3. The result of Duncan test regarding the morphological characteristics

When the relationships between the measured seedling characteristics were examined, it was found strong positive correlations between the seedling length and root collar diameter of both species. The correlation coefficient between seedling length and root collar diameter in common hornbeam and oriental hornbeam were determined as $R^2 = 0.69$ and $R^2 = 0.51$, respectively (Figure 4).

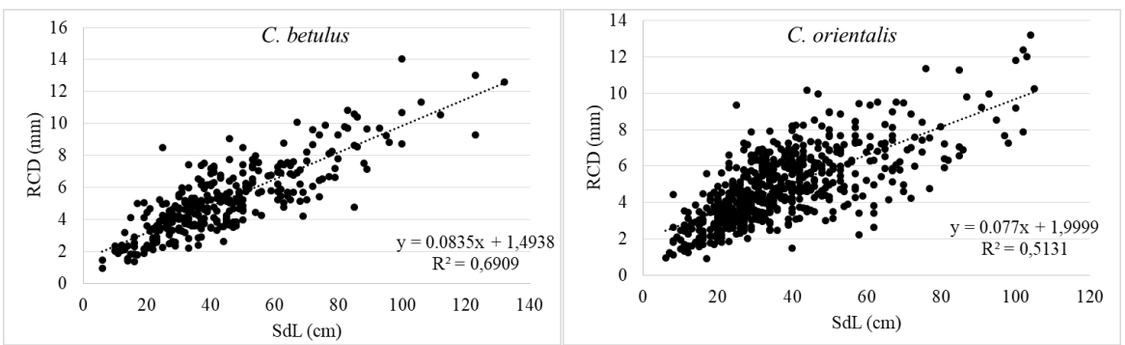

Figure 4. The relationship between RCD-SdL in common hornbeam and oriental hornbeam seedlings

TSI standards suitability of the seedlings was evaluated according to the seedling length and root collar diameter criteria. It was determined that 72.7% of the common hornbeam is in the 1st quality class, 18.0% is in the 2nd and 9.3% of the seedlings are discarded. It was found that 58.4% of the oriental hornbeam is in the 1st quality class, 28.0% is in the 2nd quality class, and 13.6% of the seedlings are discarded. According to the sturdiness quotient, 87.6% of common hornbeam seedling and 72.1% of oriental hornbeam seedlings were in the low quality seedling class (Table 5). Also, depending on the altitude, it was determined that the quality classes of the seedlings belonging to the 1st altitude for both species had the lowest value.

Table 5. Quality classification according to TSI standards and sturdiness quotient for species

		Quality classes of TSI (%)			SQ (%)		
		I	II	Non-standard	Quality	Medium Quality	Low Quality
C. betulus	1st Altitude	68.7	23.9	7.5	6.0	13.4	80.6
	2nd Altitude	73.8	13.8	12.5	3.8	5.0	91.3
	3rd Altitude	75.8	16.2	8.1	3.0	6.1	90.9
	Mean	72.7	18.0	9.3	4.2	8.2	87.6
C. orientalis	1st Altitude	53.3	29.3	17.4	14.0	16.7	69.3
	2nd Altitude	66.6	26.4	7.0	11.7	13.4	74.9
	3rd Altitude	55.8	28.6	16.6	10.2	17.7	72.1
	Mean	58.4	28.0	13.6	12.0	15.9	72.1

In the first studies of seedling quality classification were used seedling length as the criterion (Yahyaoğlu and Genç 2007). Depending on the habitat conditions of the forestation area, it is reported that more successful results are obtained after planting sometimes high length, sometimes low length and even rarely medium-length seedlings. For this reason, the most suitable seedling length depends significantly on the ecological conditions prevailing in the forestation area. In a study conducted by Semerci (2002), while a positive correlation was found between seedling length and survival success, some researchers stated that there was a negative correlation between these two parameters (Larsen et al. 1986, Tuttle et al. 1987, Dirik 1991). Also, it is notified that the root collar diameter is a more important criterion in the seedling quality classification than the seedling length (Şimşek 1987, Yahyaoğlu and Genç 2007). Cleary and Greaves (1979) reported that the root collar diameter is an important parameter that indicates the strength of the seedling. Within the scope of the study, the highest mean seedling length for common hornbeam was determined as 48.76 cm at the 3rd altitude, while the highest mean seedling length for oriental hornbeam was found as 38.90 cm at the 2nd altitude. The mean seedling lengths were determined as 44.03 cm in common hornbeam and as 36.48 cm in oriental hornbeam. The mean root collar diameters were varied between 4.97-5.23 mm in common hornbeam and 4.62-5.09 mm in oriental hornbeam. Ayan et al. (2020) was determined that the average height of 3+0 year-old common hornbeam seedling was 70.8 cm and the average RCD was 6.70 mm. In a study conducted on the oriental beech, it was found significantly differences seedling length and root collar diameter in terms of populations (Gülseven et al. 2019). In a study investigating the four-year growth performance of common hornbeam seedlings by Atar et al. (2018), they stated that there were significant differences in seedling heights and root collar diameters according to populations. Similar results were found by Atar and Turna (2018) on *Castanea sativa*, by Hatipoğlu (2013) on *Carpinus orientalis*, by Yahyaoğlu et al. (2012) on the *Pinus pinea* and by Güney (2009) on the *Fagus orientalis*. Aksu and Tilki (2015) reported that the origin and seed size were effective on the morphological characteristics of the *Quercus pontica* seedling.

Genç (1992) stated that another criterion used as seedling quality classification is the sturdiness quotient, the lower the SQ value is a desired feature in terms of the quality of the seedling and the planting success is higher. According to Aphola and Rikala (2003), all origins of the seedling with a SQ<50 are evaluated in the quality seedling class. Gülseven et al. (2019) stated to the SQ value of all the studied populations was less than 50 in on seedling belonging to different oriental beech populations. In the study conducted on one–year-old oak seedlings was notified that the highest SQ value was obtained in control seedling grown routinely as 39.6% and the lowest SQ value was obtained in containerized seedlings as 28.7% (Kestek 2012). In another study, it was stated that the SQ values of *Quercus brantii* Lindley differ according to the planting spacing and the values varied between 43 and 53 (Çanakçı 2011). In a research conducted by Bilgin (2019), the SQ values were found as 39.11 for *Pinus pinea* seedling, 36.84 for *Quercus ithaburensis* seedling, and 23.79 for *Quercus cerris* seedlings. In other study investigating the morphological characteristics of some deciduous broadleaf forest tree seedling, it was reported that 100% of mountain maple, 93.3% of oriental beech and 97.8% of common hornbeam according to SQ values

were in the category of low-quality seedling (Ayan et al. 2020).

According to the sturdiness quotient in this study, only 11.5% of common hornbeam seedlings are in the quality and medium quality class, and 88.6% of them are in the low quality class that is not suitable for use. 83.4% of common hornbeam seedlings were in 1st class,6.3% of them were in 2nd class in terms of TSI standards, and only 10.3% of the seedlings were considered as substandard seedling. For oriental hornbeam seedlings, it was determined that 72.8% of the seedlings were in low quality according to the sturdiness quotient, but 88.7% of them were in the 1st and 2nd classes according to TSI standards. It was occurred significant differences between the two seedling quality assessments and consistent results were not obtained. This shows that both TSI seedling quality standards and the sturdiness quotient criteria are not sufficient to determine the seedling quality of common hornbeam and oriental hornbeam.

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