



Substrate influence on the quality of seedlings of ornamental trees produced in pots

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Abstract

The production of high-quality planting material for the most commonly used woody species in urban greening is a complex challenge influenced by several factors. One of the key factors in seedling production, especially in pots, is the selection of an appropriate substrate. Testing various substrates for different species is an ongoing process.

In Bosnia and Herzegovina, four of the most frequently used taxa for urban planting in the region were tested: two varieties of northern white-cedar (*Thuja occidentalis* L.), namely 'Smaragd' and 'Columna', as well as European boxwood (*Buxus sempervirens* L.) and Forsythia (*Forsythia × intermedia*). One-year-old rooted cuttings were transplanted into two-liter pots using five different substrates: plain soil, compost, lumbrico humus, peat, and a combination of all these substrates. At the end of the growing period, morphological parameters of the seedlings were measured, and based on these measurements, seedlings quality were assessed.

The results showed that each species and variety responded differently to the various substrates. Generally, the best results for most of the taxa were obtained using locally produced lumbrico humus and compost. However, some seedlings, such as *Thuja occidentalis* 'Smaragd', exhibited similar growth characteristics across all substrates tested.

Considering the varying costs of the substrates, it is possible to plan the production of these seedlings with significantly better quality while also reducing production costs.

Keywords

Growing media; Rooted material; Seedlings quality

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1 Introduction

The production of ornamental plants is one of the most diverse sector of horticulture and it has a very long tradition starting with the first civilizations on our planet. Production of planting material for the purpose of greening of towns and settlements is an important segment in nursery production. The quality of seedlings depends, among other factors, on growing media – substrate (Schmilewski 2008). Producing planting material in pots with controlled substrates has many advantages (Grafadellis et al. 2000; Grossnickle and Kassaby 2016; Montagnoli et al. 2022) and the prime one is to use substrate which will make possible to have adequate shoot and root development (Haase et al. 2021). Different substrates are therefore tested in an attempt to find those that are the best and the cheapest for the production of planting material.

The issue of substrate and soil mixture composition for high-quality and rapid seedling production has always attracted the attention of scientists and practitioners (Sloan et al. 2010). Problems with substrates have been known for a long time and are related to substrate quality, specifically their physical and chemical properties (Verdonck et al. 1982; Verdonck and Gabriëls 1988; Fonteno 1993; Szász-Len et al. 2015a and 2015b; Mariana et al. 2016; Schindler and Muller 2017). The substrate is a very important factor in ornamental plant cultivation, as it is limited to small quantities in pots and serves as a growing medium (Zeljkočić et al. 2017).

The formation of peats is related to the accumulation of organic matter under anaerobic conditions, which makes these habitats one of the most sensitive ecosystems to climate change. At the same time, peat forms a substrate with suitable physical and chemical characteristics, which is the main reason for its use as a traditional growing substrate in nursery production (Gruda et al., 2023). The consequences of the degradation of peat ecosystems and climate change indicate that finding sustainable solutions for peat use in horticulture is of global importance for the preservation of the biodiversity of such habitats.

In the current production of seedlings in pots, peat has been predominantly used (Mariotti et al. 2023). Although the main pressures in choosing substrates in the past were defined by performance and economic analyses (such as costs and availability), the societal focus on environmental issues has added a new level of complexity to the selection process (Barrett et al. 2016). There were several research about horticultural plants rooting in substrates in Bosnia and Herzegovina, mainly ornamental and fruits (Parađiković et al. 2009; Stojnić et al. 2015).

The often-used taxa used for urban planting are seedlings which belong to geniuses: *Thuja*, *Buxus* and *Forsythia*. The issue of reducing production costs in seedlings production through the selection of adequate substrate, while maintaining good quality, is necessary to be concerned. Substrate problems are known earlier and relate to the quality of substrates, i.e. their physical and chemical properties (Verdonck et al. 1982; Verdonck and Gabriëls 1988; Fonteno 1993; Szász-Len et al. 2015; Mariana et al. 2016; Schindler and Müller 2017), as well as the absence of the influence of expensive biostimulators and mycorrhizal fungi (Abbey and Rathier 2005), where the use of the appropriate substrate is sufficient. Also, the correlation between time of rooting and substrates can be found for investigated species (Davidescu et al. 2003).

Research of the development of horticultural taxa in various low-cost substrates is an important factor for survival of nursery and production of horticultural

reproductive material (Landis and Morgan 2009). In the same time, it should be determined which substrate are the most cost efficient (Blievernicht et al. 2013). Cheaper substrates allow more cost-effective production and reduced import dependence. There are more than 100 substrates used in horticulture and ornamental tree production and some new growing substrates outcomes peat as a based substrate in seedlings production (Mariotti et al. 2023). The idea of this paper is to investigate the most effective substrate for development of rooted ornamental taxa which are most commonly used in South-East Europe.

