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Evaluation of selected growth parameters of *Paulownia cotevisa* plantation in the Danubian Lowland

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Abstract: The main objective of this study was to assess the growth of the established *Paulownia cotevisa* plantation during an extended time period and compare it with values reviewed in the literature. Seven years after planting, mean diameter at breast height and height of the aboveground part of *P. cotevisa* 2® (*P. cotevisa*) plantation were similar to values reported in the literature and they reached 21.5 cm and 11.2 m, respectively. Besides the crown damage caused by wind, development of the *P. cotevisa* plantation established in the Danubian Lowland was not affected by any other harmful environmental factor or biological pest. The results suggest that *P. cotevisa* could be used to a larger extent in diversification of biomass production on abandoned arable lands of the Danubian Lowland.

Keywords: agroforestry systems, arable lands; biomass production; fast-growing tree species

In Slovakia, current climate change as well as ongoing extension of restrictions related to nature conservation make the production of main commercial tree species with cutting age exceeding 80 years more difficult (Kovalčík et al. 2012; Hlásny et al. 2021). Thus, the demand for a stable and safe source of wood biomass provokes interest of land managers also in the cultivation of plantations with markedly shortened production period (Dimitriou, Rutz 2015; Yavorov et al. 2015). In the lowlands of Slovakia, the attention was focused primarily on the native tree species including poplars and willows and utilization of the maximum production potential of these tree species through hybridisation (Bartko 2011; Kohán 2012). However, a distinctively more efficient mechanism of carbon integration during photosynthesis ensuring the ability to reach a diameter of 27.3–39.6 cm and a height of 9.9–13.2 m within the 10-year period (Wang, Shogren 1992) makes from non-native *Paulownia* sp. one of the most prominent objects of interest (Yavorov et al. 2015; Jankovič et al. 2016). Regarding its high adaptation ability to a wide range of climatic conditions as well as its still non-invasive character (Franz 2007; Buzan et al. 2018), *Paulownia* sp. is also considered suitable for the improvement of abandoned agricultural lands or for land rehabilitation, where the main intention is not focused on the biomass production (Yadav et al. 2013; Buzan et al. 2018).

Thus the establishment of a *Paulownia* plantation in the Danubian Lowland in 2015 offers a unique opportunity to study the production characteristics

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of this non-native tree species in the new environment. The main objective of this study was to assess the growth of the established *Paulownia cotevisa* 2® (*P. cotevisa*) plantation during an extended time period and compare it with values reviewed in the literature.

MATERIAL AND METHODS

The study site was situated in the SW of Slovakia, cadastral area of the Búč municipality (47.79°N, 18.45°E) located in the Danubian Lowland. The plantation was established in the spring 2015 on a flat site at an altitude of 108 m a.s.l. that had been cleared of natural vegetation and ploughed. The soil of the study site is classified as sandy loam Calcari-Haplic Chernozem (FAO 2015). Mean annual air temperature at the study site is 10.4 °C and mean monthly temperature for the warmest month (July) is 20.8 °C and for the coolest month (January) –1.1 °C. Annual precipitation averages 540 mm and is evenly distributed across the seasons (SHMI 2021b).

Air temperature and precipitation over seven consecutive years of plantation monitoring were recorded daily by a meteorological station of the Slovak Hydrometeorological Institute in Hurbanovo (SHMI 2021a) situated approximately 15 km NW of the study site at the similar altitude.

Two hundred one-year-old containerized seedlings of the hybrid *P. elongata* × *fortunei (P. cotevisa* 2®) (iPaulownia, Sueca, Spain) obtained from a private nursery were planted in rows at spacing of 4 × 4 m (625 seedlings·ha^{-1}). One year after planting, seedlings were cut to the ground in order to recruit one straight healthy stem from among the multiple sprouts that emerge from the stump at the start of the second growing season. Post-planting care included ploughing and disking of soil between the lines of trees twice a year (spring and autumn). No protection of the plantation from damage by game (fencing, individual protection) was installed.

