Hungarian University of Agriculture and Life Sciences

Study of ornamental plants grown in conventional (CAG) and pot in pot (PIP) production systems and comparison of their physiological characteristics

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RESEARCH BACKGROUND

The spread of container production started in the southern states of the United States after World War II. In Europe, container production launched after 1960s (Schmidt and Tóth, 2004), while in Hungary started to spread from the 1970s. Container cultivation shows an increasing trend, in the USA nearly 70% of nursery products are containerized (Janick, 2011), while in Hungary the proportion is about 50%. Typically, evergreens and ornamental shrubs are grown in containers in larger quantities (Jankuné Kürthy et al., 2010; MDSZ, 2014).

Container cultivation is only a partially weather-independent cultivation method, such as rainfall modifying irrigation demand. Irrigation water requirements is also determined by the water demand of the plant. The irrigation demand can be calculated from equation specified by the crop coefficient. The crop coefficient of agricultural crops rarely exceeds 1.3, whereas the coefficient of container grown ornamental plants ranges from 1 to 5. The contiguous vegetation of agricultural areas has different properties in terms of the perception of incident solar radiation or the heat flow within the crop. In contrast, container plants do not behave as an uniform vegetation area, they capture more of the sun's radiation and also have greater resistance to heat flow. In nursery practice, many growers use a simple timer for automatic irrigation systems and relies on their own experience. As a result, most crops are irrigated on an empirical basis, sometimes underestimating or overestimating water needs and degrading the quality of the crops grown.

The pot in pot (PIP) system is an alternative container production method. The system is a hybrid of open field cultivation and conventional above ground container cultivation. Since the spread of PIP system in the USA, experience has shown that plants grown in the PIP system have better conditions compared to plants grown in conventional container cultivation. However, research on all types of container farming with a view to more economical water use is also relevant for the PIP system.

Our aim, therefore, is to examine the impact of diffrent container production systems on plant development, productivity, and water demand for selected taxa.

RESEARCH OBJECTIVES

- The literature of hungarian container production is small, the existing one is less current. The observation of the development of container grown taxa is necessary in as many ornamental nursery plant groups as possible, considering the increasing trend of the production method both domestically and internationally.
- The application of sustainable cultivation technologies and the precise knowledge of the water demand of the plant increasing the water use efficiency. The diverse and constantly expanding variety offer of ornamental plant production requires plant-water relations research. Furthermore, at the domestic level, such research is completely lacking.
- The peculiarities of plant stress factors (water and heat stress) occurring during the container production, especially in the production of woody ornamental plants are less known, in summary we do not encounter the topic. These can be explored and understood through the most important physiological processes (photosynthesis, transpiration).

  The evaluation of the photosynthetic process requires a different approach than for agricultural or even forestry crops.

The investigations are as follows, which are compared for plants grown in the conventional container (CAG) and pot in pot (PIP) nursery production system:

- ✓ Observation of morphological and nutrient content characteristics of taxa grown in different types of container production systems
- ✓ Measurement and calculation of water use and water use efficiency of container grown plants
- ✓ Observation of physiological processes in container plants (photosynthesis; transpiration) considering the plant water use

MATERIAL AND METHOD

The experimental site and the container production systems

The experiment was carried out in the Jaroslaw Chabin Ornamental Nursery in Páty, located 15 km away from Budapest. During the experiment, two production systems were set up. In the pot in pot system (PIP), two pots placed below the ground level, one is the holding pot, and the other is the growing pot, which is contained the plant. The other production system is the conventional container production system, referred in the study as container above ground (CAG).

Setting the experimental plants

The following taxa were involved in the experiment: *Cornus alba* L. 'Sibirica'; *Prunus laurocerasus* L. 'Novita' (Belgian propagating material); Thuja occidentalis L. 'Smaragd'; *Thuja occidentalis* L. 'Brabant'. 20 plants were selected per taxa, randomly. The plants were transpalanted to 5L black plastic containers (Interplast Plastic Products, Poland) with an upper diameter of 23 cm and an 18 cm high wall. The containers were filled with white peat (100%) (Pindstrup Substrate, Latvia) premixed with 3.5-4.5 g L^{-1} controlled release fertilizer (11N + 10P + 19K + 2MgO + trace elements (TE), Osmocote Pro, 8-9 months). Plants were set up in the same way in both experimental years (2015; 2016).

The experimental plot was set up on 01.04.2015 and 07.04.2016, respectively. The experimental plot was closed on 26.10.2015 and the following year on 10.18.2016.

The drip irrigation system in the pot in pot was equipped with new spaghetti tubes, and then the spaghetti tube spikes were connected to each plant (1. Figure). Plants were irrigated with same frequency and amount (2 L h^{-1}) (3x6 minutes (8; 12 and 18 hours) in summer and 2x6 minutes (8 and 18 hours) for the rest of the year) in both systems (CAG; PIP).

1. Figure Newly installed drip tubes in the pot in pot plot

(Ónody; 2015)

Morphological measurements

Plant height; canopy diameter; trunk diameter. The morphological parameters of the experimental plants were measured in all four taxa, in all individuals (80) at the time of setting up the experiment (01.04.2015 and 07.04.2016) and at the end of the experiment (26.10.2015 and 18 October 2016). on). In the dissertation, we analyzed the increment of growing season for each parameter.