Northern white cedar (*Thuja occidentalis* L.) is a species known for a wide distribution area and great variability (Matthes-Sears and Larson 1991). It is often used in the greening of surfaces and contains elements that can reduce the appearance of the most serious human disease (Naser et al. 2005; Biswas et al. 2006; Tsiri et al. 2009). That is why it is called "tree of life". Researches in the surrounding countries were mostly carried out for assessment of fertilization efficiency (Katić et al. 2006) and others researches are very rare. Nursery practitioners mostly rely on their experience and practices that are exchanged at fairs and exhibitions. Therefore, the study of the effects of substrates on the growth of *Thuja occidentalis* 'Smaragd' in small-scale growing conditions may represent important data for nursery growers.

Similar to *Thuja occidentalis* 'Smaragd', a variety 'Columna' is often used in greening urban areas. In addition to the aesthetic role, it can also play a very important role in improving people's health and therefore is recommended for planting (Alves et al. 2014).

Boxwood (*Buxus sempervirens* L.) is one of the most widely used horticultural species in Bosna and Herzegovina. It is used to form fences, and has great application in landscape architecture. Almost every nursery in Bosnia and Herzegovina has this species in its assortment because it is relatively easy to reproduce, resistant and decorative. Differences were observed in the production of boxwood seedlings in the different containers (Wang et al. 2015) and in various substrates (Jahromi et al. 2018). One of the issue affecting boxwood (*Buxus spp.*) is the invasive pest, *Cydalima perspectalis*, which reduces drastically use of this species.

Forsythia x intermedia is hybrid represents one of the very frequent horticultural shrub plants which are planted due to the decorative flowers. It is a valuable source of active lignans, which may be potential candidates for the treatment of inflammatory diseases (Michalak et al. 2018). In the same time, it is the often subject to breeding programs, particularly on the color of flowers (Rosati et al. 2003). It grows fast spreading around the primary stool. Well responds to fertilizer treatments. Under drip irrigation, dibble placement of CRF promoted growth of container grown *Forsythia* species compared to traditional incorporation and topdress (Alam et al. 2009).

2 Material and methods

Rotted cuttings, with developed roots, of four different taxa planted in 5 different substrates were subjected to the investigation. The rooting was done in nursery "Tamaris co." j.s.v., (44°58'26.85; 17°21'07.79", a.s.l. 107m), Mrčevci, Laktaši, Republic of Srpska, Bosnia and Herzegovina. Rootings were collected in summer 2012. The taxa investigated were *Thuja occidentalis* 'Smaragd', *Thuja occidentalis* 'Columna', *Forsythia x intermedia* and *Buxus sempervirens*. grown on 4 different substrates.

Substrates which were used are:

- Compost (made by the Tamaris company using leaves, branches and grass)
- Lumbrico humus (made by local producer PFE „Industrial plantations“ j.s.c.)
- Peat
- Plain soil
- Mixture of above-mentioned substrates

Each substrate consists of 80% of above-mentioned substrates and 20% of sand. The mixture was made of equal ration (20%) of all above-mentioned pure substrates plus 20% of sand. The data about substrates are presented in Table 1.

Table 1. Types and characteristics of tested substrates.

No	Parameters	Type of substrate			
		Plain soil	Compost	Lumbrico humus	Peat
1.	pH in H ₂ O	7,9	7,2	6,6	6,6
2.	Moisture %	18,3	58,6	68,5	67,1
3.	Organic substance [%]	6,1	66,3	57,8	78,4
4.	Ash %	93,9	33,7	42,2	21,6
5.	Nitrate nitrogen mg of NH ₄ ⁺ /100gr	1,8	3,6	5,0	6,0
6.	mg of NO ₃ /100gr	1,7	34,5	5,1	5,3
7.	Phosphorus (mg P ₂ O ₅ /100g)	2,2	1,5	824,0	7,4
8.	Potassium (mg K ₂ O/100gr)	2,8	0,4	38,7	1,8

Rooted cuttings were used as the starting material (Figure 1).



Figure 1. Rooted cuttings of *Thuja occ.*(left) and *Buxus sempervirens* (right).

Rootings were taken out from the rooting area for regular nursery production and then transplanted planted in 2liter poly-bags with tested substrate. The experimental plot is on flat terrain, with irrigation provided depending on weather conditions. All plants are equally exposed to sunlight, without shading, and contact with the soil is prevented by a PVC barrier installed before arranging the seedling bags. No fertilizer was applied.

The experiment was organized in 5 repetitions, 280 rooted cutting per substrate. After one year, seedlings produced from rooted cuttings were taken in autumn second out of the substrate and measured. Sampling was done randomly sampling of 4 seedlings from each repetition.