The established plantation was evaluated after the fifth, sixth and seventh year from outplanting. Recorded data included diameter at breast height (*DBH*), tree height (*H*) and visual assessment of damage (biotic/abiotic factors). Collected data for *DBH* and *H* were sorted into diameter (interval: 2 cm) and height (interval: 2 m) classes, and histograms for *DBH* and *H* of the *Paulownia* plantation were constructed. *DBH* and *H* increments were calculated as a difference between the mean values of selected growth parameter for each consecutive year.

RESULTS AND DISCUSSION

In this study, the plantation of *P. cotevisa* established in the Danubian Lowland reached mean *DBH* 21.5 cm and mean *H* 11.2 m seven years after planting (Figure 1). Dimensions of the largest individuals exceed 28 cm for *DBH* and 12 m for *H*, the smallest individuals had *DBH* lower than 16 cm

Figure 1. *P. cotevisa* plantation after 5th, 6th and 7th year after planting in the locality of Búč, Danubian Lowland (Slovakia) (photo: Jankovič)

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and *H* not exceeding 10 m (Figures 1 and 2). In the fifth, sixth and seventh year, the annual average increment reached 3.4 cm for *DBH* and 2.3 m for *H*. The standard 10-year period used for the cultivation of *Paulownia* in the country of origin, China, enables trees to develop *H* 8–12 m and *DBH* 30–40 cm, with crown radius 3–5 m (Wang, Shogren 1992). In Europe, the ability of *Paulownia*