Fresh and dry weight. Determination of fresh and dry weight was performed for two taxa: *Cornus alba* 'Sibirica' and *Prunus laurocerasus* 'Novita' at the end of the experiment, in the last week of October in both years (2015 and 2016). For the measurement, 5-5 plants per production system were selected. Individuals were disassembled and fresh weights of roots, shoots, and leaves were measured directly in the site. For dry weight measurements, individual plant parts were sampled and dried in an oven at 105 °C to constant weight and weighed again. In the dissertation we analyzed the fresh and dry weights of the root, shoot, leaf and total.

Individual leaf area and total leaf area measurements. The individual leaf area was determined for *Cornus alba* 'Sibirica' and *Prunus laurocerasus* 'Novita' using a leaf scanner (AM350, ADC BioScientific Ltd.). For the measurement, we collected (30) leaves from 5-5 plants per cultivation system, from both varieties. Sampling was performed in June 2015 and 2016, and at the end of the experiment, in October 2015 and 2016. The total leaf area was determined by counting all the leaves of the selected individuals by multiplication the average individual leaf size.

Gravimetric plant water use measurements (IWC; DWU; RWU)

Gravimetric water use was measured for *Cornus alba* 'Sibirica' and *Prunus laurocerasus* 'Novita' taxa on 3 days in each experimental year (2015 and 2016). The containers received normal watering the day before measurement. The containers were then removed from the irrigation system at the next morning, then the containers (8 am) were weighed. The wheighing was repeated in the evening (8 pm). Three parameters were defined to determine water use of each container grown plant. These are the initial weight of the container (IWC), the daily water use of the container (DWU), and the relative water use of the container (RWU). The difference between the weight of container measured in the morning and evening provides the DWU, while the ratio of DWU to IWC provides the RWU. The daily evolution of these three parameters was analyzed in the dissertation.

Measurements for determining the moisture content of growing medium (GSWC)

The moisture content of the peat based growing medium was determined by the following equation:

$$GSWC\ \% = \frac{m_{wet} - m_{dry}}{m_{dry}} * 100$$

(Campbell and Campbell, 2013), where GSWC (gravimetric soil water content) is the gravimetrically measured soil - in our case the moisture content in %, m - the mass of the medium sample (g).

According to the sampling procedure, 5-5 individuals / taxa / production system were sampled in the morning and evening, dried in an oven at 105°C to constant weight, and finally weighed again. The sampling days were 5 June and 30 June and 22 September in 2015.

Water use efficiency of container grown plants

The calculation of water use efficiency based on the ratio of total water supply during the growing season (precipitation + irrigation) and the dry matter production measured at the end of the vegetation period.

$$Water\ use\ efficiency_{container} = \frac{dry\ matter\ production\ (g)}{water\ supply\ (L)}$$

where water use efficiency refers to the container grown plant (5L), as well as dry matter production and water supply.

Leaf gas exchange measurements

Leaf gas exchange measurements were measured with a portable infrared gas analyzer (LCi, ADC Scientific Ltd.).

The output parameters are photosynthetic rate (A) and transpiration rate (E). The daily and diurnal changes were observed and daily amounts were also calculated. The photosynthetic rate (A) was multiplied by the molar mass of carbon dioxide, the transpiration rate (E) was multiplied by the molar mass of water. These values formed the daily amount of carbon dioxide assimilation (g m^{-2}) and the daily amount of transpiration (kg m^{-2}). Stomatal conductance (g_s) was also examined in relation to the transpiration rate (E) and the water stress index.

Leaf gas exchange measurements were performed for *Cornus alba* 'Sibirica' and *Prunus laurocerasus* 'Novita' on the same days as gravimetric water use measurements were carried out. One leaf per plant was measured every second hour from 8 am until 4 or 6 pm.

Meterological data

The meteorological station located 3 km away from the experimental plot (imetos® Telki, Petőfi Sándor utca 1.). Based on data provided by the local meteorological station, during the experimental period (1 April to 26 October), the precipitation was 411.60 mm, the ET_0 was 586.30 mm, and the average temperature was 17.77°C. In 2016 (7 April to 18 October), the precipitation was 521.80 mm, the ET_0 was 543.20 mm, and the average temperature was 17.61°C.

Statistical analyzes

Statistical analyzes were performed in each case using the SPSS (version 23) software package. Evaluations were performed using one-way analysis of variance (ANOVA) or repeated measures analysis of variance (RM ANOVA) or regression analysis.

RESULTS

Morphological parameters

The seasonal increment of plant height, canopy - and trunk diameter were evaluated for all four taxa (*P. laurocerasus* 'Novita', *C. alba* 'Sibirica', *T. occidentalis* 'Smaragd' and 'Brabant'). The individual and total leaf area, as well as the fresh and dry weights of the plant parts, were determined only for *P. laurocerasus* 'Novita', *C. alba* 'Sibirica'.