The following parameters were investigated: height (H), root depth (D), root collar (R), ratio height/depth (Ratio H/R), weight of aboveground part of seedling (M ab), weight of belowground part of seedlings (M bel), ratio - aboveground and belowground weight of seedlings (Ratio M/N), weight of aboveground part of seedlings dried on 60°C (W ab 60) and below ground dried on 60°C (W bel 60), ratio of weights of dried seedlings – aboveground and below ground (Ratio M/N 60), weight of water in the aboveground part of seedlings (Wat ab) and belowground part of seedlings (Wat bel), percentage of water in aboveground part of seedlings (% Wat ab) and percentage of water in belowground part of seedlings (% Wat bel) and Dixon quality index (QI).

The height and root depth were measured by ruler expect for *Forsythia* which height was measured by 2m wooden ruler. The root collar was measured by the nonuse and weights by the scale with precision of 0.01 g (scale ACOM SHJW 600).

Owing process, for the purpose of dry weight seedlings measurements and amount of water was 48 hours long or to the moment when mass was not change after extended period of drying (more than 24 hours) (Owen type SSW-33).

For data processing Microsoft EXCEL and Statistica 13 software (Dell™Statistica™ 13.0) were used. Results presented for correlations are presented with statistical significance where red color of numbers indicated statistical significance correlations.

3 Results and discussion

Many authors have studied the problems related to substrates and their impact on seedling quality, specifically the interdependence between their physical and chemical properties and seedling quality (Verdonck et al. 1982; Verdonck and Gabriëls 1988; Fonteno 1993; Szász-Len et al. 2015a; 2015b; Schindler and Müller 2017). Additionally, correlations between rooting time and substrate can be found for the studied species (Davidescu et al. 2003). Numerous studies confirm that peat could remain the main substrate component in the coming decades due to its unique qualities, low cost, and availability (Caron and Rochefort 2013). At the same time, significant efforts are being made toward more responsible peatland management, considering the increasing public pressure in the context of climate change and the need for rational carbon dioxide storage in organic matter. Therefore, transitioning from peat to alternative components, such as compost and other industrial by-products, appears to be a valuable alternative (Mariotti et al. 2023).

Thuja occidentalis 'Smaragd'

In the experiment *Thuja occidentalis* 'Smaragd' showed that the highest seedlings were seedlings in peat. The average height was 25.05 cm, the diameter of the root collar reached the highest values for seedlings in the lumbico humus (5.33 mm), and the highest value of roots depth was determined in plain soil (19.90 cm). The smallest ratio of height and root collar was recorded seedlings in compost and it was 4.66 but the highest was recorded for the mixture and the plain soil - 5.40 and 5.32 respectively (Table 2).

When it comes to the weight of the above-ground and underground part of the seedlings, the smallest ratio is established for the plain soil. This relationship is important because it shows how much the underground part of the plants are evenly developed. As this ratio is lower, the seedlings should be better.

Thuja occidentalis is a species that can grow on extreme habitats that are characterized by shallow lands (Matthes-Sears and Larson, 1995) and therefore it can be the one of the reasons why substrate effect has not come to a significant extent for the indicated parameters.

The weight of the aboveground part of the seedlings after drying at 60°C was maximally 11.10 g in lumbrico humus, and the largest weight of the underground part of the seedlings was also recorded in lumbrico humus, on average 3.11g. The ratio of the weights of the above-ground and underground parts is the smallest in lumbrico humus which, in addition to the other parameters indicated, makes this substrate the most suitable for growing. Also, when it comes to the content of water, the highest content in absolute amount is determined in the lumbrico humus, which is in favor of the highest value of the quality index of seedlings (Table 2).

ANOVA pointed to the existence of data heterogeneity only for 3 out of 15 observed parameters. These are: Ratio H/R, % Wat ab. and % Wat bel. The results of the Duncan test indicate the existence of 2 homogeneous groups for the first two features, while the third feature has 3 homogeneous groups (Table 2). Small differences in different substrates *Thuja occidentalis* 'Smaragd' have also been shown in other studies (Meisl et al. 2012).

Table 2. Morphological and physiological properties of *Thuja occidentalis* 'Smaragd'.