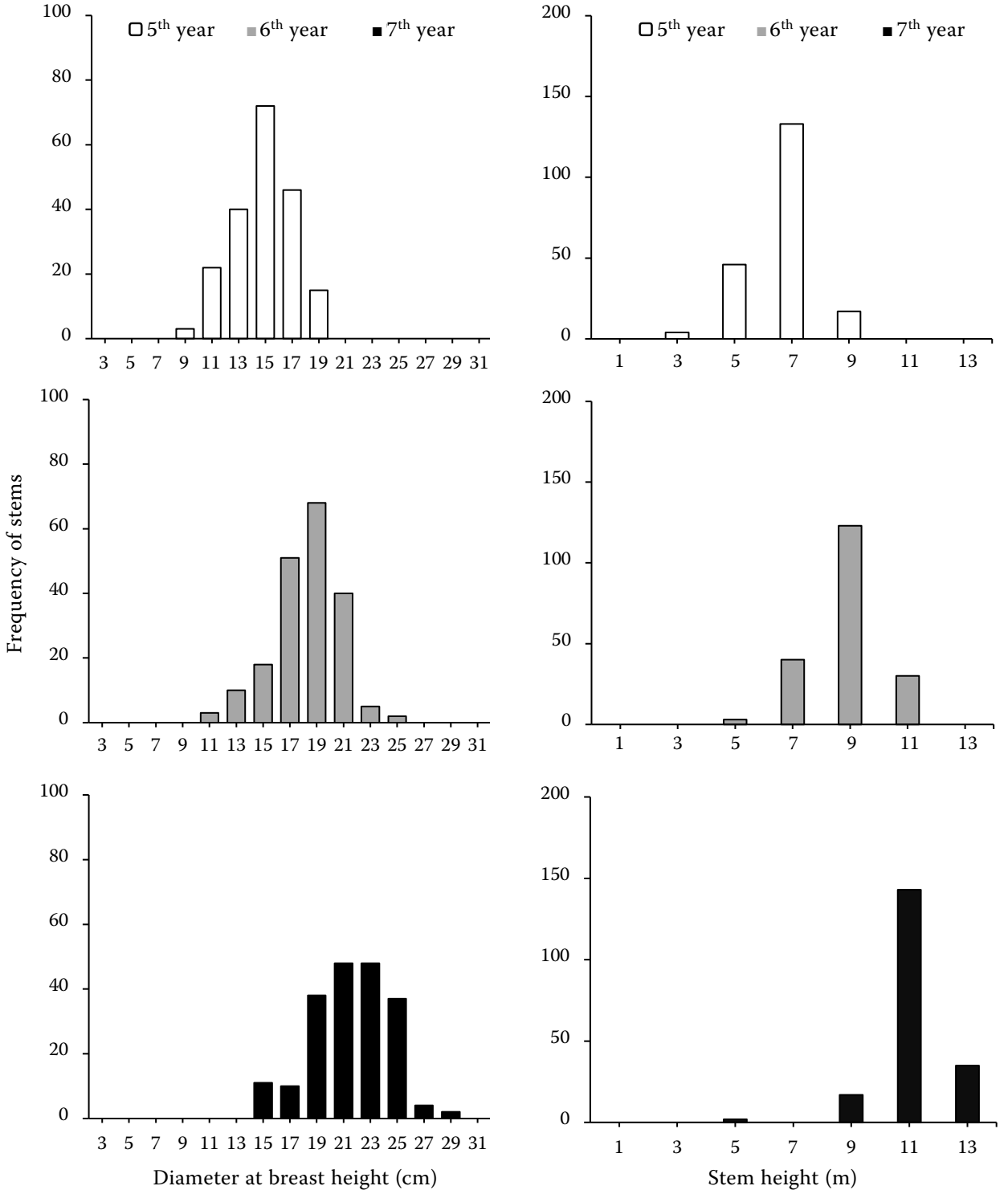

Figure 2. Diameter at breast height and stem height distribution of individuals of *P. cotevisa* after 5th, 6th and 7th year after planting in the locality of Búč, Danubian Lowland (Slovakia)

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to exhibit similar field performance has been observed in several studies, but only on sites located in southern parts of the continent (Table 1). In Romania, 30-years-old individuals reached *H* 15–16 m and *DBH* 40–58 cm (Buzan et al. 2018). Similarly, Ayrilmis and Kaymacki (2013) reported that samples of wood used in their study were from an 8-years-old solitaire of *P. elongata* with DBH 65 cm (Table 1). On the other hand, *Paulownia* plantations established in the USA on an abandoned agricultural field in Virginia (Johnson et al. 2003) or in the Southern Appalachians in North Carolina (Bergman 2003; Berg et al. 2020) as well as in Ireland (Olave et al. 2015) showed much worse results (Table 1). Johnson et al. (2003) and Berg et al. (2020) described serious problems with the preservation of established plantations, when the overall survival of *Paulownia* plantations did not exceed 30% seven years after planting. Weak performance of *Paulownia* plantations reviewed in Table 1 was attributed predominantly to unusual weather events (low freezing temperatures, drought and strong winds) or diseases during the early years of plantation development. According to Olave et al. (2015), especially freezing temperatures during exceptionally