1. Table Seasonal increment of plant height for conatiner grown (5L) ornamental plants in 2015 and 2016, respectively

	Plant height increment (cm)							
	'Sibirica'		'Novita'		'Smaragd'		'Brabant'	
2015								
CAG	62,3	aB	18,7	aB	34,6	aB	39,8	aB
PIP	64,3	aB	22,5	aB	36,9	aB	39,0	aB
2016								
CAG	17,0	aA	5,7	aA	18,9	aA	31,9	bA
PIP	26,4	aA	10,7	aA	22,9	aA	23,7	aA

Note: different letters following means discriminate within groups for each parameter at a significance level of 0.05; lower case - among the production system within taxa and year, upper case - among the years within production system and taxa.

The increase in plant height during the growing season was mainly influenced by the year, much more than the production system. However, plants grown in the PIP system were typically higher in both years, although the population can be considered statistically homogeneous. According to the result of the year effect, the plants produced half to one third growth in 2016 than in the previous year (1. Table).

Analysis of the canopy development showed the year had a significant effect on its growth. The canopy development of *C. alba* 'Sibirica' was 35% stronger in the PIP system compared to the plants grown in the CAG system (2. Table).

2. Table Seasonal increment of canopy diameter for conatiner grown (5L) ornamental plants in 2015 and 2016, respectively

	Canopy development (cm)							
	'Sibirica'		'Novita'		'Smaragd'		'Brabant'	
2015								
CAG	37,3	aA	14,4	aA	2,4	aA	22,3	aA
PIP	50,4	bA	13,3	aA	3,2	aA	18,1	aA
2016								
CAG	54,1	aB	13,3	aA	8,6	aB	25,3	aA
PIP	73,3	bB	18,2	aA	6,2	aB	28,3	aB

Note: different letters following means discriminate within groups for each parameter at a significance level of 0.05; lower case - among the production system within taxa and year, upper case - among the years within production system and taxa.

3. Table Evaluation of leaf parameters of container grown (5L) taxa

	Individual leaf area (mm^2)			
	'Sibirica'		'Novita'	
2015				
CAG	2334	aA	2682	aB
PIP	2615	aB	2372	aA
2016				
CAG	1780	aA	1842	aA
PIP	1925	aA	2081	aB
	Total leaf area (m^2)			
	'Sibirica'		'Novita'	
2015				
CAG	0,69	aB	0,49	aA
PIP	0,72	aB	0,4	aA
2016				
CAG	0,56	aA	0,33	aA
PIP	0,57	aB	0,32	aA

Note: different letters following means discriminate within groups for each parameter at a significance level of 0.05; lower case - among the production system within taxa and year, upper case - among the years within production system and taxa.

The year had a strong effect on the individual leaf area, while the total leaf area was characterized by the cultivars. Both cultivars developed smaller leaf area and total leaf area in 2016 than in the previous year. The two different cultivars have statistically the same leaf size, however, in terms of total leaf area, *C. alba* 'Sibirica' developed 67% bigger total leaf area during the growing season than *P. laurocerasus* ‘Novita’ (3. Table).

4. Table Fresh and dry weight of *Cornus alba* 'Sibirica' and *Prunus laurocerasus* 'Novita' plant parts grown in different production systems (CAG and PIP) in 2015 and 2016.

	Fresh weight g plant^{-1}				Dry weight g plant^{-1}			
	leaf							
	'Sibirica'		'Novita'		'Sibirica'		'Novita'	
CAG	93	a	156	a	35,2	a	56	a
PIP	112	a	131	a	42,5	a	48	a
2015	115	a	158	a	42	a	54	a
2016	77	a	131	a	29,7	a	50	a
	shoot							
CAG	137	a	140	b	65	a	57,0	b
PIP	176	b	112	a	86	b	47	a
2015	146	a	141	b	68	a	54	a
2016	151	a	115	a	73	b	50	a
	root							
CAG	643	a	662	b	171	a	183	b
PIP	861	b	465	a	357	b	134	a
2015	641	a	329	a	143	a	92	a
2016	739	b	911	b	227	b	255	b
	total							
CAG	873	a	959	b	271	a	297	b
PIP	115	b	709	a	485	b	228	a
2015	902	a	628	b	253	a	201	a
2016	968	b	1157	a	330	b	355	b

Note: different letters following means discriminate within groups for each parameter at a significance level of 0.05

The fresh and dry weight of the plant parts clearly shows the effect of the production system - in addition to the year effect - which is typically significant in the case of root mass and total biomass, to the same extent for both cultivars.

With the exception of the fresh and dry weight of the leaf, each plant part such as shoot, root, and total fresh and dry weight are in all cases significantly higher for *C. alba* 'Sibirica' grown in the PIP system, while the same difference is true for P. laurocerasus 'Novita' grown in the CAG system (4. Table).

Gravimetric water use measurements

The water use measurement parameters are the initial weight of the container (IWC), the daily water use of the container (DWU) and the relative water use of the container (RWU). Measurements were performed on *C. alba* 'Sibirica' and *P. laurocerasus* 'Novita' taxa.

The IWC of the cultivars differed significantly in both years, typically the container weight of *P. laurocerasus* 'Novita' was heavier. The effect of the PIP system was significant for *P. laurocerasus* 'Novita' on each sampling day. *C. alba* 'Sibirica' showed as well as higher IWC in the PIP than in the CAG system, in both years, however data shown it only in 2016.

