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Preliminary results from a plantation of semi-arid hybrid of *Paulownia* Clone in vitro 112® under conditions of the Czech Republic from the first two years

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Abstract

A private owner established a plantation of a semi-arid hybrid of *Paulownia* Clone in vitro 112® near the village of Střelice u Brna in 2016. We split the plantation into three expositions (according to terrain micro-relief – South slope, Plain area and North slope) and two parts (according to the applied biotechnology of planting – each with planting into 20 and 30 cm holes in diameter). We tested various winter protection techniques for above and belowground plant organs. The results suggest that plants inside 30 cm holes survive and grow better than those inside 20 cm ones, regardless of terrain micro-relief. On the other hand, plants inside the 20 cm holes survive and grow better on flat areas. The most effective protection of the root system against frost during the wintertime seems to be simple soil covering. We also recognized that bandage of non-woven fabric is the best protection for the above-ground parts of the plants. However, growing conditions in the Czech Republic (CR) are different to those in the semi-arid climate for which researchers bred the *Paulownia* Clone in vitro 112®. It is possible to achieve well-growing and surviving *Paulownia* plants under growing conditions of the CR when appropriate biotechnology and continuous treatment are applied.

Keywords: *Paulownia* Clone in vitro 112®, plantation, exposition, mortality, growth, protection against frost damage

Introduction

Knauf and Frühwald (2015) predict that availability of high-quality assortments of wood for the wood industry will become limited in the future. The main factor influencing the availability of assortments is the rising demand for wood used for energy purposes or for the production of wood-fibre boards (Michanickl 2007). In the distant future, changes in tree species composition of forest stands in the Czech Republic (CR) will play an important role. Then, representation of coniferous tree species, especially Norway spruce (*Picea abies* L. Karst.), will decrease and the representation of broadleaf species, especially European beech (*Fagus sylvatica* L.) and various oak species (*Quercus* L.), will increase. Furthermore, the amount of actionable wood on the market, mainly to produce furniture and in civil engineering, will decrease because of calamities caused by drought, wind throw, heavy snow, ice-break, frost, bark beetle attack, etc. One of the possibilities of how to meet market demands is the use of an appropriate fast-growing species (Buchholzer 1992).

We can use many tree species to meet market demands: *Acacia* spp. Miller, *Ailanthus altissima* (Mill.) Swingle, *Alnus* spp. Mill., *Casuarina* spp. L., *Fraxinus* spp. L., *Paulownia* spp. Siebold & Zucc., *Platanus* spp. L., *Populus* spp. L., *Prosopis* spp. L., *Robinia pseudoacacia* L., *Salix* spp. L. or *Tectona* spp. L. f. and others (Armstrong et al. 1999, Sixto et al. 2007).

Plantations of tree species, which do not produce timber, cannot meet market demands for high quality assortment but may fill the gap in the energy industry; or can be used to produce wood-fibre products. *Paulownia* spp. could be chosen in the sawmill industry as one possible variation for the utilization of fast-growing trees in Czech conditions. The genus *Paulownia* consists of 6-to-17 species depending on the taxonomic classification (Ates et al. 2008, Woods 2008). *Paulownia* ssp. comes from China (Zhao-Hua et al. 1986) and it is a deciduous tree species that can grow to a height of 12-to-30 m (Smiley 1961). The stem diameter at breast height is commonly about 1 m (Úradníček 2013), however, it can reach 2 m in the area of origin (Innes 2009). In general, *Paulownia* wood is light, strong, light coloured (Akyildiz and Hamiyet 2010), it is easy to work (with) and therefore suitable for carving (Ates et al. 2008). It can be used for building constructions (García-Morote et al. 2014) or for cellulose and biofuel production (Yadav et al. 2013). Plantations are being established with control-breeding hybrids of *Paulownia* (Maľová et al. 2016) and, for this plantation, we had chosen Paulownia Clone in vitro 112®. This clone is a hybrid of *Paulownia fortunei* (Seem.) Hemsl. and *Paulownia elongata* SYHu and is certified as non-invasive because of its infertile seeds (Bikfalvi 2014, Stochmal et al. 2018). However, this clone is suitable for a semi-arid area (García-Morote et al. 2014), but it is highly adaptable in diverse conditions, as documented by Bikfalvi (2014). Cuomo (2014) highlighted its high resistance to extremely low temperatures (down to –25°C). *Paulownia* Clone in vitro 112® has not only high resistance to frost and illness but it is also fast growing in contrast to other hybrids (Icka et al. 2016).