cold winters might be the most important factor limiting the successful growth of *Paulownia* sp. in northern latitudes. In this study, the lowest daily winter temperature of –13 °C was recorded in January 2017 two years after planting. Except of winter 2017/2018, winter temperatures (December–February) ranged only

Table 1. Growth of *Paulownia* sp. plantations under various conditions

Site location	Mean air temperature (°C)		Mean annual precipitation (mm)	Species	Age (years)	*DBH* (cm)	*H* (m)	Reference
	warmest month	coldest month						
China	–	–	–	*Paulownia* sp.	10	30.0–40.0	8.0–12.0	Wang and Shogren (1992)
Romania	0.0	25.0	623	*Paulownia* sp.	4	7.7	6.2	Buzan et al. (2018)
					30	40.0–58.0	15.0–16.0	
Ireland	6.8	16.9	715	*P. elongata*	3	NA	1.5	Olave et al. (2015)
				P. fortunei			1.5	
				P. elongata × *fortunei*			1.0	
				P. elongata × *fortunei* × *tomentosa*			0.4	
New Zealand	13.8	22.6	625	*P. tomentosa*	5	30.7–34.0	11.3–11.5	Barton et al. (2007)
Turkey	2.9	27.2	510	*P. elongata*	2	30.0	6.0–7.0	Ates et al. (2008)
Turkey	1.7	30.9	693	*P. elongata*	8	65.0	NA	Ayrilmis and Kaymacki (2013)
USA (North Carolina)	2.3	22.5	1 214	*P. tomentosa*	9	2.5–28.7	10.4–12.0	Berg et al. (2020)
				P. elongata		3.0–28.7	2.1–14.0	
				P. fortunei		1.0–34.0	2.0–14.5	
USA (Virginia)	–4.3	16.1	787	*P. tomentosa*	7	7.8–9.1	3.8–4.0	Johnson et al. (2003)
Italy (Sardinia)	14.3	30.8	428	*P. tomentosa*	2	4.4	4.3	Puxeddu et al. (2012)
Albania	4.0	29.0	723	*P. tomentosa*	13	38.0–40.0	10.0	Icka et al. (2016)
				P. tomentosa	1	5.2	4.3	

