

*Mirjana OCOKOLJIĆ, Dragica VILOTIĆ,
Mirjana ŠIJAČIĆ-NIKOLIĆ, Đurđa STOJIČIĆ and Mirjana MILENKOVIĆ¹*

**PAULOWNIA PLANTATION ESTABLISHMENT IN
MEDITERRANEAN AND SUBMEDITERRANEAN REGIONS OF
MONTENEGRO WITH THE GOAL OF SUSTAINABLE
ECONOMIC DEVELOPMENT**

ABSTRACT

In the development of a sustainable economy in rural areas, the most important species are those with higher productivity and resistance to phytological and entomological pathogens and air pollution, and also with adaptability to major climate changes. *Paulownia* is one of the Asian species that satisfies the above criteria and that has been very successful worldwide for over two centuries. Plant cultivation outside the natural range depends on the ecological valence within which species survival is possible. *Paulownia* is characterised by wide ecological amplitude. It is also characterised by good vitality and fast growth in different soil types, even in very poor and acidic soils. It grows on degraded terrains and can be used for the reclamation of soil loaded with heavy metals. Its limiting factors are low temperatures and lack of light and moisture. The latest studies show that *Paulownia* is a halophyte which makes possible its irrigation with saline water. Also, *Paulownia* has excellent commercial and bio-reclamation significance because it can reach the height of 4 m in one year, has soft wood of good technical quality, and its flowers are fragrant and rich in essential oils (because of this it is used in traditional Chinese medicine and apiculture). Based on the comparative and SWAT analyses of site conditions in the Mediterranean and sub-Mediterranean regions of Montenegro, and based on *Paulownia*'s ecological requirements, suitable zones for the establishment of short rotation mixed forests and agricultural plantations and pure *Paulownia* plantations were selected. Depending on the region and standards for the utilisation of natural resources, this paper presents the methods and rules of *Paulownia* plantation establishment, as well as agricultural crops for mixed plantations, aiming at the achievement of the maximal yield of biomass and safe food.

Keywords: *Paulownia tomentosa* Thunb. Steud., sustainable development, biomass, irrigation

¹ Mirjana Ocokoljić, (corresponding author: mirjana.ocokoljic@sfb.bg.ac.rs), Dragica Vilotić, Mirjana Šijačić-Nikolić, Đurđa Stojičić, Faculty of Forestry, University of Belgrade, Kneza Višeslava, 11030 Belgrade, Serbia; Mirjana Milenković, Republic Hydrometeorological Service of Serbia, Kneza Višeslava 66, 11030 Belgrade, Serbia

INTRODUCTION

For the development of a sustainable economy in rural areas it is very important and appropriate that adaptive species are chosen for the establishment of plantations for biomass production, raw materials for veneer or pulp, as well as for agro forestry and the improvement of environmental quality. *Paulownia tomentosa* Thunb. Steud., the princess or imperial tree, is one of the Asian species that meet these criteria and has been very successfully grown around the world over the past two centuries (Ocokoljić, 2011), following introduction from East Asian countries into Europe (1830) and North America (1840). It belongs to the order Scrophulariales and family Scrophulariaceae Juss. (Ocokoljić, 2006).

This deciduous tree that can reach a height of 25 meters with a 1 metre trunk diameter has a short life span, and it is rare if it lives longer than 70 years (Badun, 1983). Since the first introduction in suitable habitats it has had a large expansion, in the U.S. it spreads spontaneously in the western, north eastern and southern regions (Bonner and Burton, 1974; Langdon and Johnson, 1994). In the eastern countries of Asia the biomass yield for the year is 36 to 53 m³ per hectare, and as a fast growing species for commercial purposes it is planted to obtain large amounts of biomass in a short time interval (Fang and Huang, 1979), and to obtain a good technical quality of wood. Tang et al. (1980) state that *Paulownia* in adulthood achieved a height of 9 to 21 m, and at the age of 11 years the plantations in Russia have reached a height of 13 m (Immel et al., 1980).