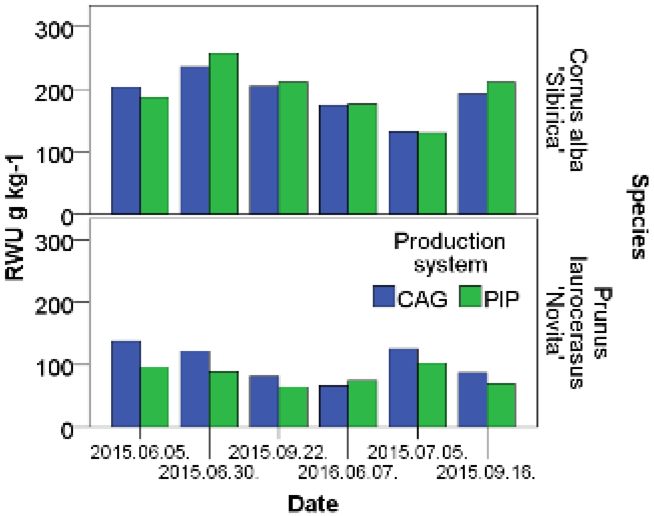
5. Table Variation in daily water use of container (DWU g day-1) subjected to species, sampling day and production system (CAG and PIP) in 2015 and 2016.

DWU (g day^{-1})							
C. alba 'Sibirica'							
Date	05/06/15		30/06/15		22/09/15		
CAG	444	aA	707	bB	674	bB	608
PIP	464	bA	788	bB	681	bB	644
Average	454		747		678		626
Date	07/06/16		05/07/16		16/09/16		
CAG	384	bB	183	aA	433	bB	333
PIP	534	**bB**	229	aA	516	**bB**	426
Average	459		206		474		380
AVERAGE							503
P. laurocerasus 'Novita'							
Date	05/06/15		30/06/15		22/09/15		
CAG	425	aB	415	aB	271	aA	370
PIP	355	aB	340	aAB	239	aB	311
Average	390		377		255		341
Date	07/06/16		05/07/16		16/09/16		
CAG	183	aA	271	bB	241	aAB	232
PIP	256	aA	277	aA	212	aA	248
Average	219		274		226		240
AVERAGE							290

Note: different letters following means discriminate within groups for each parameter at a significance level of 0.05; lower case - among the taxa within the production system and year, upper case - among the sampling days within the production system and taxa (*Tukey* $p < 0.05$), bold case - among the production system within the sampling days and taxa.

The DWU of the taxa averaged for the two years was between 290 and 503 g day^{-1}. *C. alba* 'Sibirica' showed significantly higher DWU than *P. laurocerasus* 'Novita' in both years, for most of the sampling days. Sampling days are typically divided into two statistical groups. The effect of the production system was found to be significant for *C. alba* 'Sibirica', which is clearly indicated by the 2016 data. At this time, the DWU in the PIP system was higher compared to the CAG system (5. Table).

The relative water use (RWU) was obtained from the ratio of IWC and DWU (2. Figure).

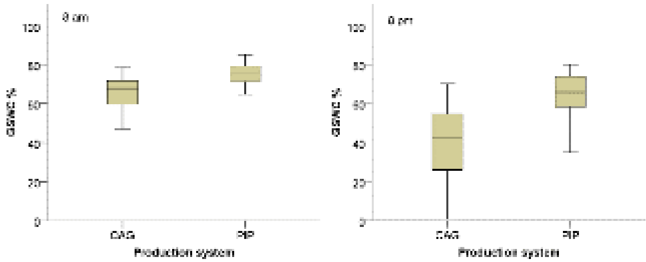


2. Figure Development of relative water use (RWU g kg^{-1})

Regarding the sampling days, the effect of the production system is did not show clear effect. However, the taxa showed up different character in RWU. The RWU was significantly higher for *C. alba* 'Sibirica' compared to P. laurocerasus 'Novita', in all sampling days with one exception (05.07.2016).

Moisture content of growing medium

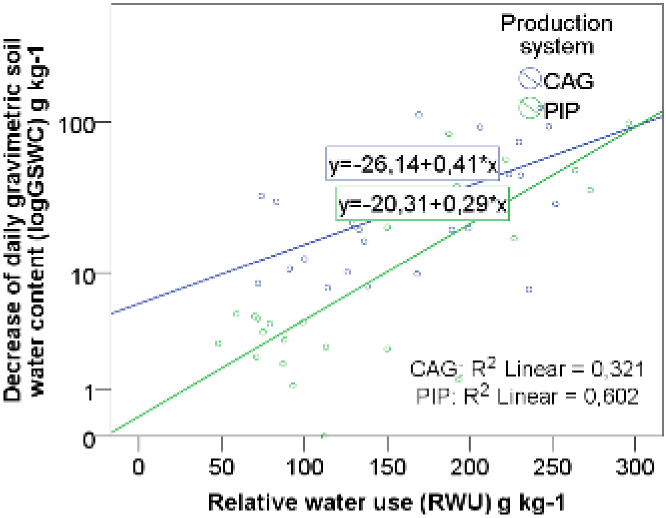
The taxa had no effect on the moisture content of the growing medium either the morning or evening hours. In contrast, the production system was significant in both the morning and evening hours. Based on this, it can be concluded that the PIP system has a higher moisture content, already in the morning – quasi the previous day's reserve – than the CAG system. Furthermore, the measurement at the evening hours showed well, that PIP lost fewer amount of the moisture than CAG (3. Figure).