DBH – diameter at breast height; *H* – height; NA – not assessed

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from –8 °C to +8 °C during plantation monitoring, without any negative effect on the *Paulownia* plantation development (Figure 3).

Observations of Berg et al. (2020) suggested that strong winds might also be another factor affecting the development of *Paulownia* plantation. Barton et al. (2007) observed that the breakage of young stems and branches of *Paulownia* trees occurred when the wind speed exceeded 40 km·h^{-1}. Higher susceptibility of *Paulownia* to damage caused by wind was observed partially also in our study. Five years after planting almost 25% of planted individuals of *Paulownia* showed signs of crown damage (broken branches or central stem). However, the observed level of damage had no marked effect on further development of assessed *Paulownia* individuals. Besides the registered crown damage caused by wind, the individuals of *P. cotevisa* in this study were not affected by any other negative environmental factor (high temperatures, water shortage) or biological pest (insect, rodents, ungulates etc.).

In lowlands of Slovakia, Kohán (2012) reported that the most commonly used fast-growing hybrids of poplars can reach *H* 20 m and *DBH* ranging from 19 cm to 26 cm already after a 10-year period.

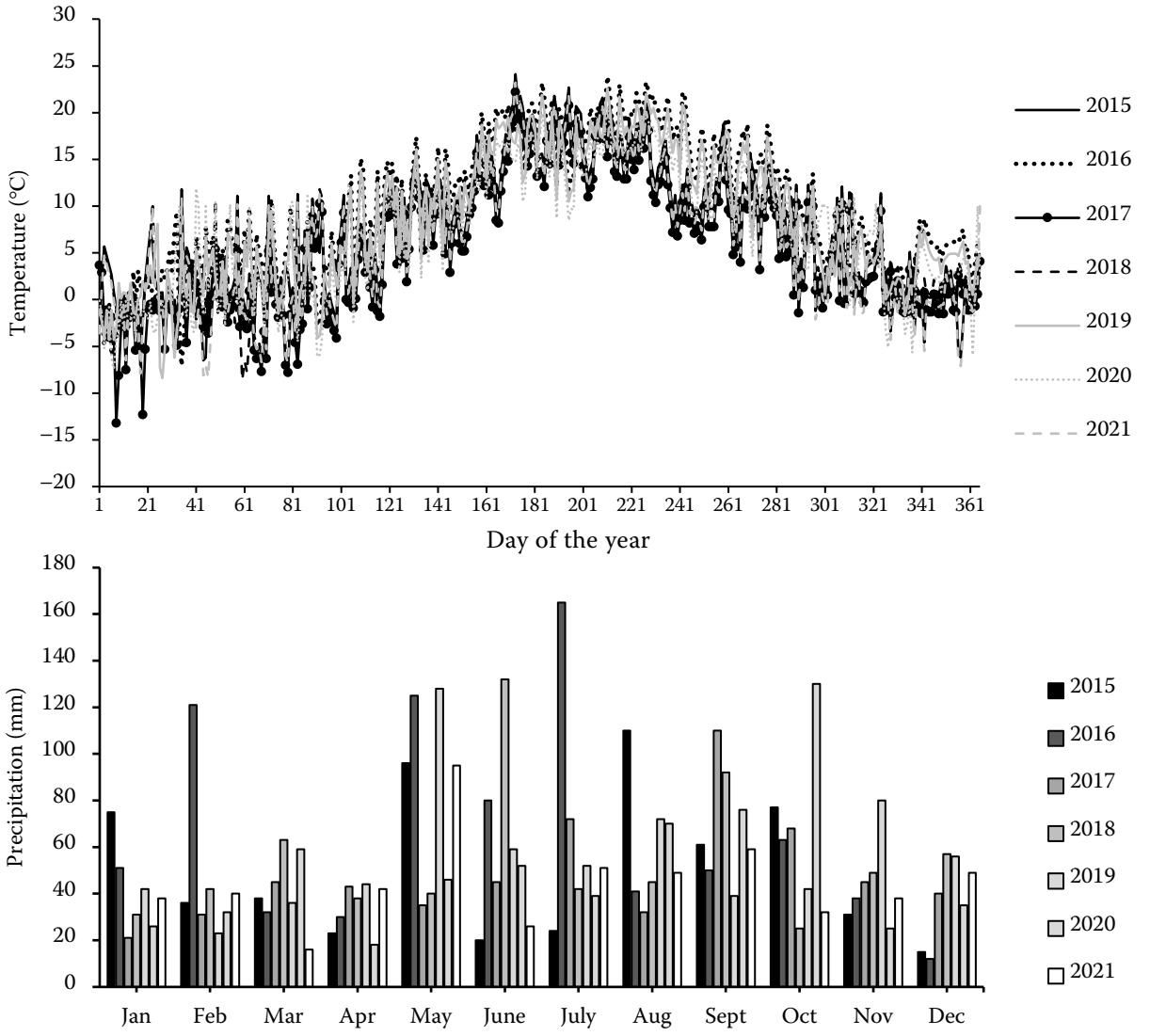

Figure 3. Minimal daily air temperature and monthly precipitation totals over seven consecutive years of *P. cotevisa* plantation development recorded by meteorological station of Slovak hydrometeorological institute in Hurbanovo (SHMI 2021a) situated 15 km NW of the study site

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The ability of the assessed *P. cotevisa* individuals to reach approximately similar values of evaluated growth characteristics in this study indicates that this tree species could contribute to the expansion of the wood biomass resource base, without any considerable production losses.

CONCLUSION

The preliminary results of this study suggest that the hybrid *P. cotevisa* 2® could be used for the purpose of wood production in conditions of the Danubian Lowland. Seven years after planting, mean *DBH* and *H* of the assessed *P. cotevisa* plantation reached 21.5 cm and 11.2 m, respectively. Besides the crown damage caused by wind, development of the evaluated plantation established in the Danubian Lowland was not affected by any other harmful environmental factor or biological pest. However, the results presented in this study are restricted only to the examined material and described conditions of the selected site and further research including comparison of different environmental scenarios or experimental treatments is needed.

REFERENCES

Ates S., Ni Y., Akgul M., Tozluoglu A. (2008): Characterization and evaluation of *Paulownia elongota* as a raw material for paper production. African Journal of Biotechnology, 7: 4153–4158.

Ayrilmis N., Kaymacki A. (2013): Fast growing biomass as reinforcing filler in thermoplastic composites: *Paulownia elongata* wood. Industrial Crops and Products, 43: 457–464.

Bartko M. (2011): Recent results of poplar testing and regionalization of poplar clone in Slovakia. Lesnícky Časopis – Forestry Journal, 57: 261–268. (in Slovak)

Barton I.L., Nicholas I.D., Ecroyd C.E. (2007): *Paulownia*. Forest Research Bulletin No. 231. Rotorua, New Zealand Forest Research Institute Limited: 76.