Substrate	N	H	D	R	Ratio H/R	M ab.	M bel.	Ratio M/N	W ab. 60	W bel. 60	Ratio M/N 60	Wat ab.	Wat bel.	% Wat ab.	% Wat bel.	QI
Plain soil	20	24,45	19,90	4,71	5,32 a	22,35	11,30	2,30	8,92	2,86	3,59	13,43	8,44	60,11a	74,49a	1,44
Compost	20	23,70	17,30	5,15	4,66 a	22,64	9,43	2,74	8,70	2,24	4,45	13,94	7,19	61,45b	76,22b	1,28
Lumbrico	20	24,65	17,50	5,33	4,71 a	28,75	13,75	2,32	11,10	3,11	4,04	17,65	10,64	61,68b	77,58c	1,75
Peat	20	25,05	19,30	5,09	5,08 b	26,69	12,01	2,60	10,30	2,83	4,09	16,39	9,17	61,71b	75,94b	1,56
Mixture	20	23,70	16,25	4,50	5,40 b	23,56	9,24	2,82	8,90	2,21	4,42	14,67	7,03	62,11b	75,85b	1,22
Average	100	24,31	18,05	4,96	5,03 b	24,80	11,14	2,56	9,58	2,65	4,12	15,22	8,49	61,41	76,02	1,45
F		0.51 ^{ns}	1.59 ^{ns}	2.13 ^{ns}	3.40*	1.36 ^{ns}	1.75 ^{ns}	1.74 ^{ns}	1.28 ^{ns}	1.43 ^{ns}	1.55 ^{ns}	1.43 ^{ns}	1.88 ^{ns}	3.40*	5.20***	1.43 ^{ns}

When it comes to correlations between the observed parameters, the greatest interest of nursery growers refers to the height, diameter of the root collar, root depth and quality index.

In the case of *Thuja occidentalis* 'Smaragd', the root depth and the height of the seedlings are in weak correlation ($r = 0.39$), while there is a strong correlation with the water content of the above-ground and underground part of the seedlings with the average height and diameter of the rooted seedlings.

The Dixon quality coefficient has the highest correlation with the water content in the above-ground and sub-seedlings of the seedlings, but it also has a high correlation with the root collar diameter (0.86), which can simplify the quality assessment of the seedlings based on the measurement of the diameter of the root collar. High correlation was found with root depth (0.65), and somewhat smaller with the height of the seedlings (0.58) (Table 3). Compared to other tested taxa, *Thuja occidentalis* 'Smaragd'

has the greatest dependence of the morphometric parameters of height and diameter of the root collar in relation to all other taxa.

The correlation analysis indicates a very strong correlation of seedlings weights and water content. The quality index shows a medium strong relationship with height, which means that height, as morphometric parameters, is not the most valid indicator of quality of planting material. On the other hand, the diameter of the root collar is highly correlated with the quality index, and it can be said that, based on this parameter, the quality of the planting material can in principle be consolidated.

Research in neighboring countries has mostly been conducted to assess the efficiency of fertilization in the production of seedlings of this species (Katić et al. 2006).

Table 3. Correlation matrix of analyzed properties for *Thuja occidentalis* 'Smaragd'.

Variables	H	D	R	Ratio H/R	M ab.	M bel.	Ratio M/N	W ab. 60	W bel. 60	Ratio M/N 60	Wat ab.	Wat bel.	% Wat ab.	% Wat bel.	QI
H	1,00														
D	0,39	1,00													
R	0,64	0,52	1,00												
Ratio H/D	0,06	-0,32	-0,70	1,00											
M ab.	0,75	0,51	0,81	-0,39	1,00										
M bel.	0,59	0,68	0,81	-0,51	0,85	1,00									
Ratio M/N	-0,18	-0,60	-0,49	0,51	-0,37	-0,70	1,00								
W ab. 60	0,75	0,54	0,82	-0,41	0,99	0,86	-0,38	1,00							
W bel. 60	0,59	0,68	0,78	-0,49	0,83	0,99	-0,70	0,84	1,00						
Ratio M/N 60	-0,18	-0,55	-0,43	0,43	-0,35	-0,67	0,93	-0,35	-0,70	1,00					
Wat ab.	0,74	0,49	0,79	-0,38	1,00	0,84	-0,36	0,98	0,82	-0,34	1,00				
Wat bel.	0,59	0,67	0,81	-0,52	0,85	1,00	-0,70	0,86	0,98	-0,66	0,84	1,00			
% Wat ab.	-0,10	-0,29	-0,23	0,21	-0,07	-0,16	0,16	-0,17	-0,19	0,10	0,00	-0,15	1,00		
% Wat bel.	0,01	0,10	0,15	-0,20	0,13	0,14	-0,20	0,10	0,01	0,12	0,14	0,17	0,27	1,00	
QI	0,58	0,65	0,86	-0,58	0,88	0,98	-0,64	0,90	0,98	-0,62	0,87	0,98	-0,20	0,07	1,00

Thuja occidentalis 'Columna'

Earlier researches mostly referred to rooting success (Szász-Len et al. 2015a; 2015b). Concerning morphometric parameters in the case of *Thuja occidentalis* 'Columna', the highest value of the seedlings was achieved in the common soil (31.25 cm) and the least seedlings grown was recorded in peat, on average 25.85 cm. The reversed situation occurs in the root depth with the deepest root in the peat (27.00 cm) and the least root depth was in the lumbrico humus and compost. It is interesting that the root penetrates deeper into the common soil (24.10 cm) than in two, in general the more fragile substrate - compost and lumbrico humus. The largest diameter of the root collar is 6.35 cm which seedlings were reached in the compost and a mixture of substrates. The smallest diameter of the root collar has reached the seedlings in the common soil of 5.40 mm.