3. Figure Daily variation in gravimetric soil water content (GSWC) of different production system (CAG; PIP) (5L)

With the relationship between the GSWC and the RWU, we would like to point out on which specific scale the proportion of the daily water use of different production systems that the medium loses from its moisture content moves.

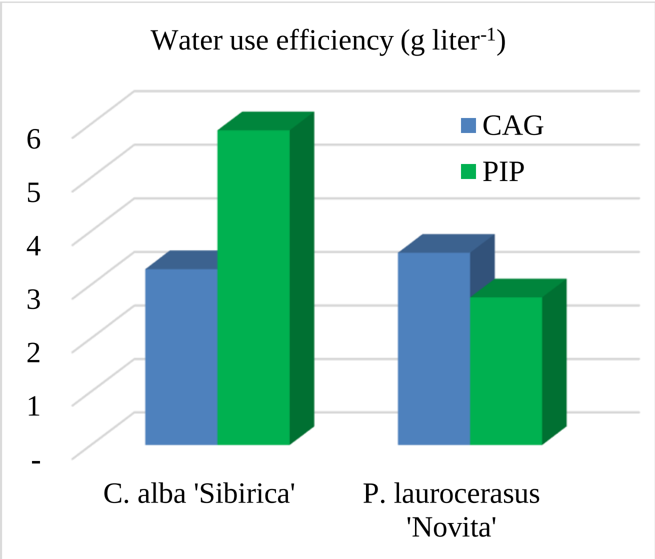
We found that there is a functional relationship between GSWC and RWU. Solving the equations for the daily average RWU values, we get that CAG: 12.4-53.4 g kg^{-1}, while PIP: 6.95-35.95 g kg^{-1} loses moisture mass only from the medium during the day (4. Figure).



4. Figure Relationship between gravimetric soil water content (GSWC) and relative water use (RWU)

Water use efficiency of container grown ornamental shrubs

Water use efficiency developed differently for ornamental shrub taxa grown in different production systems. The *C. alba* 'Sibirica' variety produced 3.29 g of dry matter in the CAG system using 1 liter of water, compared to 5.88 g in the PIP system. *P. laurocerasus* 'Novita' produced 3.60 g of dry matter product in the CAG system and 2.76 g in the PIP system using 1 liter of water, taking into account the entire growing season (5. Figure).



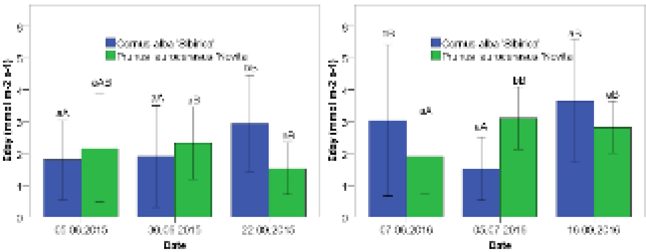
5. Figure Water use efficiency of ornamental shrub taxa in different production system

Leaf gas exchange measurements, transpiration rate

In this study, four types of transpiration parameters were defined: the daily average of the transpiration rate (E_{day}), diurnal changes of the the transpiration rate (E_{period}) and the daily amount of transpiration (E_{sum}), and the transpiration rate for the entire measurement period (E_{total}).

The daily average of the transpiration rate (E_{day})

E_{day} was significantly affected by taxa and sampling day. *C. alba* 'Sibirica' showed lower E_{day} values in summer than in autumn (except 07/06/2016), so the transpiration of the plant was increased on cooler days. No such trend was observed for *P. laurocerasus* 'Novita', however, the opposite behavior of the two taxa was observed (6. Figure).

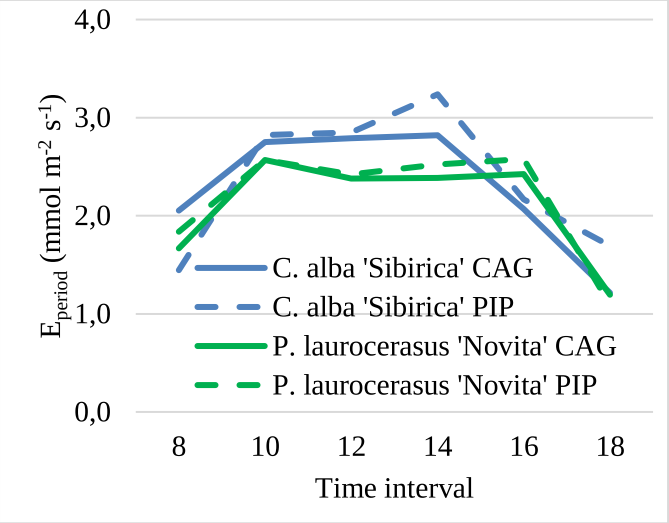


6. Figure The average of the daily transpiration rate (E_{day}) of *Cornus alba* 'Sibirica' and *Prunus laurocerasus* 'Novita' on the sampling days in the year of 2015 and in 2016.