The ecosystems of the Balkan region have been seriously disrupted through increased soil erosion, reduced soil moisture capacity, a decrease in humidity, an increase in air temperature and a precipitation regime change. Given this information, and the fact that the expansion of urbanization in the Balkans and the consumption of timber has resulted in the reduction of natural forest ecosystems, this paper cites the regions, methods and rules of *Paulownia* plantations and agricultural crops for mixed plantations in order to develop a sustainable economy (achieving a maximal yield of biomass and food safety).

MATERIALS AND METHODS

During this research the methods of comparative and SWOT analyses, the synthesis of habitat conditions in the Mediterranean and sub-Mediterranean regions of Montenegro and an evaluation of the environmental requirements of *Paulownia* were used.

The method of SWOT analysis was used to evaluate the infection categories: S (Strength)- benefits (factors that help the internal origin), W (Weakness)- weaknesses (factors that damage the internal origin), O (Opportunity)- opportunities (factors that help external origin) and T (Threat)-risks (factors that damage the internal origin). The analysis of weakness and positive elements, in order to determine suitable sites for the establishment of plantations with *Paulownia tomentosa* Thunb. Steud., in the Mediterranean and sub-Mediterranean regions has an E of Montenegro. Quantification estimates the

significance of these categories and is defined as follows: + + + highly significant, + + medium significance, + a bit significant and 0 no significance.

From an environmental perspective the requirements of *Paulownia* are the abilities to adapt to a devastated habitat after fire or insect attack after defoliation, as well as its ability to grow in different soil types, even very poor and acidic soils. The limiting factors for the planting of *Paulownia* are low temperature and lighting conditions (as a pioneer species, *Paulownia* is expressly heliofit). Young trees freeze to the ground at low temperatures, however older trees can withstand low temperatures down to -20°C (Stojičić et al., 2010). *Paulownia* thrives in practically any soil, although the growth rate depends on the type of soil, climate, care and other factors. In addition to freezing temperatures, unsuitable strong winds are also a factor because this species has large leaves that can act like sails in the wind. A final disadvantage is high standing groundwater, which must be at least 1.5 m below the ground surface (Vukovojac and Vilotić, 2007).

Since the possibility of growing *Paulownia* is primarily limited by climatic factors, only the optimal ones are shown in the work and analysed in detail. In Montenegro there are many climate types with several subtypes and varieties that are a condition of its geographical position, articulation of relief, substrate character and confrontation of air masses with different physical properties. According to Burić et al. (2007), the climate districts selected were: Mediterranean and sub-Mediterranean, temperate-continental variations and mountain climates.

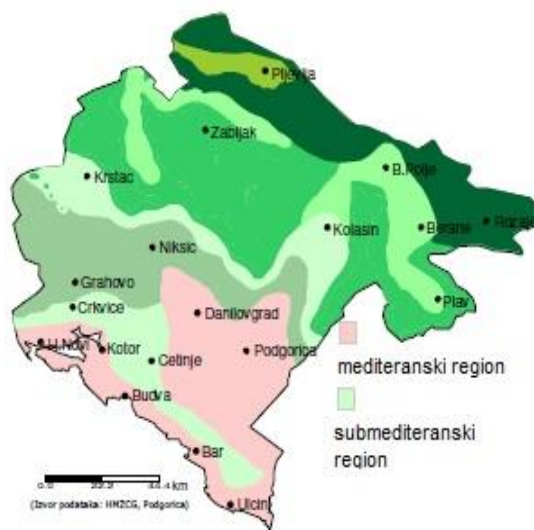


Figure 1: Detailed climatic zoning of Montenegro for Köppen (based on reference to climatic periods from 1961 to 1990) (Burić et al. 2007)

A more detailed separation into districts, based on the Köppen climate standard period of thirty years (reference interval: 1961-1990 Data HMZCG 2006-2008), shows regions in which *Paulownia* can be grown (Fig. 1): (1)

Mediterranean climate which is hot (mean monthly temperature of the warmest month $> 22\text{ }^{\circ}\text{C}$), bright and dry (total rainfall in the most humid months is greater than the sum of rainfall most dry months) and (2) Mediterranean climate with dry (primary maximum rainfall is in autumn and secondarily in the spring), warm summers (monthly temperature of the warmest month $< 22\text{ }^{\circ}\text{C}$ and the monthly temperature of the coldest month $> 10\text{ }^{\circ}\text{C}$).