Berg E.C., Zarnoch S.J., McNab W.H. (2020): Survivorship, attained diameter, height and volume of three *Paulownia* species after 9 years in the southern Appalachians, USA. Journal of Forestry Research, 31: 2181–2191.

Bergmann B.A. (2003): Five years of *Paulownia* field trials in North Carolina. New Forests, 25: 185–199.

Buzan L.R., Maxim A., Odagiu A., Balint C., Hartagan R.M. (2018): *Paulownia* sp. used as an energetic plant, for the phytoremediation of soils and in agroforestry systems. ProEnvironment, 11: 76–85.

Dimitriou I., Rutz D. (2015): Sustainable Short Rotation Coppice: A Handbook. Munich, Germany WIP Renewable Energies: 102.

Franz E. (2007): From ornamental to detrimental? The incipient invasion of Central Europe by *Paulownia tomentosa*. Preslia, 79: 377–389.

FAO (2015): World reference base for soil resources, international soil classification system for naming soils and creating legends for soil maps. Available at: https://www.fao.org/3/i3794en/I3794en.pdf (Accessed Dec 20, 2021).

Hlásny T., Zimová S., Merganičová K., Štěpánek P., Modlinger R., Turčáni M. (2021): Devastating outbreak of bark beetles in the Czech Republic: Drivers, impacts, and management implications. Forest Ecology and Management, 490: 119075.

Icka P., Damo R., Icka E. (2016): *Paulownia tomentosa*, a fast growing timber. The Annals of "Valahia" University of Targoviste – Agriculture, 10: 14–19.

Jankovič J., Maľová M., Longaureová V., Sujová K. (2016): Potenciál a riziká pestovania klonov Paulovnie na Slovensku. In: Štefančík I., Bednárová D. (eds): Aktuálne problémy v zakladaní a pestovaní lesa, Sliač, Oct 19–20, 2016: 96–108. (in Slovak)

Johnson J.E., Mitchem D.O., Kreh R.E. (2003): Establishing royal *Paulownia* on the Virginia Piedmont. New Forests, 25: 11–23.

Kohán Š. (2012): Assessment of the research on growing poplars in row planting on non-forest land in the Eastern Slovak Lowland. Lesnícky Časopis – Forestry Journal, 58: 159–16. (in Slovak)

Kovalčík M., Sarvašová Z., Schwarz M., Moravčík M., Oravec M., Lásková J., Tutka J. (2012): Financial and socio-economic impacts of nature conservation on forestry in Slovakia. Journal of Forest Science, 58: 425–435.

Olave R., Forbes G., Muñoz F., Lyons G. (2015): Survival, early growth and chemical characteristics of *Paulownia* trees for potential biomass production in a cool temperate climate. Irish Forestry, 72: 42–57.

Puxeddu M., Marras G., Murino G. (2012): *Paulownia* tree planting in Sardinia (Italy) and its evaluation for agroforestry systems and sustainable land use. Journal of Environmental Science and Engineering B, 1: 1192–1195.

SHMI (2021a): Climatological services. http://shmu.sk/en/?page=1&id=klimat_operativneudaje_1&identif=11858&rok2021&obdobie=1981-2010&sub=1/ (accessed Dec 20, 2021).

SHMI (2021b): Klimaatlas. http://klimat.shmu.sk/kas/ (in Slovak; accessed Dec 20, 2021).

Wang Q., Shogren J.F. (1992): Characteristics of the crop-*Paulownia* system in China. Agriculture, Ecosystems and Environment, 39: 145–152.

https://doi.org/10.17221/155/2021-JFS

Yadav N.K., Vaidya B.N., Henderson K., Lee J.F., Stewart W.M., Dhekney S.A., Joshee N. (2013): A review of *Paulownia* biotechnology: A short rotation, fast growing multipurpose bioenergy tree. American Journal of Plant Sciences, 4: 2070–2082.

Yavorov N., Petrin S., Valchev I., Nenkova S. (2015): Potential of fast growing poplar, willow and *Paulownia* for bioenergy production. Bulgarian Chemical Communications, 47: 5–9.

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