



# Variability in morphological traits of seedlings from five *Euonymus japonicus* cultivars

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**Abstract** In this study, we investigated the variability in morphological traits of seedlings from five *Euonymus japonicus* cultivars. We measured seedling heights, root collar diameters, leaf lengths and widths, root lengths, root numbers, and twig numbers of 60 seedlings from each cultivar. The *E. japonicus* cultivars Variegata and Green Rocket had the highest (95.8%) and lowest (70.3%) rooting percentages, respectively. With the exception of root lengths ( $p > 0.05$ ), all morphological characteristics significantly differed among all cultivars ( $p < 0.05$ ). In particular, the cultivar Green Rocket performed better than all other cultivars, with greater seedling heights and root collar diameters. These data

warrant further studies for quantifying differences in traits among these cultivars.

**Keywords** *Euonymus japonicus* · Ornamental plant · Landscape design · Morphological traits · Variability

## Introduction

Rapid global urbanization has led to the destruction of many natural green areas. However, cities with more green land and cleaner air are increasingly preferred as people's incomes and awareness levels increase. Consequently, the importance of landscape designs and plants in urban centers has increased, and they are regarded as indicators of the quality and livability of cities (Cetin 2016, 2017; Sevik et al. 2017, 2018). Aesthetic properties of plants are important in landscape studies, and plants with more extraordinary and visible qualities are more highly valued. Therefore, the use of such plants outside natural environments is commonly reported during studies of landscape designs (Cetin and Sevik 2016).

Its global location and three main climate types distinguish Turkey. Previous landscape studies have characterized the growth of many plants in fields where all three climatic types dominate (Cetin et al. 2018a, b, c; Sevik et al. 2017, 2018; Yigit et al. 2016a, b). Among these widely studied plants, the bush (*Euonymus japonicus* Thunb.) is an evergreen member of the Celastraceae family and is widely cultivated in gardens. It is used as an ornamental due to its attractive, brightly colored fruits and variegated foliage as well as a hedge

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**Table 1** Morphological comparisons of seedlings from *E. japonicus* cultivars

Cultivars	SH (cm)	RCD (cm)	LL (cm)	LW (cm)	RL (cm)	RN	TN
	ANOVA signature						
	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p > 0.05$	$p < 0.05$	$p < 0.05$
Green Rocket	34.47a <sup>1</sup>	0.64b	1.99e	1.15d	40.71a	3.94ab	4.64b
Variegata	29.57b	0.73a	4.24c	2.54a	40.44a	4.33a	3.98c
Aureapictus	26.76c	0.47d	3.96d	2.00c	34.02a	3.13c	2.92d
Aurea	25.23c	0.40e	4.81a	2.54a	34.38a	3.10c	3.80c
Microphyllus Pulchellus	32.91a	0.56c	4.50b	2.28b	33.98a	3.65b	5.89a
Overall	29.80	0.56	3.90	2.10	37.30	3.63	4.24

<sup>1</sup> Differing letters in the columns indicate significant differences between mean growth traits for each cultivar ( $p < 0.05$ )

plant in many parts of the world (Gülgün et al. 2007; Orwa et al. 2009). This plant is also highly resistant to air pollution and grows well in areas of intensive industrial activity (Ekren 2014).

In studies on controlled irrigation, weed control, hoeing, and manure conditions, qualified seedlings have shown to have superior morphological, physiological, and genetic characteristics than even-aged seedlings from the same seed origin (Gezer and Yücedağ 2013). Morphological traits are widely used for classifying seedling qualities globally (Yigit et al. 2016a, b), yet the morphological traits of seedlings of *E. japonicus* have not been reported previously. Thus, we compared morphological traits of seedlings from five *E. japonicus* cultivars.

## Material and methods

The study was conducted in the Gökçeşey Forest Nursery of Zonguldak, Turkey (41° 19' N, 32° 05' E, 45 m above sea level), where the annual precipitation is

approximately 1242.9 mm and the annual average temperature is 13.5 °C (Atik 2013). The five *E. japonicus* cultivars Green Rocket, Variegata, Aureapictus, Aurea, and Microphyllus Pulchellus were studied and compared.