In the Mediterranean regions (etesian) the average climate temperature in the coldest month is between $-3\text{ }^{\circ}\text{C}$ and $18\text{ }^{\circ}\text{C}$, and the air temperature in the warmest month is greater than $22\text{ }^{\circ}\text{C}$ (HMZCG 2006-2008). This region is characterized by bright, dry and clear summers and mild and rainy winters. The maximum rainfall occurs in November, and the lowest in July. It has a coast and Zeta-Bjelopavlic plains, but *Paulownia* plantations can be watered with salt water.

During the fall and winter, dry and cold wind blows from the land (wind storm), while in autumn, winter and spring a south wind blows from the sea bringing warm air from northern Africa and large amounts of rainfall (HMZCG 2006-2008).

The thermal regime of the Podgorica-Skadar valleys and Bjelopavlić plains differs from the actual Mediterranean climate. Because of the greater degree of continentality, summers are a bit warmer and winters slightly cooler than on the Montenegrin coast. This special variant of the Mediterranean climate (Podgorica, Danilovgrad) stands out as a sub-Mediterranean climate (Burić et al., 2007). If the Mediterranean impact assessment is based on the space where olives can be grown, certainly it can be separated into Adriatic-Mediterranean and sub-Mediterranean regions, as the areas under the typical Mediterranean climate and the regions with the transitional variant etesian climate belong to the Mediterranean climate in a broader sense. These are the transitions between the Mediterranean and moderately warm and humid climates. Here there is one very distinct maximum and minimum rainfall (HMZCG 2006-2008). Monthly rainfall reduces from November (primary maximum) to the beginning of spring, when the secondary maximum occurs (in March or April) (Cetinje, Crkvice, Krstac and Kolašin, HMZCG 2006-2008).

RESULTS AND DISCUSSION

The demand for wood as a raw material has been growing from year to year, therefore the important species that are characterized by rapid growth, short rotation and different uses are valuable. Studies worldwide have shown that such a type is *Paulownia tomentosa* Thunb. Steud., which has been cultivated in China since nearly 3000 years ago (Hu, 1959).

Comparative analysis shows that *Paulownia* can be successfully grown in more than one region of Montenegro (Tab. 1). Suitable sites for planting are at elevations of 2 m (Budva) to 1000 m (Žabljak = 1450 m), with average annual temperatures of $15.8\text{ }^{\circ}\text{C}$ to $4.6\text{ }^{\circ}\text{C}$ and annual rainfalls of 802 (Pljevlja) to 4623 mm (Crkvice). In these conditions, *Paulownia* has a yearly diameter increment of

3.0 to 4.0 cm and growth height of 2.5 to 3.0 m (Ocokoljić, 2006; 2011). The crown is wide but light so the floor beneath it can foster broad leaf species. Because of its rapid growth, in a short time period it can provide a favourable environment for the growth of other species (Wang and Shogren, 1992).