This particular clone had not been tested in the conditions of the CR. Therefore, our study presents the first practical experiment focused on growth and mortality of plants by comparison of:

i) different applied planting biotechnologies;
ii) microclimatic conditions of the site during the first two years after planting.

We also present the results from the testing of protection against frost damage to the root system as well as to the above-ground part in the same period.

Material and methods

The research site was a fenced private plantation (owner: TopTree s.r.o.) near the village of Střelice u Brna (49°09'16.1"N 16°28'25.7"E). The altitude of the research site ranges from 300 to 320 m a.s.l. The private owner established the plantation on agricultural land, luvic brown soil with a depth of up to 1.1 m. The annual precipitation was 524 mm and 452 mm in 2016 and 2017, respectively. The lowest air temperatures of –3.9°C and –8.8°C were recorded in January 2016 and 2017, respectively.

In May 2016, the owner planted 686 container plants, originating from cultivation using the vegetative method *in vitro* (University of Castilla-La Mancha, Spain), sold by Oxytree Solutions s.r.o, with a height of 20 cm ± 2 cm (mean ± SE) and root neck thickness of 5 mm ± 1 mm (mean ± SE). Before transport, the saplings were poured through with a sufficient amount of water and transported by a wind-proof means of transport. After being placed into a dug out trough, they were again poured through with water and covered up to the root neck with soil. The plants were planted with a spacing of 4 × 4 m. The depth of the holes was 80 cm. Of the 686 plants, the owner planted 102 plants into 20 cm holes and the rest into 30 cm holes. They used level planting, which means that the soil surface is covered with another 2 cm of soil. An irrigation bowl was created around each sapling in the shape of a circle 80 cm in diameter with raised edges with the sapling in centre. The bowl protected the saplings from herbaceous vegetation, and rainwater remained in the bowl slowly seeping through. The plantation was split into three sectors differing in exposition: South slope, Plain area, and North slope (hereinafter referred to as South, Plain and North respectively; Table 1).

Each plant received a unique code according to row and its position in each. In June 2016, the plant mortality (caused by transplanting) was investigated, and the owner replaced dead plants with new ones, one month after planting. The new plants were marked, and they were not measured further. In the years 2016 and 2017, tree height and stem diameter at 10 cm above the ground surface were measured at the end of the growing season. In the years 2017 and 2018, the live part of each tree was measured at the beginning of the growing season. After this measurement, in spring 2017, the owner cut off the above-ground part of all plants with a pair of scissors near the soil surface, as it is a common procedure that supports the development of the root system. Mortality was determined by comparison with the previous measurement in the autumn and/or spring. Cumulative mortality was calculated from autumn 2016 until the last monitoring at the beginning of the growing season in 2018. Therefore, two mortality types were registered, one of them after transplanting because of planting shock (which is caused by harm to the plant roots during the transplanting process and/or by the action of other climatic and pedological conditions on transplanted plants) and the other after each growing season and winter.

In the autumns of 2016 and 2017, selected plants (of those planted into the 30 cm holes) were tested for resistance to potential frost damage. In 2016, soil and peat cov-

Table 1. Description of the sectors, number of plants in the sectors

Sector	Exposure	Shape of slope	Slope	Number of plants (pcs)	
				Hole 20 cm	Hole 30 cm
1.	South	Line	10%	34	195
2.	Plain	Concave	0%	34	195
3.	North	Line	10%	34	194
Total				102	584

Table 2. Evaluation of representativeness of chosen plants for winter protection in 2016

