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ADAPTABILITY OF *PYRUS PYRASTER* AND *SORBUS DOMESTICA* TO DROUGHT AS PREREQUISITE OF THEIR UTILIZATION IN URBAN ENVIRONMENT

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The aim of study was identification and assessment of the adaptive responses of roots and shoots of two tree species *Pyrus pyraster* and *Sorbus domestica* to water scarcity in the juvenile stage of their growth. One-year old seedlings were placed in the plant boxes filled with fertilized peat substrate and maintained (for 170 days) in a differentiated water regime with two variants of the substrate saturation at 40% and 60% of the full water capacity. For each taxon were analysed 10 plants in both variants of the water regime. Following characteristics were examined: dry weight of above-ground organs (leaves + shoots) DW_S, dry weight of roots DW_R, dry weight of whole plant DW_P, total water content of above-ground organs TWC_S, the total water content in the root system TWC_R, specific leaf area *SLA* (the ratio of leaf area to dry mass) and shoot to root ratio (*S* : *R*). According to the obtained results adaptability of the studied tree species to water scarcity is different. *Pyrus pyraster* in both variants of water regime maintained balanced values for all parameters of dry matter, distributed them evenly to aboveground organs and roots. Under drought created smaller and thicker leaves and significantly invested more resources to root growth (*S* : *R* = 0.42). *Sorbus domestica* has fast growth – created almost three times higher amount of dry matter compared with pear, but lower potential for adaptability to water scarcity. In reaction to water scarcity significantly reduced the total dry matter and dry matter of roots (*S* : *R* = 0.71). In drought created thinner leaves.

Keywords: adaptability, drought, dry mass, urban conditions, water regime

Introduction

Just little research is devoted to relationship between tree roots and aboveground organs, especially in the urban environment (Johnson and Thornley, 1987; Coder, 1998; Tworkoski and Scorza, 2001; Day et al., 2010). Nevertheless, the characteristics of the roots and aboveground organs can be important criteria within selection of the species, or clones intended for urban environment as well as for management of their nutrition, irrigation, and planting density.

Beside this, relationships between plant organs indicate and describe plant adaptations to stand conditions, especially humidity conditions in the soil (Lyr and Hoffman, 1967).

According the obtained knowledge in this field, the root growth probably reflects the need to increase the absorptive surface of the plant, which is particularly active during absence of water (Kuhns et al., 1985). But the ratio of roots and aboveground organs changes also during the year, depending on seasonal changes which respond to climate in the place of origin of particular species.

In terms of function, the size and function of above-ground organs is comparable with the size and function of the root system. According to Richards and Rowe (1977) there is a functional balance between them. The role of shoots is utilize and convert carbon in the process of photosynthesis and on the plant structural substances and a part of them transport to the root. The role of the root is to utilize these substances for their own growth, as well as to capture water and minerals from the soil and transport them to the shoots

Giovannini et al. (1994) Tworkoski and Scorza (2001) studied distribution of dry matter within differentiated organs of the peaches. There was confirmed that dry matter distribution is correlated with root morphology. The basic model of these relationships is changed under unfavourable environmental factors (soil compaction, changes of the physical and chemical properties of soil, soil contamination, and impact of organic pollutants, pesticides, urea and drought).

The paper is devoted to identification and assessment of the adaptive responses of roots and shoots of two woody plants (*Pyrus pyraster* and *Sorbus domestica*) to water deficit in the juvenile stage of their growth.

Material and methods

Pyrus pyraster and *Sorbus domestica* are considered to be a light-demanding tree species. They naturally appear also on xerophytic habitats with negative water balance during the growing season. Therefore we suppose that both taxa have adaptability to drought and resistance

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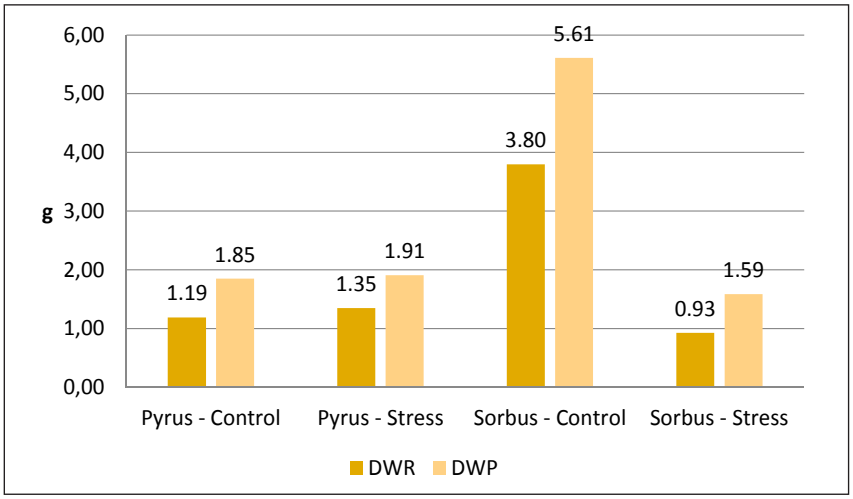

Figure 1 Average values of dry weight per plant (DW_P) and dry weight of roots (DW_R) in particular variants of water regime

to the limited amount of available water in the substrate. These qualities are crucial for plant establishment and successful growth in extreme conditions of urbanized area.