In general, the values of the weights of seedlings and the content of water, aboveground and underground, seedlings reached in the combination of substrates. This also affected the quality of seedlings and they had the highest quality index in the substrate which is a mixture of all used substrates (Table 4).

ANOVA showed that there are statistically significant differences for 10 to 15 observed parameters. When it comes to the root depth, the results are divided into two homogeneous groups. In one homogeneous group there are compost and lumbico humus, substrates in which the plums of the root are recorded. In the second homogeneous group there are a peat and a mixture of substrates, and the seedlings from the common soil are classified in both homogeneous groups. As for as ratio of height and root collar diameter, the existence of 3 homogeneous groups was determined (Table 4).

The ratio of the mass of the above-ground and underground part of the seedlings in the moist state indicates the existence of 2 homogeneous groups where compost and lumbico humus in one group, peat and mixture in the other, and the humus is present in both homogeneous groups. The masses of seedlings in the dry state, as well as the share of water in the seedlings, are classified in two to three homogeneous groups, whereby a plain soil always belongs to a exempt homogeneous group. Concerning the quality index, results are also classified into two homogeneous groups, whereby the common soil is in the group that showed the lowest results and the mixture in the group that showed the highest results in the observed parameters. Other parameters belonged to both groups (Table 4).

Table 4. Morphological and physiological properties of *Thuja occidentalis* 'Columna'.

Supstrat	N	H	D	R	Ratio H/D	M ab.	M bel.	Ratio M/N	W ab. 60	W bel. 60	Ratio M/N 60	Wat ab.	Wat bel.	% Wat ab.	% Wat bel.	QI
Plain soil	20	31,25 ^{ab}	24,10	5,40	5,89 ^c	24,78 ^a	12,67 ^a	2,17 ^a	9,63	3,44	3,06	15,15 ^a	9,23 ^a	61,14 ^a	72,57 ^a	1,55 ^a
Compost	20	30,10 ^a	21,75	6,35	4,86 ^{ab}	34,21 ^b	17,35 ^{ab}	2,12 ^a	12,15	4,29	3,07	22,06 ^b	13,06 ^{ab}	64,40 ^b	75,36 ^b	2,20 ^{ab}
Lumbrico	20	30,35 ^a	21,60	6,18	5,00 ^b	34,05 ^b	18,69 ^{ab}	2,03 ^{ab}	12,24	4,31	3,08	21,81 ^b	14,38 ^b	64,40 ^b	76,78 ^c	2,18 ^{ab}
Peat	20	25,85 ^b	27,00	6,01	4,30 ^a	29,71 ^{ab}	18,9 ^{ab}	1,71 ^b	10,98	4,38	2,75	18,73 ^{ab}	14,52 ^b	62,66 ^c	76,90 ^c	2,21 ^{ab}
Mixture	20	29,30 ^b	26,65	6,35	4,62 ^{ab}	36,51 ^b	22,96 ^b	1,69 ^b	13,27	5,38	2,62	23,24 ^b	17,58 ^b	63,57 ^{bc}	76,60 ^{bc}	2,64 ^b
Average	100	29,37	24,22	6,06	4,93	31,85	18,12	1,94	11,65	4,36	2,92	20,20	13,75	63,23	75,64	2,15
F		2.11 ^{ns}	3.08*	2.34 ^{ns}	7.50***	2.66*	3.19*	3.89**	1.76 ^{ns}	1.84 ^{ns}	1.81 ^{ns}	3.25*	3.70**	12.9***	15.8***	2.66*

As for as *Thuja occidentalis* 'Columna's correlations between the height of the seedlings, the diameter of the root collar and the root depth of the root system are weak. The influence of height, root depth and root diameter on the quality index is somewhat lower than *Thuja occidentalis* 'Smaragd'. The water content of seedlings correlates with the quality index to the highest level, which is logical, as Dixon's formula for calculating the quality index relies heavily on weights of seedlings. The largest correlation of the Dixon index is with the diameter of the root collar (Table 5).

***Buxus sempervirens* (Boxwood)**

In the nursery test in the pots, the highest value seedlings' height reached the seedlings in the compost with an average height of 33.75 cm, while the seedlings in the common soil were the lowest, on average 20.20 cm. Similar to the root depth, the highest value of the root depth was in compost (24.65 cm) and the least in the ordinary soil (19.35) as well as the diameter of the root collar. The largest diameter of the root collar was determined for the seedlings in the compost (5.92 cm), and the smallest in the ordinary soil - 4.37 cm (Table 6).

When it comes to the weights of seedlings and water content in the seedlings, the largest weights were recorded in seedlings grown in the compost. The masses of seedlings in the compost were significantly higher than the weights of seedlings in other substrates. In general, the poorest results achieved seedlings planted in the plain soil for almost all observed parameters.