Winter protection variant	Exposure	Tree height (± SD) [cm]	SS*	Stem diameter (± SD) [mm]	SS*	Average of protection height (± SD) [cm]
Without protection	All plantation	72.5 (± 24.9)	ns	17.6 (± 5.6)	ns	-
	South	72.6 (± 28.2)	ns	17.4 (± 6.1)	ns	-
	Plain	80.7 (± 22.9)	ns	19.2 (± 5.1)	ns	-
	North	67.7 (± 22.6)	ns	16.8 (± 5.4)	ns	-
Non-woven material	All plantation	75.2 (± 15.1)	ns	19.2 (± 4.0)	ns	76.3 (± 15.1)
	South	71.6 (± 12.7)	ns	16.0 (± 2.2)	ns	72.6 (± 12.6)
	Plain	79.5 (± 13.8)	ns	21.9 (± 3.0)	ns	80.7 (± 14.2)
	North	74.6 (± 18.6)	ns	19.9 (± 4.1)	ns	77.7 (± 20.9)
Peat	All plantation	76.0 (± 12.9)	ns	17.9 (± 3.8)	ns	22.9 (± 3.1)
	South	67.7 (± 14.9)	ns	14.8 (± 3.8)	ns	23.1 (± 3.3)
	Plain	81.0 (± 12.5)	ns	19.8 (± 3.8)	ns	20.4 (± 2.8)
	North	79.2 (± 9.5)	ns	19.2 (± 2.2)	ns	21.4 (± 2.9)
Soil	All plantation	77.5 (± 22.7)	ns	18.9 (± 5.0)	ns	22.1 (± 3.1)
	South	62.1 (± 20.8)	ns	15.9 (± 5.2)	ns	21.4 (± 3.0)
	Plain	74.9(±20.3)	ns	17.9 (± 4.5)	ns	23.3 (± 3.2)
	North	95.8 (± 13.2)	ns	23.0 (± 1.9)	ns	22.7 (± 2.9)

* SS stands for statistical significance; ns stands for statistically not significant values ($p = 0.95$).

Table 3. Evaluation of representativeness of chosen plants for winter protection in 2017

Winter protection variant	Tree height (± SD) [cm]	SS*	Stem diameter (± SD) [mm]	SS*
Without protection	65.4 (± 20.3)	ns	18.5 (± 6.4)	ns
Non-woven material	61.1 (± 17.8)	ns	15.9 (± 5.4)	ns
Tubex	68.7 (± 30.4)	ns	20.4 (± 8.5)	ns

* SS stands for statistical significance; ns stands for statistically not significant values ($p = 0.95$).

ering and binding using non-woven fabric, together with the increased thickness of the soil, were applied to ten sample plants of similar size per sector (Table 2).

The soil or peat fill had the shape of a truncated cone with a height of 20–25 cm. These fills were intended for the protection of the root system and lower above-ground part. The non-woven material was wrapped around the trunk downward from the treetop and it covered the ground around the trunk. The part of the material, which covered the ground around the trunk, was overlaid with an approximately five-centimetre layer of soil. In 2017, the root system protection against possible frost damage was not repeated. Wrapping of non-woven material without soil overlap and the insertion of the stem into a hollow cylinder of polyethylene TUBEX® foam ("Tubex") were two methods employed for the protection of the above-ground part. Twelve plants of similar size from each sector were chosen for determining the efficiency of this protection (Table 3).

Statistical analysis of the data was performed using STATISTICA software package (StatSoft 2013). Normality of the data distribution was examined before the main analysis. The main effects were tested using ANOVA. After ANOVA analysis, Fisher's LSD test was used to identify differences among the main effects and interactions. Confidence intervals were set at 95%.

Results

Mortality

The mortality was from 0 to 8% depending on the exposure and the diameter of the drilled hole (Table 4), one month after planting.

There was no mortality on Plain, regardless of the diameter of the drilled hole and there was no mortality in the 20 cm holes on South. The plants inside the 20 cm holes on the North exposure showed the highest mortality (7.7%). In the spring of 2018, the mortality of those planted into the 30 cm holes was more-or-less consistent across all exposure variants, i.e., from 4.6 to 6.8%. On the other hand, we noted big differences in the mortality of those plants inside the 20 cm holes within the exposure variants. There, we recorded the highest mortality on the North (19.2%) and the South (14.3%) exposures. We did not establish the plant mortality on Plain.