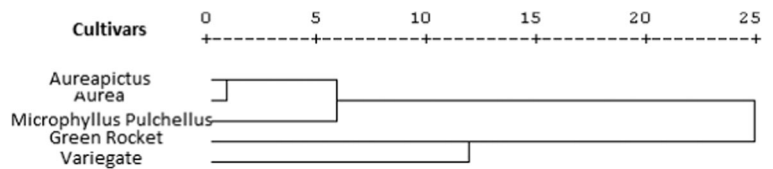
Experiments were performed in paper pots of 5 × 1.20 dimensions inches under greenhouse conditions at 18–22 °C. Seedlings were grown in media containing equal volumes of sand, perlite, and forest soil, and comparisons were made using a randomized complete block design with three repetitions. Cuttings were provided by Karadeniz Ereğli of Zonguldak, and no hormone application was performed for the cuttings. In October 2017, 300 seedlings (60 seedlings for each cultivar) were uprooted without harming the roots. Subsequently, seedling heights (SH), root collar diameters (RCD), leaf lengths (LL) and leaf widths (LW), root lengths (RL), root numbers (RN), and twig numbers (TN) of seedlings were determined.

Mean growth parameters were calculated and compared between cultivars using analysis of variance

**Table 2** Pairwise Pearson correlations of seedling traits across cultivars

	SH	RCD	LL	LW	RL	RN	TN
SH	1.000						
RCD	0.297***	1.000					
LL	-0.308***	-0.111	1.000				
LW	-0.213***	-0.036	0.728***	1.000			
RL	0.135*	0.117*	-0.064	0.053	1.000		
RN	0.181*	0.152**	-0.151**	0.033	0.035	1.000	
TN	0.217***	0.128*	-0.001	-0.061	-0.046	-0.061	1.000

**Fig. 1** A dendrogram of hierarchical cluster analyses based on squared Euclidean distances among cultivars



(ANOVA) and adjusted Duncan’s multiple range tests ( $p < 0.05$ ). In addition, pairwise correlations between seedling traits were evaluated using Pearson’s correlation coefficients. Morphological differences among cultivars were visualized using an unweighted pair group method with arithmetic mean dendrograms, and hierarchical cluster analyses were performed based on squared Euclidean distances. All statistical analyses were conducted using SPSS statistical software (SPSS Inc 2011).

**Results**

Rooting percentages of the *E. japonicus* cultivars Green Rocket, Variegata, Aureapictus, Aurea, and Microphyllus Pulchellus were 70.3%, 95.8%, 92.4%, 91.2%, and 83.6%, respectively. The best rooting time for *E. japonicus* is June–August, when the light intensity is the highest (Anonymous 2002; Gülgün et al. 2007). Blythe and Sibley (2003) have previously indicated that the most important hormone for rooting of *Euonymus* cuttings is indolebutyric acid, and Gülgün et al. (2007) reported an average rooting percentage of 70.2% in *E. japonicus* plants. Mean growth parameter values for seedlings of the present cultivars are summarized in Table 1. ANOVA showed significant differences among cultivars for all morphological characteristics ( $p < 0.05$ ), with the exception of RL ( $p > 0.05$ ).

Pairwise Pearson correlation coefficients (Table 2) revealed strong positive correlations between SH, RCD, and TN and strong negative correlations between LL and LW. RCD were also positively correlated with RL, RN, and TN. In contrast, LL was negatively correlated with RN.

To quantify similarities among cultivars, we performed hierarchical cluster analyses of all measured characteristics (Fig. 1). These analyses distinguished two main groups at the 10.0 distance unit, comprising Aureapictus, Aurea, and Microphyllus cultivars and Green Rocket and Variegata cultivars, and this hierarchical clustering corresponded with the results of Duncan tests (Table 1).

**Conclusions**

All traits studied herein were important contributors to morphological variabilities among all cultivars and groups of cultivars, reflecting sufficient heterogeneity in traits among cultivars. However, the poor resolution of the dendrogram reflects a lack of morphological differentiation at the cultivar level despite highly significant overall differences. “Green Rocket” performed better than all other cultivars with respect to SH and RCD, warranting inclusion in landscape studies. Further studies are required for quantifying differences in growth traits among the present cultivars.

**Author contributions** Mehmet and Hakan conceived and designed the experiments. Cengiz, Halil, Hakan, and Mehmet performed the experiments. Cengiz, Halil, and Mehmet analyzed the data. Cengiz, Mehmet, and Hakan contributed reagents/materials/analysis tools. Halil, Cengiz, and Mehmet wrote the paper.

**Electronic supplementary material**

**Conflict of interest** The authors declare that they have no conflict of interest.

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