Table 5. Correlation matrix of analyzed properties for *Thuja occidentalis* 'Columna'.

Variables	H	D	R	Ratio H/D	M ab.	M bel.	Ratio M/N	W ab. 60	W bel. 60	Ratio M/N 60	Wat ab.	Wat bel.	% Wat ab.	% Wat bel.	QI
H	1,00														
D	0,24	1,00													
R	0,47	0,39	1,00												
Ratio H/D	0,60	-0,12	-0,41	1,00											
M ab.	0,62	0,45	0,77	-0,07	1,00										
M bel.	0,45	0,55	0,74	-0,20	0,87	1,00									
Ratio M/N	-0,03	-0,51	-0,43	0,37	-0,29	-0,64	1,00								
W ab. 60	0,61	0,48	0,77	-0,08	0,99	0,89	-0,33	1,00							
W bel. 60	0,49	0,53	0,74	-0,16	0,87	0,98	-0,60	0,89	1,00						
Ratio M/N 60	-0,16	-0,45	-0,43	0,22	-0,32	-0,63	0,93	-0,36	-0,64	1,00					
Wat ab.	0,62	0,42	0,76	-0,06	1,00	0,85	-0,27	0,98	0,85	-0,30	1,00				
Wat bel.	0,44	0,56	0,73	-0,22	0,87	1,00	-0,64	0,89	0,97	-0,63	0,85	1,00			
% Wat ab.	0,17	-0,20	0,06	0,10	0,21	0,01	0,27	0,09	-0,04	0,19	0,27	0,02	1,00		
% Wat bel.	-0,22	0,19	0,13	-0,39	0,11	0,21	-0,33	0,08	0,05	-0,01	0,13	0,25	0,26	1,00	
QI	0,35	0,50	0,82	-0,37	0,87	0,96	-0,57	0,89	0,96	-0,58	0,85	0,95	-0,03	0,12	1,00

Table 6. Morphological and physiological properties of *Buxus sempervirens*.

Supstrat	N	H	D	R	Ratio H/D	M ab.	M bel.	Ratio M/N	W ab. 60	W bel. 60	Ratio M/N 60	Wat ab.	Wat bel.	% Wat ab.	% Wat bel.	QI
Plain soil	20	20,20a	19,35a	4,37a	4,63a	9,55a	11,01a	0,95	4,74a	2,93a	1,74	4,80a	8,08a	50,68	73,20a	1,25a
Compost	20	33,75b	24,65b	5,92d	5,75b	29,19b	36,81b	0,84	14,19b	8,52a	1,75	15,00b	28,30b	51,44	76,96b	3,10b
Lumbrico	20	30,15c	24,00b	5,44cd	5,62b	21,10c	27,86c	0,84	10,43c	6,98bc	1,65	10,67c	20,88c	51,00	75,13c	2,56bd
Peat	20	27,85c	23,40b	4,82ab	5,87b	15,13cd	22,24c	0,78	7,57d	5,06d	1,66	7,57d	17,18c	50,21	76,70b	1,78ac
Mixture	20	29,30c	22,95b	5,25bc	5,36b	17,89d	25,44c	0,75	8,77cd	6,28cd	1,49	9,12cd	19,16c	50,95	75,47bc	2,33cd
Average		27,94	22,87	5,16	5,45	18,57	24,67	0,83	9,14	5,95	1,66	9,43	18,72	50,86	75,49	2,21
F		16,73***	9,13***	9,02***	5,02**	28,21***	14,07***	1,37 ^{ns}	4,77***	11,31***	0,858 ^{ns}	30,86***	14,74***	0,68 ^{ns}	8,0***	8,96***

ANOVA pointed to the existence of statistically significant differences for almost all of the observed features. Statistically significant differences were not determined only for the weight ratio of the above-ground and underground parts in dry and wet conditions, as well as the percentage of water in the above-ground part of the seedlings. The most viable property in four homogeneous groups are: R, M ab., W ab. 60, W bel. 60, W ab. and QI. The three homogeneous groups are grouped substrates for variables: H, M white, Wat bel. and % Wat bel. The results of the root depth of the roots are classified into two homogeneous groups, whereby in one homogeneous group is common soil, and in the rest all the other tested substrates (Table 6).

The fact is that the seedlings showed the best results in compost with the best results compared to other substrates. Therefore, compost can be recommended for producers of planting material for planting seedlings.

When it comes to correlations between the observed parameters, a strong correlation between the height and the diameter of the root collar (0.64) is established, in contrast to *Thuja's* where the dependence is mostly weak. The quality index, compared to the morphometric parameters, highly correlates with the diameter of the root collar (0.81), and high dependence is determined with the water content (Table 7).