Table 4. Mortality of *Paulownia* according to exposure and drill diameter

	Exposure	South		Plain		North	
	Drill diameter [cm]	30	20	30	20	30	20
Mortality [%]	Mortality of transplanting	4.9	0	0	0	1.8	7.7
	SHG	A	B	B	B	B	A
	2016 Autumn	1.2	0	0.7	0	0	3.8
	SHG	A	A	A	A	A	A
	2017 Spring	4.3	7.1	2.6	0	0.9	3.8
	SHG	A	B	A	A	A	A
	2017 Autumn	4.9	14.3	3.9	0	3.6	3.8
	SHG	A	B	A	A	A	A
	2018 Spring	6.8	14.3	4.6	0	5.5	19.2
	SHG	B	B	A	A	A	B

* Capital letters denote statistically homogeneous groups (SHG) between variants of different frost protection ($p = 0.95$).

The effect of terrain exposure and hole diameter

Plant height and stem thickness were similar (± 2 cm in height, ± 1 mm root neck thickness) in the time of planting.

The plants inside the 30 cm holes were significantly higher than those planted in the 20 cm ones (Figure 1).

On average, they were about 76% higher at the end of the 2016 growing season and about 18% higher in 2017. Similarly, the non-frozen live above-ground parts of the stem, on average, were about 63% higher in the plants inside the 30 cm holes than those in the 20 cm ones after the 2016/2017 winter and about 11% higher after the 2017/2018 winter.

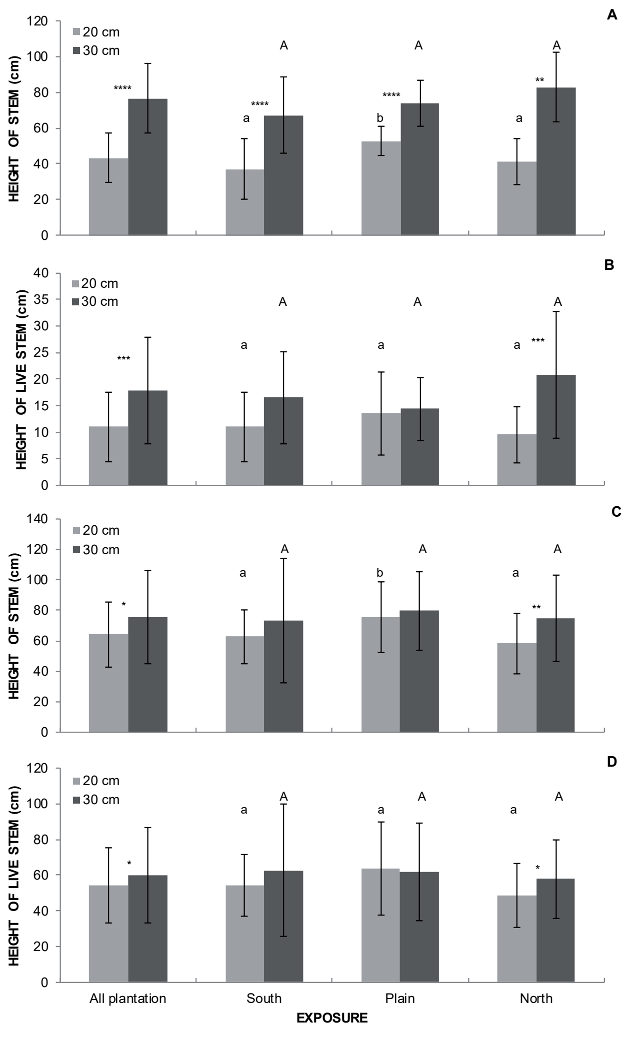

Figure 1. Height of plants

A is for the height of tree in the end of growing season 2016; B is for the height of live above-ground part of stem after winter 2016/2017; C is for the height of stem at the end of growing season 2017; D is for the height of live above-ground part of stem after winter 2017/2018. Whiskers denote standard deviations. Statistically significant differences between variants of drilled hole diameter are marked by stars (* $P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$). Small letters denote homogeneous groups between variants of exposure for 20 cm hole diameter ($p = 0.95$). Capital letters denote homogeneous groups between variants of exposure for 30 cm hole diameter ($p = 0.95$).