Table 1: Strengths and weaknesses for the establishment planting of the species *Paulownia tomentosa* Thunb. Steud. in the regions of Montenegro

S - (Strength): advantages	W - (Weakness): weaknesses
Revitalization of the Habitat ++	Urbanization +++
New measures to protect ecosystems, restoration and revitalisation ++	Increased consumption of timber ++
Conservation of landscape features +	Disturbance of ecosystems ++
Ensuring sustainable use of natural resources ++	Limited resources +
Simply planting with minimal investment +++	Sensitivity of species to low temperature
Price of 1 m ³ <i>Paulownia</i> wood, depending on the quality, \$250 to \$2000 ++	Sensitivity of species to strong winds +
Possibility of salt water irrigation +++	Shaded sites are unsuitable 0
Plantation can be exploited repeatedly +++	The presence of invasive grasses (e.g. fescue in the genus) +
Sustainable, renewable source of timber +++	Herbicides can be used for 6-8 weeks before founding plantation 0
O - (Opportunities): opportunities	T - (Threats): risks
Sustainable harvesting of bee pasture –control of beekeepers, conclusion of annual contract grazing for number of hives. Branding eco products ++	Intense global deforestation +++
Technical and professional support for scientific research projects +	Increasing demand for wood mass in the world market +
Adaptation of the permitted uses of natural resources with the need for protecting and preserving natural resources and developing the principles of sustainable development ++	Global climate change ++
Environmentally sustainable source of timber ++	
Row planting (the use of agro-forestry) ++	
Sustainability of small rural communities ++	
Reducing the effects of global climate change +	
Reduction in global deforestation +	

Paulownia is a kind of rapid growth tree so in plantations the necessary spacing between plants is 1.2 x 1.2 m or 1.8 x 1.8 m in order to achieve the maximum yield of biomass at the age of 15 years. Spacing between plants is conditioned by the need for inter-row seeding (Wang and Shogren, 1992) of wheat, corn, vegetables (potatoes, onions) and other crops (tea, tobacco, cotton, watermelon). Row sowing or planting is recommended, especially for regions with small areas that are typical for Montenegro. In China's case this is the way the yield of wheat was raised by 20%. However, in individual and small agricultural holdings using the interregional system of planting, one may achieve significant revenues from wood material and in the yield of inter-row cultures. During hot sunny days the *Paulownia* crown protects against fumes and the well-developed root system absorbs moisture from deeper soil horizons (Hartmann et al., 1990).

In addition, *Paulownia* wood can be used for furniture, joinery, panelling, framing and musical instruments, however it is not recommended for structural elements. The tree produces small amounts of secondary metabolites (tannins, etc.) and is used to obtain pulp for the paper industry because this shortens the process and reduces the amount of chemicals needed for bleaching, which is of particular importance for environmental protection. The wood has good insulating properties and is resistant to decay. Low thermal and electrical conductivity makes it suitable for isolation. Its good sound propagation is the reason for the use of *Paulownia* wood in making musical instruments (Ocokoljić, 2011). The wood of older trees is used for underwater equipment, equipment for boats, barrels, hives for bees, and modelling because it is hard for moisture to penetrate the wood structure. Also, *Paulownia* wood is used for composting, and leaves that are rich in nitrogen are used for animal nutrition (Hu, 1961).

Based on the comparative analysis of the strengths and weaknesses of *Paulownia* plantations in the Mediterranean and sub-Mediterranean regions of Montenegro, what stands out are the effects on global climate change and deforestation, habitat rehabilitation and reconstruction, while preserving the landscape features and securing the sustainable use of natural resources. *Paulownia* plantations are environmentally friendly and a sustainable source of timber that can be exploited repeatedly with minimal investment and large economic gains because the price for 1 m³ of *Paulownia* wood, depending on the quality, ranges from \$250 to \$2000. In addition, *Paulownia* can help to develop a sustainable economy and contribute to the sustainable use of bee pasture (branding of ecological products) and row planting (in the application of agro-forestry). The harmonization of natural resource usage, with the need for protecting and preserving natural resources, calls for the application of the principles of sustainable development using the technical and professional support of scientific research projects.