Unlike *Thuja occidentalis* 'Smaragd' and *Thuja occidentalis* 'Columna', this species has clearly and unequivocally higher values of morphometric parameters in the compost substrate and the lowest values in the plain soil substrate. Therefore, compost can be recommended to seedling producers for planting. Previous research also confirms differences in boxwood seedling production in different containers (Wang et al. 2015) and on different substrates (Jahromi et al. 2018). It can be concluded that this species has higher substrate requirements compared to the previously analyzed two.

Table 7. Correlation matrix of analyzed properties for *Buxus sempervirens*.

Variables	H	D	R	Ratio H/D	M ab.	M bel.	Ratio M/N	W ab. 60	W bel. 60	Ratio M/N 60	Wat ab.	Wat bel.	% Wat ab.	% Wat bel.	QI
H	1,00														
D	0,41	1,00													
R	0,64	0,49	1,00												
Ratio H/D	0,63	0,03	-0,17	1,00											
M ab.	0,73	0,48	0,80	0,12	1,00										
M bel.	0,55	0,55	0,73	-0,00	0,82	1,00									
Ratio M/N	-0,04	-0,45	-0,22	0,19	-0,08	-0,48	1,00								
W ab. 60	0,73	0,50	0,81	0,12	0,99	0,83	-0,11	1,00							
W bel. 60	0,51	0,51	0,76	-0,08	0,81	0,98	-0,45	0,83	1,00						
Ratio M/N 60	0,09	-0,36	-0,21	0,34	-0,02	-0,42	0,94	-0,04	-0,45	1,00					
Wat ab.	0,72	0,46	0,78	0,13	1,00	0,79	-0,06	0,98	0,79	-0,00	1,00				
Wat bel.	0,56	0,55	0,71	0,02	0,81	1,00	-0,49	0,82	0,96	-0,41	0,79	1,00			
% Wat ab.	-0,14	-0,19	-0,21	0,02	-0,06	-0,20	0,23	-0,15	-0,22	0,16	0,02	-0,19	1,00		
% Wat bel.	0,31	0,31	0,01	0,39	0,15	0,26	-0,36	0,13	0,06	-0,07	0,16	0,31	0,14	1,00	
QI	0,39	0,48	0,81	-0,27	0,80	0,92	-0,37	0,82	0,96	-0,39	0,78	0,90	-0,21	-0,02	1,00

Forsythia x intermedia

This hybrid represents one of the very frequent horticultural shrub plants which are planted due to the decorative flowers. *Forsythia x intermedia* is a valuable source of active lignans, which may be potential candidates for the treatment of inflammatory diseases (Michalak et al. 2018). In the same time, it is the often subject to breeding programs, particularly on the color of flowers (Rosati et al. 2003). It grows fast spreading around the primary stool. Well responds to fertilizer treatments. Under drip irrigation, dibble placement of CRF promoted growth of container grown *Forsythia* species compared to traditional incorporation and topdress (Alam et al. 2009).

Concerning morphometric parameters, the highest value of height was reached by the seedlings whose cuttings were cultivated in compost with an average height of 274.95 cm. The highest value of roots depth was recorded for peat, while the highest

value of root collar diameter was recorded for seedlings in compost. As with boxwood, almost all parameters showed the highest values in compost, but unlike the boxwood, the quality index was the best for seedlings in lumbrico humus (1.59) and then in compost (1.45) (Table 8).

ANOVA points to statistically significant differences for almost all observed parameters except for the weights of the above-ground and underground part of the seedlings and for the percentage of water contained in the underground part of the seedlings. Four homogeneous groups were identified for the characteristics of M ab. and % Wat ab., three homogeneous groups for H, R, M white. W ab. 60, W bel 60, Wat bel and QI. The existence of 2 homogeneous groups was determined for the characteristics: D, Ratio H/R, % Wat ab (Table 8).

Table 8. Correlation matrix of analyzed properties for *Buxus sempervirens*.

Supstrat	N	H	D	R	Ratio H/D	M ab.	M bel.	Ratio M/N	W ab. 60	W bel. 60	Ratio M/N 60	Wat ab.	Wat bel.	% Wat ab.	% Wat bel.	QI
Plain soil	20	140,45ac	24,60a	6,82a	20,53a	14,91a	25,53a	0,62	6,57a	8,82a	0,79	8,34a	16,71a	55,97a	65,65	0,77a
Compost	20	274,95b	25,45a	9,57b	29,17b	42,40b	68,80b	0,62	18,88c	22,50b	0,86	23,53d	46,30b	55,68a	67,63	1,45bc
Lumbrico.	20	240,70bc	29,15b	9,46bc	25,88b	37,89bc	67,68b	0,56	17,55bc	22,28b	0,79	20,34c	45,39b	53,87b	67,20	1,59c
Peat	20	229,75c	29,95b	8,71c	26,66b	30,84c	50,42c	0,62	14,43b	16,44c	0,88	16,41bd	33,97c	53,08b	67,45	1,17b
Mixture	20	259,15bc	28,70b	9,33bc	27,83b	35,34cd	65,85b	0,56	15,79bc	21,81b	0,75	19,56bc	44,04b	55,28a	66,98	1,38bc
Average		229,00	27,57	8,78	26,01b	32,28	55,65	0,60	14,64	18,37	0,81	17,63	37,28	54,78	66,98	1,27
F		13,36***	8,64***	17,59***	3,87**	19,70***	33,29***	0,62ns	19,29***	25,02***	1,13 ^{ns}	19,78***	36,07***	9,71***	2,10 ^{ns}	9,83***

Table 9. Correlation matrix of analyzed properties for *Forsythia x intermedia*.