Moreover, the plants in the 30 cm holes were thicker than those in the 20 cm ones by about 85% at the end of the 2016 growing season, and by about 30% in 2017 (Figure 2).

On the North exposure, the plants in the 30 cm holes were always taller than those in the 20 cm ones. There, the greatest difference was 118% after the 2016/2017 winter, and the smallest difference was 19% after the 2017/2018 winter. These higher plants were also thicker by about 6% in 2016 and 17% in 2017. On the South and Plain exposures, the plants in the 30 cm holes were bigger than those in the 20 cm ones in 2016:

- in height by about 45% on South and about 29% on Plain;
- in stem thickness by about 20% on South and about 42% on Plain.

In contrast, we did not record any differences in plant height on these exposures at the end of the 2017 growing season and after the 2016/2017 and 2017/2018 winters. The difference in stem thickness between the plants in the 20 cm and 30 cm holes was about 38% on the South exposure at the end of the 2018 growing season.

The effect of protection against frost damage after the 2016/2017 winter

We expected there to be mortality (due to frost damage) during the winter period on the above-ground plant parts as well as on the root systems. We identified the high-

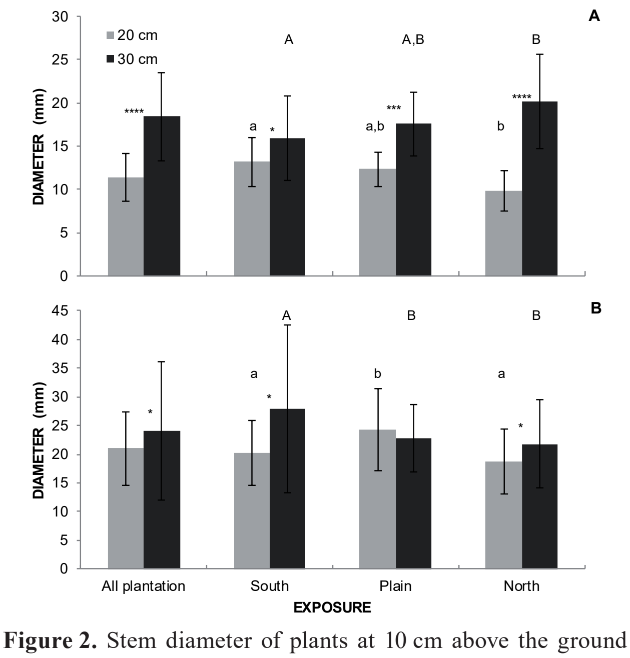

Figure 2. Stem diameter of plants at 10 cm above the ground (d10)

A is for the d10 at the end of growing season 2016; B is for the d10 at the end of growing season 2017. Whiskers denote standard deviations. Statistically significant differences between variants of different hole diameter are marked by stars (* $P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$). Small letters denote homogeneous groups between the variants of exposure for 20 cm hole diameter ($p = 0.95$). Capital letters denote homogeneous groups between the variants of exposure for 30 cm hole diameter ($p = 0.95$).

est mortality in the plants which had no protection on the South exposure (8.7%; Table 5) and the lowest on the Plain exposure (3.9%). Application of plant protection against frost damage results in a lower mortality, compared to the variant without protection. We did not observe any mortality when we used peat fill as protection. There was a mortality (caused by frost) of only 3% in the cases of the soil fill and the non-woven material on the South exposure. After the winter period we found that the above-ground part on all plants had been damaged by frost. Generally, the height of the live above-ground part of the stem (i.e., the part of the stem without frost damage) was the greatest with the non-woven material (27.3 cm ± 10.2 cm; Table 5) and the smallest with the soil fill (15.4 cm ± 6.9 cm). We observed similar trends for non-woven material (28.9 cm ± 11.9 cm; 23.8 cm ± 9.6 cm) and soil fill (11.7 cm ± 7.2 cm; 13.1 cm ± 6.7 cm) on the South and Plain exposures. The differences among the plants in the height of the live above-ground part of the stem were not statistically significant on the North exposure.