In the juvenile stage of growth the response to water scarcity of both taxa was verified under experimental conditions. Plant material comes from the original stands in Slovakia (Table 1), which represent typical habitats of the analysed taxa (*Pyrus pyraster* and *Sorbus domestica*). Seeds are extracted from the fruits immediately after harvest. After cleaning, seeds were stored for short time and treated by cold stratification at temperatures of -5 °C to +5 °C. Then germinated in plastic seed trays filled with sowing substrate based on peat.

In the phenological growth stage "expanded cotyledons" Šenšel and Paganová (2010) seedlings were placed in the plant boxes filled with fertilized peat substrate (white sphagnum, pH 5.5–6.5, fertilizer 1.0 kg m^{-3}). The construction of metal root boxes with special pull-out front wall enabled careful extraction of the whole plants for analysis and detailed study of the root system and its structures.

The plant boxes were placed under a polyethylene cover with 60% shading and maintained in a differentiated water regime with two variants of the substrate saturation at 40% and 60% of the full water capacity. Variant "Stress" was supplied with water at 40% of full substrate saturation and variant "Control" at 60% of full substrate saturation. The model of differentiated water regime was maintained for 170 days (from April to the end of September 2013). At the end of the experimental period, all plants were removed from the root boxes. In both variants of the water regime for each taxon were analysed 10 plants. Several characteristics were examined: dry weight of above-ground organs (leaves + shoots) DW_S, dry weight of roots DW_R, dry weight of whole plant DW_P. There were also measured total water content of above-ground organs TWC_S, the total water content in the root system TWC_R, specific leaf area *SLA* (the ratio of leaf area to dry mass) and leaf dry weight ratio of aboveground and underground organs (*S* : *R*).

A statistical assessment of the data was conducted using software Statgraphics Centurion XV (StatPoint Technologies, USA, XV (license number: 7805000000722). The impact of drought, as well as significance of the interspecific differences of the studied parameters was evaluated by analysis o variance ANOVA.

Results and discussion

The aim of study was quantification of the dry matter created by young plants during the growing season, as well as studies of their ability retain water in shoots and root system. Reliability of the found differences between taxa (*Pyrus pyraster* / *Sorbus domestica*) and variants with different levels of the substrate saturation (Control / Stress) were evaluated by multifactor analysis of variance. There was assessed impact of drought on growth and dry matter content in aboveground and underground organs of analysed woody plants. Quantitative data for all studied parameters have a normal distribution (Shapiro Wilk's test at significance level α = 0.001) and meet the assumption of homogeneity (Leven's test at significance level α = 0.05).

Based on the results of analysis of variance it was possible to reject the hypothesis of equality of mean values for the parameters of dry matter content in plant organs

Table 1 Climate-geographic description of the original stands of analysed woody plants /3/

	Location	Altitude in m	Exposure	TI. in °C	TVII. in °C	Precipitation in mm	Climate Type	Subtype
Pyrus pyraster L. Burgsd.	Slatinka	350	SE	-2	18	700	W	W7
Sorbus domestica L.	Kosihovce	250	S-SE	-2	19	600	W	W4

TI. – average temperature in January, TVII. – average temperature in July, Precipitation – annual sum of precipitation, W – warm climate

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(Table 2). Significant differences between wild pear (*Pyrus pyraster*) and service tree (*Sorbus domestica*) were identified for dry weight of whole plant ANOVA (F (1.35) = 9.77, p = 0.0036), dry weight of roots ANOVA (F (1.37) = 7.38, p = 0.0009), dry weight of above-ground organs (F (1.35) = 16.50, p = 0.0003), as well as for the parameter distribution of dry matter into shoots and roots $S : R$ (F (1.35) = 7.41, p = 0.0100). The hypothesis of equality of mean values was rejected for the majority of evaluated parameters in different variants of water regime (Control / Stress). The null hypothesis was accepted only for parameter $S : R$ (Table 2).

The results of quantitative analysis of the accumulation of dry matter are documented by multiple range test. There was applied the Bonferroni test (Table 3), because of unequal number of observations (18, 20).

The seedlings of *Sorbus domestica* compared to *Pyrus pyraster* created nearly double amount of dry matter per plant (3.48 g), and have higher weight of dry matter in roots (2.28 g) compared to the dry matter of above-ground organs (1.20 g). The production of dry matter has been significantly influenced by the regulated water regime. In the variant "stress" plants created just half of the dry weight per plant (1.75 g) compared with the control (3.61 g).