Note: different letters following means discriminate within groups for each parameter at a significance level of 0.05; lower case - among the taxa within the sampling day, upper case - among the sampling days within the taxa (*Tukey* p <0.05).

Diurnal changes of the the transpiration rate (E_{period})

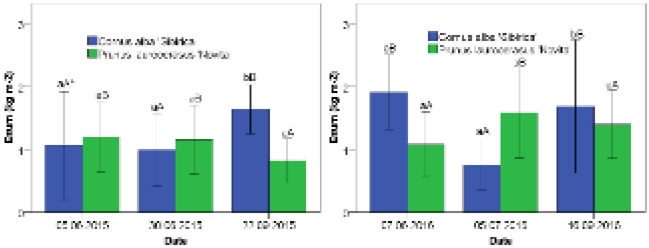
The daily evolution of the transpiration curve shows a bell curve character. The daily peak is reached by both taxa in the PIP system, *C. alba* 'Sibirica' around 2 pm and *P. laurocerasus* 'Novita' around 4 pm (7. Figure). Based on the statistical analysis, the E_{period} values for each time interval differed more for *C. alba* 'Sibirica' than for *P. laurocerasus* 'Novita'.



7. Figure Diurnal changes of the transpiration rate (E_{period}) of container grown ornamental shrubs (5L) in different production systems

Daily amount of transpiration per unit of leaf area (E_{sum})

The daily amount of transpiration ranged from 0.76 to 1.91 kg m^{-2} during the experimental period (8. Figure). The daily transpiration of the two taxa developed differently on each measurement day. *C. alba* 'Sibirica' showed higher E_{sum} on cooler days, while producing lower values on warmer days. *P. laurocerasus* 'Novita' reacted to the weather conditions of the measurement days in exactly the opposite way: on cooler days (two autumn and one summer) the E_{sum} was lower, while on the warmer, e.g. summer days it showed a higher E_{sum} (8. Figure).

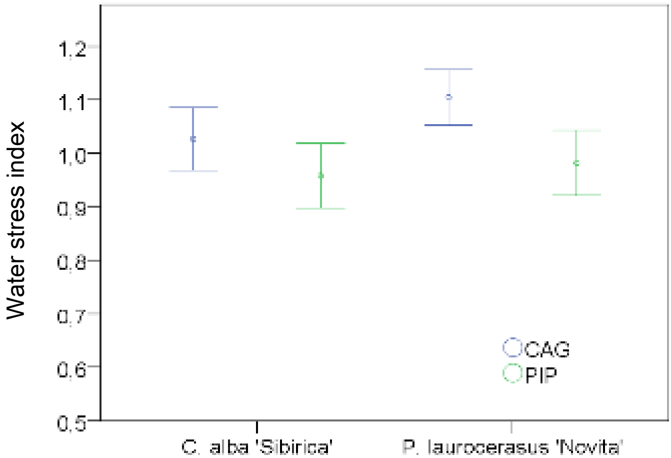


8. Figure Daily amount of transpiration per unit of leaf area (E_{sum}) of *Cornus alba* 'Sibirica' and *Prunus laurocerasus* 'Novita'

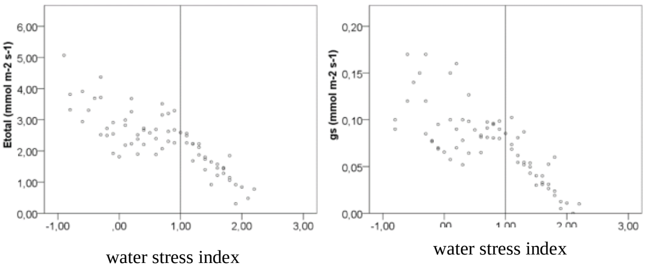
Note: different letters following means discriminate within groups for each parameter at a significance level of 0.05; lower case - among the taxa within the sampling day, upper case - among the sampling days within the taxa (*Tukey* $p < 0.05$), * - significant effect of the production system within the sampling day and taxa.

Relationship between transpiration (E_{total}) and water stress index

The difference between air temperature and plant temperature characterizes the water supply of a plant, which is called the water stress index. Water stress index values ranged from –1 to +2 on sampling days, and were lower in the PIP system than in the CAG system, regardless of taxa (9. Figure).



9. Figure Water stress index of *Cornus alba* 'Sibirica' and *Prunus laurocerasus* 'Novita' in different production system



10. Figure Relationship between transpiration rate (E_{total}) and water stress index, and between stomatal conductance (g_s) and water stress index.

As the water stress index increases, the transpiration rate (E_{total}) decreases, however, above a +1 water stress index, a linear decrease in E_{total} is clearly visible. Thus, it can be concluded that if the leaf surface temperature is at least one degree higher than the ambient air temperature, E_{total} decreases. In the absence of water, transpiration is reduced due to stomatal closure. The relationship between stoma function and water stress index shows the same trend as that observed for E_{total}; its value decreases linearly, above +1 (10. Figure).