The effect of protection against frost damage after the 2017/2018 winter

The highest mortality of plants occurred when protected with Tubex (12.5%), whereas the mortality of plants protected using non-woven material was 8.3%, and the mortality of plants without protection was 9.1% (Table 5).

The height of the live above-ground part of the stem was the greatest when the non-woven material was used (26.8 cm ± 7.8 cm; Table 5). The height of the live above-ground part of the stem with Tubex was about 30% lower compared to that with the non-woven material and was the lowest of all.

Discussion

There are, unfortunately, very few scientific papers and works dealing with the cultivation of different clones of *Paulownia*, especially in the CR. We consider the presented results of this work as preliminary due to the small number of plants tested and plan to acquire more results in future.

Mortality of *Paulownia* plants and seedlings is caused by several factors such as unfavourable soil and weather conditions or inappropriate biotechnology of planting and cultivation (Colak 2003, Balcar et al. 2012, Barbeito et al. 2012). The soil conditions on our plantation were mostly the same across the whole area, which means that it is most probably the biotechnology of planting and/or the specific field microclimate conditions that have the greatest influence on plants.

The small size of the hole might be one of the inappropriate biotechnologies of planting. However, Zhao-Hua et al. (1986) state that a depth of 0.2 m is sufficient for planting; PaulowniaMoravia company recommends that the depth should be around 0.3 m (PaulowniaMoravia 2013) and Bio Tree company recommends that the depth should be around 0.4 m depending on the proportion of clay in the soil (Bio Tree 2017). The depth of the holes was 0.8 m for both biotechnologies of planting in the Střelice plantation. A depth of 0.8 m has been presumed to be sufficient because agricultural land is usually compact (caused by heavy machines) between the upper layer of soil (which is 0.2–0.3 m thick) and a depth of up to 0.7 m. Not only the depth but also the width of the hole seems to be crucial. Biotechnology of planting with the use of a 20 cm diameter proved to be less efficient than a 30 cm diameter, as the growth of *Paulownia* plants was lower and mortality higher, especially during the first year after planting. Mortality of plants inside the 30 cm holes was lower regardless of terrain exposure. PaulowniaMoravia (PaulowniaMora-

Table 5. Mortality of winter protection in 2016 and 2017 and height of live stem part after winter 2016/2017 by protection 2016 and after winter 2017/2018 by protection 2017

Year of winter protection	Exposure	Winter protection variant	Mortality [%]	SHG	Height of live stem part	SHG
2016	All plantation	Without protection	6.7	A	(19.5 ± 10.9)	A
		Non-woven material	1.1	B	(21.2 ± 0.5)	A
		Peat	0	B	(20.1 ± 5.3)	AB
		Soil	1.1	B	(15.4 ± 6.9)	B
	South	Without protection	8.7	A	(22.2 ± 13.0)	A
		Non-woven material	3.3	B	(24.9 ± 11.9)	A
		Peat	0	B	(20.0 ± 7.1)	AB
		Soil	3.2	B	(11.7 ± 7.2)	B
	Plain	Without protection	3.9	A	(21.0 ± 11.3)	A
		Non-woven material	0	B	(21.3 ± 9.6)	AB
		Peat	0	B	(19.5 ± 7.1)	AB
		Soil	0	B	(13.2 ± 5.6)	B
	North	Without protection	7.1	A	(17.2 ± 8.5)	A
		Non-woven material	0	B	(17.9 ± 10.0)	A
		Peat	0	B	(20.8 ± 1.0)	A
		Soil	0	B	(21.3 ± 3.9)	A
2017	Without protection		9.1	AB	12.2 (± 5.5)	A
	Non-woven material		8.3	A	26.8 (± 7.8)	B
	Tubex		12.5	B	8.6 (± 5.9)	C

* Capital letters denote statistically homogeneous groups (SHG) between variants of different frost protection ($p = 0.95$).

via 2013) recommends a hole diameter of at least 40 cm. Zhao-Hua et al. (1986) recommends a trapezoid shape of hole 60 cm wide at the top and 25 cm wide at the bottom across the entire length of the plantation. We can assume that a 30 cm hole does not provide optimum conditions for growth of the plants and a 20 cm one is insufficient.