Interesting is detailed analysis of dry matter in both species at different levels of the substrate saturation (Fig. 1). The reduction of watering in the juvenile stage of growth has not been negatively expressed with parameters of dry matter of *Pyrus pyraster*, as in the variant "Stress" pear has created 1.91 g of total dry matter per plant and in the "Control" just 1.85 g. Under the influence of drought pear invested more to growth of the root system, that is documented by higher mean value of the dry weight of roots DW_R = 1:35 g versus control (1.19 g). *Sorbus domestica* in "Control" created significantly (three times) higher amount of dry matter per plant (DW_P = 5.61g) compared to *Pyrus pyraster* (DW_P = 1.85g). However, *Sorbus domestica* responded to drought by significant reduction of the total dry matter (DW_P = 1.85g) and dry matter of root system.

In the juvenile stage of growth significant differences were found between analysed species. Service tree produced more dry matter than pear in the control variant, but the lack of water significantly reduced production of dry matter in aboveground organs and roots of this taxon. Wild pear in both variants of water regime maintained balanced content of all parameters of dry matter. Distribution of dry matter to aboveground and underground organs within regulated water regime was evaluated by one-way analysis of variance separately for each taxon. Pear in the variant "Stress" significantly (p = 0.0078) more invested to growth of root system ($S : R$ = 0.42). The distribution of dry matter to aboveground organs and roots of service tree was significantly (p = 0.0157) more balanced, in the variant "Stress" ($S : R$ = 0.71) compared to "Control" ($S : R$ = 0.51). The ability of plants to survive drought also depends on their ability maintain water in above variants with different level of water regime the null hypothesis of equality of mean values of water content in aboveground and underground organs was rejected. In variant "Stress" seedlings had significantly higher water content in the root system (TWC_R = 54.71%) and in the aboveground organs (TWC_S = 55.06%) compared to the "Control".

Table 2 Multifactor analysis of variance for parameters of dry matter production and distribution for one-year old seedlings of *Pyrus pyraster* and *Sorbus domestica* in the differentiated water regime at 40% and 60% of substrate saturation

Parameter	DW_P		DW_R		DW_S		$S : R$	
Source of variation	*F*-value	*p*-value	*F*-value	*p*-value	*F*-value	*p*-value	*F*-value	*p*-value
Taxon	9.77	0.0036**	7.38	0.0102*	16.50	0.0003**	7.41	0.0100*
Substrate saturation	13.22	0.0009 **	11.63	0.0016**	16.11	0.0003**	0.36	0.5499 n.s.

DW_P – dry weight of whole plant, DW_R – dry weight of roots, DW_S – dry weight of above ground organs, $S : R$ – shoot to root ratio

Table 3 Average values of the analysed parameters and 95% Bonferroni test for studied taxa (*Pyrus pyraster*/*Sorbus domestica*) and for two variants of the substrate saturation (Control/Stress).

Parameter / **Source of variation**	DW_P in g	DW_R in g	DW_S in g	TWC_S in %	TWC_R in %	*SLA* in $m^2\ kg^{-1}$	$S : R$
Pyrus pyraster L. Burgsd.	1.88 A	1.27 A	0.61 A	53.59 A	52.34 A	20.53 A	0,48 A
Sorbus domestica L.	3.48 B	2.28 B	1.20 B	54.55 A	53.92 A	22.44 B	0,62 B
Control	3.61 B	2.41 B	1.20 B	53.08 A	51.54 A	21.52 A	0,53 A
Stress	1.75 A	1.14 A	0.61 A	55.06 B	54.71 B	21.45 A	0,57 A

Values with the same letter are not significantly different

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Table 4 Multifactor analysis of variance for parameters of water content and specific leaf area of the one-year old seedlings of *Pyrus pyraster* and *Sorbus domestica* in the differentiated water regime at 40% and 60% of water saturation of substrate

Parameter	TWC_R		TWC_S		*SLA*	
Source of variation	*F*-value	*p*-value	*F*-value	*p*-value	*F*-value	*p*-value
Taxon	1.11	0.2986 n.s.	1.87	0.1807 n.s.	5.00	0.0318*
Substrate saturation	4.45	0.0421*	7.90	0.0080*	0.01	0.9397 n.s.

TWC_R – total water content in roots, TWC_S – total water content of shoots, *SLA* – specific root area

Differences in the water content of the organs of analysed tree species at different levels of water regime were tested by one-way analysis of variance. The null hypothesis was accepted for wild pear, because different saturation levels of the substrate did not affect significantly the water content of above-ground organs (TWC_S), neither in the root system (TWC_R) (Fig. 2). The mean values in both variants "Control" and "Stress" are very similar for this taxon and the differences in the obtained data are not statistically significant. In the variant "Stress" service tree had significantly higher water content in the roots (TWC_R = 58%) and in above-ground organs (TWC_S = 54%) compared to the "Control". Results of analysis of variance for this woody plant allow reject the hypothesis of equality of mean values of the water content in plant organs under the influence of different saturation levels.