DISCUSSION

Evaluation of the development of morphological parameters

The habit and appearance of the experimental plants developed as well, typical of the species. The year effect was significant in this case as well, the plants grew higher in 2015 than in 2016, but the extent of the canopy developed similarly in the two years. *Thuja occidentalis* 'Smaragd' and 'Brabant' taxa with columnar and conical habit, complied with the literature in terms of their growth characteristics. In terms of plant height and canopy development, we found similar to that of *C. alba* 'Sibirica'; the plants grew taller in 2015, with narrower canopy, in 2016 the height increase was smaller, they were rather wider compared to the previous year. Therefore, the year effect was also significant for these two taxa (1. Table1. Table Seasonal increment of plant height for conatiner grown (5L) ornamental plants in 2015 and 2016, respectively).

The effect of production system on the morphological parameters

The results so far show that the effect of the PIP production system on plant properties is not always clear (Miralles et al., 2009, 2012; Ruter, 1993; Schluckebier and Martin, 1997). Based on our own results, in the PIP system *C. alba* 'Sibirica' produced outstandingly more favorable values, for *T. occidentalis* 'Smaragd' and 'Brabant ' the PIP system was mostly more favorable or its effect could not be detected, while *P. laurocerasus* 'Novita' developed better in the CAG production system.

Water use of container grown experimental plants

The morning weight of container (IWC) includes the moisture content of the growing medium and is therefore highly dependent on its amount. IWC was 12.5% (*C. alba* 'Sibirica') and 16.3% (*P. laurocerasus* 'Novita') higher in the PIP system than in the CAG system. This means that, regardless of the plant type grown, the containers started the day in PIP production system with a higher water mass.

The hypothesis that PIP containers started the day with higher moisture content is also supported by moisture content measurements. The production system was strongly significant for the PIP system, so it can be cocluded that at the same irrigation rate, the containers of the PIP system have a higher water retention capacity than the containers of the CAG system. As our results suggest PIP containers provide greater water supply capacity on the morning of sampling days have been confirmed by other authors (Ruter, 1998a, 1998b; Schluckebier and Martin, 1997). The sources of higher water capacity are moisture left over from previous days, watering the previous day, and moisture retained overnight.

The daily water use (DWU) of container plants is strongly influenced by the taxa and the size of the container. Despite the fact that both taxa (*C. alba* 'Sibirica' és *P. laurocerasus* 'Novita') have medium water demand (Tóth, 2012), their water use measured on the sample days differed significantly. The water use of *C.*

alba 'Sibirica' averaged 626 g day^{-1} on the sample days, which is 83.5% higher than the water use of *P. laurocerasus* 'Novita' measured on the same days (341 g day^{-1}), in 2015. The following year (2016), this proportion was somewhat more moderate, however, the DWU was still 58.3% higher for the *C. alba* 'Sibirica' than for *P. laurocerasus* 'Novita'. Differences in the total leaf area of the two plants presumably also contributed to the differences in water use, the total leaf area of *C. alba* 'Sibirica' was 58.4% higher in 2015 and 73.8% higher in 2016 than that of *P. laurocerasus* 'Novita'. DWU fluctuated less between sampling days for *P. laurocerasus* 'Novita', while *C. alba* 'Sibirica' responded with greater variability to sampling day conditions. The relationship between DWU and IWC in *C. alba* 'Sibirica' seems obvious. The production system in the case of *C. alba* 'Sibirica' had a definite effect on water use; the PIP system exceeding the DWU of the CAG system by 5% in 2015 and 27% the following year. However, *P. laurocerasus* 'Novita' showed more contradictory results; higher DWU (18%) was detected in the CAG systemin 2015, while in the next year (2016), the water use of the PIP system was 4% higher than the DWU of CAG system. The literature shows a similarly diverse picture of water use for different species (García-Navarro, 2004; Hagen et al., 2014; O'Meara et al., 2013).

Relative water use (RWU), which means the water use per unit mass of a container, helps in irrigation planning. Due to species-specific water use, *C. alba* 'Sibirica' and *P. laurocerasus* 'Novita' plants use 193 g kg^{-1} and 93 g kg^{-1} water, respectively. Regarding the production system, it can be stated that the loss of gravimetric soil water content (GSWC) is 33 g kg^{-1} in CAG system, while in the PIP system it is advisable to plan with 21 g kg^{-1} (4. Figure). As the irrigation practice in the nursery suggest (400-600 g water $plant^{-1}$ day^{-1}), it can be concluded that the amount of water applied by the irrigation system covered the water demand of *C. alba* 'Sibirica', but exceeded the water demand of *P. laurocerasus* 'Novita'. It is recommended to place the two taxa on different irrigation circle.

Evolution of the transpiration rate

The transpiration rate showed greater variability between the two taxa than the photosynthetic rate. The average daily rate of transpiration (E_{day}) were lower in summer than in autumn for *C. alba* 'Sibirica'. *P. laurocerasus* 'Novita' behaved just the opposite; transpiration intensity was higher in summer than in autumn (6. Figure).

The diurnal change of transpiration (E_{period}) was lower in the CAG system than in the PIP system. This result can be related to the lower water content of CAG containers (3. Figure).

Diurnal changes highlighted the species-specific physiological responses. Deciduous plants reduce their transpiration to a greater extent than evergreens under drought stress (Givnish, 2002).