A specific microclimate based on microsite and terrain exposure should have an effect on the growth of *Paulownia* plants. Our results indicate that the viability of samplings was affected negatively especially on the South and North exposures immediately after planting and during the entire time of the experiment. Sunlight, which affects the surface temperature of plants and soil, is probably the reason why the viability of the samplings decreases on South (Leonelli et al. 2009). Soil on the South exposure becomes more susceptible to drought and the temperature of the soil can reach higher values there than on the Plain terrain or the North exposure (Korpeľ 1991). In addition, slope inclination could be the cause of the increase in mortality as well. Since the runoff and the infiltrated water flow down the hillside, soil moisture could be higher at the bottom part of slope and it could more evenly distributed on the plain. Moreover, cold air moves downward and stagnates in lower parts and terrain depressions (Whiteman et al. 2001). For these reasons, plant mortality could be lower on flat terrain than on hillsides. Summarizing the terrain exposure effects, we expected better growth of *Paulownia* plants on Plain and on South in the studied plot. Plants should grow well on South, due to greater light and temperature enjoyment (Leonelli et al. 2009). In the studied plot, the South exposure advances the plant growth during the first growing season, but, later on, plants in Plain grew slightly better compared to those on the other exposures. Nevertheless, the influence of terrain exposure on plant height growth was negligible, the increase in the thickness of the stem was better on the North exposure. These results coincide with the results of Sander et al. (1995). They found different responses in thickness and height growth of plants on different exposures. However, our results coincide also with the results of Havira et al. (2016), as they describe that the exposure does not affect the height of plants, but the stem thickness, especially on the North exposure.

One of the most limiting factors for the successful cultivation of *Paulownia* in the CR is the amount of precipitation. Zhao-Hua et al. (1986) state that *Paulownia* needs an annual precipitation of 500 to 3 000 mm in its natural site. UCLM (2016) noted that 750 mm of annual precipitation is sufficient for the growth of *Paulownia* Clone in vitro 112®. TGG (2011) described that the amount of precipitation must reach at least 150 mm monthly for the successful growth of *Paulownia* plants in the first year and 50 mm in the following years of growth. Zhao-Hua et al. (1986) presents that if the annual precipitation is less than 500 mm, most of it must fall during the growing season. The annual precipitation was 524 mm in 2016 and 452 mm in 2017 according to the meteorological station Brno-Tuřany (Czech Hydrometeorological Institute (CHMI)). The monthly precipitation did not exceed 100 mm in any month during the growing season in 2016 and was higher than 50 mm only in June and September during the growing season of 2017. Comparing precipitation at the plantation locality (according to CHMI) and that is reported in the literature above, the deficiency of water is evident. Therefore, good growth and viability of the *Paulownia* plants could be possible only if water is added via an irrigation system.

Another limiting factor in the cultivation of *Paulownia* in Central Europe is frost. Cuomo (2014) describes that *Paulownia* Clone in vitro 112® can endure an air temperature of up to –25°C. According to CHMI, the lowest temperature at the plantation site was –8.8°C for the investigated period. Therefore, frost should not damage the plants. However, we detected mortality and frost damage of the above-ground part during each winter. According to Zhao-Hua et al. (1986), the mortality of plants should be higher after the first winter than in the following winter periods because plants do not lignify completely after planting.

In Střelice u Brna, mortality of plants was higher after the second winter than after the first due to lower air temperatures. All the variants of the root system protection against frost helped to protect the root system, compared to that of the control plants. Zhao-Hua et al. (1986) recommend that the samplings should be sunk into the soil to a depth of 5 cm during planting. We found a similar effect when we covered the soil or peat around the plant stem, the root neck and the root ball under the soil surface and it was then less damageable by frost. Zhao-Hua et al. (1986) describe damage of the above-ground part of *Paulownia fortunei* and *P. elongata* by frost as a common phenomenon. Zhao-Hua et al. (1986) estimate the age of a tree according to the number of times it was damaged.