The water scarcity has been manifested in decrease production of dry matter of service tree. However, in the variant "Stress" service tree maintained significantly higher water content in the aboveground and underground organs compared with pear.

The interspecific differences were found even for parameter specific leaf area (*SLA*), whose values are generally reduced under water scarcity. Analysed tree species have different values of the mentioned parameter. The average value of specific leaf area (*SLA*) for pear was 20.53 m^2 kg^{-1} and for service tree *SLA* = 22.44 m^2 kg^{-1}. Pear has smaller leaf area and thicker leaves compared with service tree. Results of the multifactor analysis of variance did not confirm the significant impact of the water supply on values of *SLA*.

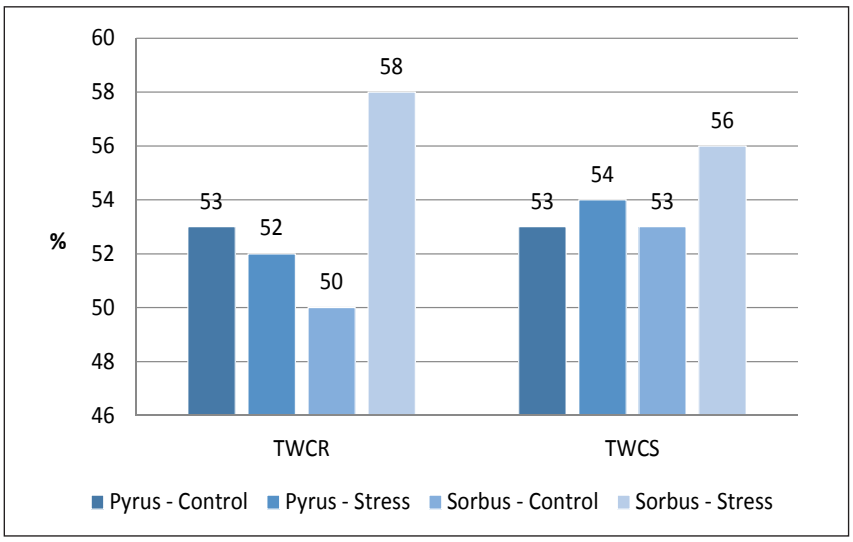

Figure 2 Average values of total water content in roots (TWC_R) and total water content in shoots (TWC_S) for *Pyrus pyraster* and *Sorbus domestica* in particular variants of water regime

A detailed analysis of the drought impact on the values of *SLA* documented for wild pear decline of the mean value (19.21 m^2 kg^{-1}) compared to control (21.85 m^2 kg^{-1}). Because production of dry matter and its accumulation in the above-ground organs were not negatively influenced by water scarcity, under drought pear created smaller but thicker leaves. In variant "Stress" the mean value of *SLA* of service tree was significantly higher (23.69 m^2 kg^{-1}) than in "Control" (20.87 m^2 kg^{-1}). In drought service tree created larger and thinner leaves.

Conclusions

The results of experimental research confirmed that adaptability of the studied tree species to water scarcity is different. It is expressed by differences in the production and distribution of dry matter to the plant organs, what in the juvenile stage of growth changes their growth, shoot to root ratio and shoot architecture.

In the juvenile stage of growth *Pyrus pyraster* has potential for adaptation to water scarcity, what is reflected in the following parameters:

a) In both variants of water regime maintained balanced values for all parameters of dry matter. Created volume of dry matter distributed evenly to aboveground organs and roots.
b) In conditions of water scarcity significantly invests more resources to root growth (*S* : *R* = 00 : 42).
c) Had significantly lower values of the specific leaf area than service tree, under drought created thicker leaves.

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In the juvenile stage *Sorbus domestica* has fast growth but low potential for adaptability to water scarcity, which resulted in the following parameters:

a) in conditions of the sufficient water-supply created almost three times higher amount of dry matter compared with pear. The dry matter preferentially distributed to roots to the detriment of above-ground organs ($S : R = 0.51$).
b) In reaction to water scarcity significantly reduced the total dry matter and dry matter of roots. ($S : R = 0.71$).
c) Service tree had significantly higher values of specific leaf area (*SLA*) than pear, under drought created thinner leaves.

Both tree species are adaptive to water scarcity and can be used for plantings in urban conditions even as street trees. *Sorbus domestica* is rather "fast-growing" specimen, that can significantly reduce production of dry mass in drought. *Pyrus pyraster* did not display any significant changes of dry matter production.

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