CONCLUSION

Paulownia is, for all of the reasons specified, a unique species of tree that is adapted to regional and global trends. In times of high demand for wood mass and decreasing forest area it provides a low cost, environmentally friendly and sustainable source of timber. Thanks to rapid growth it is possible to initiate planting projects of large or small scale, and their proper management can alleviate many of the environmental and economic difficulties that developing countries are facing in the 21st century, with respect to:

- Plantation after the first few years of establishment requires minimal maintenance
- The high technical quality of wood (in the rank of black walnut tree)
- After the first "harvest" no need for new investments (*Paulownia* has a good regenerative ability)
- Possibility of inter-row planting improves micro-climatic conditions, soil quality and provides multiple yields from the same area
- *Paulownia* is a tree with no deformities and strong resistance to decay

With the methods of SWOT and comparative synthesis of the terms and conditions of the habitats in the Mediterranean and sub-Mediterranean regions of Montenegro, and the environmental requirements of *Paulownia*, regions suitable for *Paulownia* plantations are isolated: Montenegrin coast (which is characterized by pronounced Mediterranean climate characteristics) and Zeta-valley (belonging to sub-Mediterranean climate zone), or regions of the Adriatic-Mediterranean and sub-Mediterranean climate (Map 1). Plantations can be established in other areas of the Mediterranean regime, to about 1000 m above sea level, going to the north and northeast (in the zone where the Mediterranean climate transitions to moderate variations in the hot and humid climate). A typical region is the Pljevaljska valley. In the higher mountains of continental Montenegro, mostly above 1000 m altitude, the climate is harsher without conditions for the establishment of plantations. One inconvenient factor for planting is strong winds, but since *Paulownia* is a deciduous species, and strong winds in Montenegro are expressed in winter, this effect can be ignored.

Therefore, *Paulownia*, as one of the fastest growing trees in the world, is suggested in these regions of Montenegro for the establishment of plantations with short rotation, as well for the renewal of habitats devastated by fire.

ACKNOWLEDGEMENTS

This paper was realized as a part of the project Establishment of Wood Plantations Intended for Afforestation of Serbia (31041) financed by the Ministry of Education and Science of the Republic of Serbia within the framework Technological development for the period 2011-2014.

REFERENCES

- Burić, D., Ivanović, M. & Mitrović, L. (2007): Climate of Podgorica, the Hydro meteorological Institute of Montenegro, Podgorica.
- Badun, S. (1983): Paulownia, Forest Encyclopedia 2, Zagreb, 607 pp.
- Vukovojac, S. & Vilotić, D. (2007): Project introduction and exploitation of paulownia in Yugoslavia (revised edition). Belgrade, 1-14.
- Hydro-meteorological Institute of Montenegro (2006): Climatologically report, Podgorica, 1-34.
- Hydro-meteorological Institute of Montenegro (2007): Temperature and precipitation, Podgorica, 1-4.
- Hydro-meteorological Institute of Montenegro (2008): Preliminary climatologically analysis, Podgorica, 1-3.
- Tang, RC, Carpenter, SB, Wittwer, RF & Graves, DH (1980): Paulownia-a crop tree for wood products and reclamation of surface-mined land. Southern Journal of Applied Forestry 4(1):19-24.
- Bonner, FT & Burton, JD (1974): Paulownia tomentosa (Thunb.) Sieb. & Zucc. Royal paulownia. In Seeds of woody plants in the United States. U.S. Department of Agriculture, Agriculture Handbook 450th Washington, DC. 572-573.
- Fang, JK & Huang, WC (1979): Experiment on the propagation of Taiwan Paulownia by root cutting. Quarterly Journal of Chinese forestry vol. 12 (1): 47-63
- Hartmann, T., Kester, E. & Davies, T. (1990): Plant Propagation: Principles and Practices 5th ed. Prentice-Hall, Inc., 647 pp.
- Hu, Shiu-Ying, (1961): The economic botany of the paulownias. Economic Botany 15: 11-27.
- Hu, Shiu-Ying, (1959): A monograph of the genus Paulownia. Quarterly Journal of the Taiwan Museum 7 (1 & 2): 1-54.
- Immel, MJ, Tackety, EM & Carpenter, SB (1980): Paulownia seedlings respond to increased daylength. Tree Planters'Notes 31 (1): 3-5.
- Langdon, KR & Johnson, KD (1994): Additional notes on invasiveness of Paulownia tomentosa in natural areas. Natural Areas Journal 14 (2): 139-140.
- Wang, QB & Shogren, JF (1992): Characteristics of the crop - paulownia system in China. Amsterdam: Elsevier; Agriculture, ecosystems and environment vol. 39 (3/4): 145-152.
- Stojičić, Đ., Ocokoljić, M. & Obratov-Petković, D. (2010): adaptability Paulownia tomentosa (Thumb.) Sieb. et Zucc. green space in Belgrade. Original Scientific Paper No. one hundred and first YUISSN 0353-4537. UDK 630 * 16 +630 * 17 hsilbuP ,S151100FSG/8922.01 IOD .12,619,285 : 7er of Forestry, Belgrade, 151-162.
- Ocokoljić, M. (2006): The oldest tree on the green areas of Belgrade as a starting material in the production of seedlings of ornamental trees. Ph.D., 248 pp.
- Ocokoljić, M. (2011): Influence of age on reproductive function Magnolyophita. Monograph ISBN 978-86-7244-943-3. COBISS: SR-ID 183,715,084th Library: Special edition, Foundation Andrejević, 100 pp.