Variables	H	D	R	Ratio H/D	M ab.	M bel.	Ratio M/N	W ab. 60	W bel. 60	Ratio M/N 60	Wat ab.	Wat bel.	% Wat ab.	% Wat bel.	QI
H	1,00														
D	0,15	1,00													
R	0,53	0,21	1,00												
Ratio H/D	0,85	0,08	0,05	1,00											
M ab.	0,76	0,19	0,76	0,47	1,00										
M bel.	0,59	0,28	0,74	0,29	0,75	1,00									
Ratio M/N	0,38	-0,12	0,09	0,39	0,42	-0,21	1,00								
W ab. 60	0,74	0,21	0,76	0,44	0,99	0,77	0,40	1,00							
W bel. 60	0,59	0,23	0,73	0,29	0,77	0,98	-0,17	0,79	1,00						
Ratio M/N 60	0,38	-0,05	0,11	0,39	0,44	-0,18	0,97	0,42	-0,17	1,00					
Wat ab.	0,78	0,17	0,75	0,48	1,00	0,74	0,44	0,98	0,75	0,45	1,00				
Wat bel.	0,59	0,30	0,73	0,28	0,73	0,99	-0,24	0,74	0,95	-0,19	0,72	1,00			
% Wat ab.	0,01	-0,20	-0,14	0,04	-0,16	-0,27	0,12	-0,25	-0,32	0,03	-0,08	-0,24	1,00		
% Wat bel.	-0,05	0,20	0,01	-0,05	-0,15	0,01	-0,26	-0,17	-0,18	-0,07	-0,12	0,10	0,26	1,00	
QI	0,12	0,19	0,76	-0,27	0,63	0,74	-0,13	0,66	0,75	-0,12	0,59	0,72	-0,36	-0,13	1,00

The correlation analysis indicated a very small correlation between the height of the seedlings and the root depth of the root system (0.15), as well as the diameter of the rooted collar and root depth of the root system (0.21). As for previous three taxa, the diameter of the root collar had the highest correlation with the quality index. Plant masses under different humidity conditions had a strong but still lower correlation with the quality index than other taxa. The reason can be found in the larger mass of the

lignified part of the plant belonging to the group of broadleaves, while the remaining three taxa in the group of species that maintain leaves throughout the year (Table 9).

4 Conclusions

The plants investigated taxa are the most commonly produced in nurseries in South-East Europe. They are suitable for production because they are relatively easy to reproduce vegetatively and do not require special conditions for growth and development. The problem of the successful development of seedlings after rooting, with as little cost as possible, is often associated with the use of the appropriate substrate. Several commercial substrates are available in the market, such as compost, have shown absolute dominance in quality when it comes to the development of boxwood seedlings. Lumbrico humus and compost have proven to be superior for *Forsythia x intermedia*. Both substrates have a high content of organic matter and capability to retain high humidity.

As for as *Thuja occidentalis* 'Columna' the situation is somewhat more complicated. In general, the best results were obtained using a mixture of all substrates used. Reasons can be sought in a wide range of nutrients that the plant requires during development, which are provided by different substrates.

The most interesting case is the *Thuja occidentalis* 'Smaragd'. Seedlings of this taxon, observing morphological parameters, developed best in a plain soil. This substrate was characterized by the highest pH value and the lowest humidity. At the same time, this substrate is easily accessible and inexpensive. With the appropriate methods of cultivation, formation of habitus and keeping in mind of the appearance of seedlings in the nursery, it would be possible to achieve greater sales of domestic planting material. However, it should not be forgotten that physiological parameters, such as the water content and weights of the seedlings, are important and they have shown the highest values in the lumbrico humus. This is reflected on the quality index which is the highest in the lumbrico humus.

In general, substrates where dominated peat (80%) provided only slightly better results than the substrate dominated by plain soil, confirming the fact that this substrate lacks nutrients and requires the addition of macro- and microelements for successful seedling production.

The choice of the optimal substrate allows faster, more efficient and cheaper production of planting material for urban greening, and it is possible to ensure the satisfaction of the market without importing plant material from abroad and the survival of small nurseries engaged in the production of horticultural planting material.

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