However, *Paulownia* Clone in vitro 112® should be cultivated as a highly frost-resistant variety (Cuomo 2014, Icka et al. 2016). That is why there is no mention regarding winter protection for this clone. Under the climatic conditions of the CR, a shorter growing period compared to that in its area of origin (in Spain) may lead to frost damage to the above-ground part more easily, as the top part of the stem does not sufficiently lignify. Wrapping a stem with non-woven material seems to be the most suitable protection of all the tested variants, as the height of the live stem part was the highest. On the other hand, Tubex, as an impermeable material, gives rise to water vapour condensation on the stem, which then creates a microclimate that supports the formation and growth of fungal mycelium, which damages the above-ground part. As a result, the mortality of the plants with Tubex protection increased and the live above-ground part was lower after winter compared to that which used other winter protection variants.

Comparing the plantation in the CR with foreign plantations is difficult. Currently, there are only few works on *Paulownia* Clone in vitro 112® growth in the first years after planting. In addition, we did not find any works from

Central Europe about the growth of *Paulownia* Clone in vitro 112® in the first year after planting.

According to Icka et al. (2016), *Paulownia* trees can reach a stem diameter of about 5 cm at breast height and a tree height of about 4 m after the first year of planting in Albania. The UCLM report (UCLM 2013) declares that, on average, *Paulownia* Clone in vitro 112® trees reach a stem diameter at breast height of about 11,81 in, a total tree height of about 16 m and a stem volume of about 0.5 m^3 six years after planting in Spain. There, the annual tree height increment was about 2.66 m and the annual stem thickness increment about 5 cm. After the first year, the tree height was about 0.8 m (in 2016) and 1 m (in 2017) in the Střelice u Brna plantation. None of these total and increment values reached those presented in UCLM (2013); therefore, growth speed in the CR is only 25% of that in Spain (Icka et al. 2016). We could not compare the thickness, as *Paulownia* plants did not reach the height of 1.3 m (i.e. breast height) in the investigated plantation in Střelice u Brna. The reason why the *Paulownia* Clone in vitro 112® does not reach similar tree heights and stem diameters is probably less rainfall and a shorter growing season in the CR plantation, compared to those in Albania or Spain. The growth of our plants is slow – this fact is confirmed by Bio Tree (Bio Tree 2016), which states that *Paulownia* plants can survive with less precipitation after one year from planting, but the tree growth increment is low.

Conclusion

The results from the first two years after planting (from the *Paulownia* Clone *in vitro* 112® plantation in the CR) show that the proclaimed growth rate and expected yield of wood assortments (Oxytree 2016) are not realistic in the CR. The investigated *Paulownia* plants did not achieve the morphological parameters, which are common in a semi-arid climate. The Central European climate compared to a semi-arid one is specific in that there is a shorter growing season, more frequent frost and less precipitation.

For that reason, the speed of growth of *Paulownia* trees (during the first two years in the CR) had been about a quarter of that in a semi-arid climate. Our results suggest that the size of the hole for planting could be one of the limiting factors. The hole should be wider than 0.3 m and have a depth of at least 80 cm on agricultural land. The terrain exposure has a more evident impact on the mortality of the seedlings during the first year after planting, and not so much in the following years. The Plain exposure seems to be the most suitable exposition for planting. We recommend a sufficient water supply for the *Paulownia* plants, especially in the first two-to-three years after planting, as is recommended also by other authors. Artificial irrigation is required especially in southern Moravia of the CR.

Frost damage is another important factor influencing the cultivation of *Paulownia* in the CR. The presented preliminary results show that it is possible to reduce the amount of damage to the root system caused by frost and the mortality of plants by covering the root system and the stem base with peat or soil in the shape of a truncated cone. Frost damage to the above-ground stem part was not sufficiently eliminated. Non-woven material seems to be the most appropriate of the other tested variants of protection against damage to the stem by frost. Adaptation of cultivation practices is one of the possible ways of achieving similar growth parameters in the CR, as are those in the regions of origin of *Paulownia*. They can be for example:

- the planting of stronger and taller seedlings with a well-developed root system;
- an increase in the amount of available water by irrigation during the first two-to-three years after planting;
- the use of specific protection against frost damage such as non-woven materials, the painting of the stems with wax or white reflective paint, the application of boron before wintertime.

The results of this work are preliminary, more research has yet to be conducted.

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