Mirjana OČOKOLJIĆ, Dragica VILOTIĆ, Mirjana ŠIJAČIĆ-NIKOLIĆ, Đurđa STOJIČIĆ, and Mirjana MILENKOVIĆ

ZASNIVANJE PLANTAŽA PAULOVNIJE U MEDITERANSKOM I SUBMEDITERANSKOM DIJELU CRNE GORE U CILJU EKONOMSKI ODRŽIVOG RAZVOJA

SAŽETAK

U razvoju održive privrede i ruralnih područja su vrlo bitne vrste sa povećanom produktivnošću, otpornošću na fito i entomopatogene, aerozagadjenja kao i sa adaptivnošću na sve evidentnije klimatske promene. Paulovnja je jedna od azijskih vrsta koja zadovoljava navedene kriterijume i vrlo uspešno se već dva veka gaji u celom svetu.

Gajenje biljaka izvan prirodnog areala zavisi od ekološke valence u čijim granicama je moguć opstanak vrste. Paulovnja se odlikuje širokom ekološkom amplitudom. Dobre je vitalnosti i brzog porasta na različitim tipovima zemljišta, čak i na vrlo siromašnim i kiselim. Raste i na degradiranim terenima a koristi se i za remedijaciju zemljišta koja su opterećena teškim metalima. Ograničavajući faktori za njenu primenu su niske temperature, nedostatak svetlosti i vlage. Najnovija istraživanja su potvrdila da je paulovnja halofit što omogućava da se navodnjavanje njenih plantaža može vršiti slanom vodom. Paulovnja ima izuzetan komercijalni i biomeliorativni značaj jer za godinu dana može da ostvari visinu od 4 m, drvo joj je meko i dobrog tehničkog kvaliteta, a cvetovi su mirisni i bogati esencijalnim uljima zbog čega se koristi u tradicionalnoj kineskoj medicini i pčelarstvu.

Komparativnom i SWOT analizom uslova staništa mediteranskog i submediteranskog regiona Crne Gore i ekoloških zahteva paulovnije, izdvojeni su regioni pogodni za osnivanje mešovitih šumskih i poljoprivrednih zasada kratke ophodnje, ali i čistih kultura paulovnije.

U radu se, u zavisnosti od regiona i standarda za korišćenje prirodnih resursa, navode i metode i pravila plantažiranja paulovnije kao i poljoprivredne kulture za mešovite zasade u cilju dobijanja maksimalnog prinosa biomase i zdravstveno bezbedne hrane.

Ključne riječi: *Paulownia tomentosa* (Thunb.) Steud., održivi razvoj, biomasa, navodnjavanje