Transpiration per unit of leaf area (E_{sum}) during the experimental period ranged from 0.76 to 1.91 kg m^{-2} for *C. alba* 'Sibirica' and from 0.82 to 1.58 kg m^{-2} for *P. laurocerasus* 'Novita' (8. Figure). However, the significance of these data goes beyond the characterization of physiological properties; since nursery plants provide the plant material for green areas established for different purposes. The environmental benefits of biologically active surfaces (Jószainé Párkányi, 2007; Radó, 2001) can now be measured in terms of the conditioning effect.

The difference between leaf surface temperature and ambient temperature provides the water stress index. In this study, we measured lower water stress index on plants grown in the PIP system than on plants grown in CAG system (9. Figure). There is a strong negative relationship between water supply and the water stress index. If the difference between leaf surface temperature and air temperature is 1°C, the rate of transpiration (E_{total}) begins to decrease sharply (10. Figure).

CONCLUSION

Pot in pot (PIP) had a positive effect on morphological parameters, especially in the plant height increment. Biomass and dry matter production were also more favorable, however these parameters were examined only for broadleaved taxa (because for subsequent physiological studies).

Daily water use (DWU) of container grown ornamental shrubs plant, can be a good basis for irrigation planning and does not require special calculation. In the nursery where our experiment were carried out, the daily water dose of 5L container plants was 400-600 g plant^{-1} day^{-1} (season dependent). The relative water use of container weight (RWU) was calculated from the daily water use (DWU). The species-specific results of DWU and RWU data showed that two plants with medium water demand could show a significant difference in water use. *C. alba* 'Sibirica' and *P. laurocerasus* 'Novita' consumed 193 g kg^{-1} and 93 g kg^{-1} water from the same amount of irrigation water, respectively.

We found that the production systems significantly influence the water status of the peat-based growing medium. Due to the greater water retention capacity of the pot in pot (PIP) production system, it loses 21 g kg^{-1} of moisture during the day, while the conventional container production system (CAG) showed 33 g kg^{-1} lost of moisture during the day. However, the water use efficiency of the experimental taxa showed that the positive effect of the pot in pot system can be clearly demonstrated only for *C. alba* 'Sibirica'.

During the collection of gravimetric data, we also observed physiological changes in plants. We found that their photosynthetic rate decreased as early as the morning hours. The plants were not watered on the sampling days therefore we supposed at first, plants respondended to the missed watering event at the morning with decreasing photosynthetic rate. However, since the moisture content of the growing medium was relatively high in the morning (between 60-80%), it is assumed that the stress caused by visible light may correspond to the a decrease in the photosynthetic rate measured on light leaves. The daily course of the transpiration rate, with the exception of mid-summer measurements, was nearly bell-shaped. This partly supports the assumption that the plants were not exposed to a high degree of drought stress during the one-day non-irrigation. However, on typical summer sampling days (30.06.2015 and 05.07.2016) a decrease in the transpiration rate can be detected. Overall, the deciduous *Cornus alba* 'Sibirica' responded to daily and diurnal changes with greater photosynthetic and transpiration variability than the evergreen *Prunus laurocerasus* 'Novita'. Our result such as the assimilation of carbon dioxide per unit of leaf area and transpiration per unit of leaf area express well the environmental benefits of ornamental shrub species.

The difference between leaf surface temperature and air temperature provided the water stress index. We found that if the plant temperature is + 1°C higher than its ambient temperature, stomatal conductance and transpiration rate also start to decrease linearly. Furthermore our results showed the pot in pot (PIP) production system had lower water stress index compared to conventional above ground container production (CAG).

NEW SCIENTIFIC RESULTS

1. The morphological and physiological parameters of *Cornus alba* 'Sibirica' developed more favorably as a result of pot in pot (PIP) production system.

2. The morphological and physiological parameters of *Prunus laurocerasus* 'Novita' developed more favorably as a result of conventional above ground production system (CAG).

3. For *Thuja occidentalis* 'Smaragd' and 'Brabant', the pot in pot production system (PIP) is partly more favorable in terms of morphological parameters.

4. The relative water use (RWU) applicable to irrigation planning practice for two ornamental plant taxa has been determined, which means the water use per unit mass of containers. Due to the species-specific water use, *Cornus alba* 'Sibirica' and *Prunus laurocerasus* 'Novita' consume 193 g kg^{-1} and 93 g kg^{-1} water, respectively.

5. The daily loss of gravimetric soil water content (GSWC) of the peat-based medium in the conventional above ground production system (CAG) is 33 g kg^{-1} and in the pot in pot production system (PIP) 21 g kg^{-1}.

6. Plants grown in a pot in pot system (PIP) can be characterized by lower water stress index than plants grown in conventional above ground production system (CAG).

7. If the difference between leaf surface temperature and ambient air temperature (water stress index) reaches +1°C, the transpiration rate and stomatal conductance decreases linearly.

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Water use estimation and growth of container grown tatarian dogwood (*Cornus alba* L. 'Sibirica') and cherry laurel (*Prunus laurocerasus* L. 'Novita')
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FULL PAPER

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Effect of container type on growth of *Cornus alba* 'Sibirica' and *Prunus laurocerasus* 'Novita' nursery plants. In: Miroslav, Šlosár (szerk.) 5th International Scientific Horticulture Conference 2016: Conference Proceedings Nitra, Szlovákia: University of Agriculture, (2016) pp. 92-97., 6 p.

ABSTRACT

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