THE ANNALS OF "VALAHIA" UNIVERSITY OF TARGOVISTE
2016

PAULOWNIA TOMENTOSA, A FAST GROWING TIMBER

Pirro ICKA[1], Robert DAMO[1], Engjëllushe ICKA[2]
[1]Departament of Agronomy, University Fan S. Noli, Korçë
[2]University Nehemiah Gateway Albania, Pogradec
pirroicka@yahoo.com

Abstract
The fast growing woody crops are a very important source for the generation of the bioenergetics biomass. Paulownia sp. Is a plant part of this group, and because of its fast growth, multiple values and high adaptability with climate conditions, is set recently in the centre of the intention. Paulownia is one of the fastest growing species in the world with low concentration of ash, sulphur and nitrogen and high calorific energy from its wood. It is considered as an energetic crop adequate for the production of the solid biocarburants and the bioethanol. The cultivation of the Paulownia because of the high absorption of CO_2 from the air, to support the fast growth of the biomass, is considered as an effective mean to soften the climacteric changes. The plant is also considered as suitable to improve the abandoned lands when its cultivation is concentrated to the biomass production. The genus of Paulownia (Scrophulariaceae) is autochthones species of China and East Asia and as such is not found naturally in Albania. To study the regionalization possibilities of this species in the Korça climacteric conditions, aiming its cultivation according the fast growth coppice system were planted in 2014 in Cangonj (Devoll) 300 seedlings of P. tomentosa in a distance of 1 x 1 m. during the year 2015 were planted other 400 seedlings prepared with seeds. This article deals with the preliminary data of the regionalization performance of this high energetic value crop.
Key words: Paulownia, biomass, timber, fast growth coppice.

1.INTRODUCTION

The planted plantations will be the main sources of global bioenergy, therefor the European farmers are expanding progressively the cultivation of energetic plants, following common agriculture policies and the development of the energetic sector (Durán Zuazo et al., 2013). The biomass demand is foreseen to grow by 50% in the year 2020 in Europe (Durán Zuazo et al., 2013) and 15 % in 2015 globally, (El-Showk et al., 2010) and as a result is needed the development in the biomass sector.
The use of the firewood as the main source of thermic energy during the winter time in the cold regions of Albania and the non-sustainable utilization of the forests has expanded the interest to explore for alternative sustainable energetic sources. The utilization of the biomass from the fast growth crops is a famous practice all over the world but less known and used in Albania. Among many woody and herbaceous fast growth crops, Paulownia is considered "magic" because of its fast growth rate and the high amount of the wood quantity generated in a short time period. The purpose of this article is to introduce, cultivation possibilities, seedling production and the introduction with the preliminary data of the regionalization performance in the Korça region of this high energetic crop.

2. MATERIAL AND METHOD

Taxonomy

Paulownia is recognized with many names like Princess Tree, Empress Tree, Royal tree, Kiri Tree, Phoenix tree etc. (Innes 2009; Bikfalvi 2013). Paulownia genus is nominated according the Swiss botanist Thunberg (Zhao-Hua et al., 1986) nominated in honour of the queen Anna Pavlovna of Netherlands (1795 - 1865), the daughter of Car Paul I of Russia (Woods 2008). Paulownia genus includes 6 – 17 species (depending on the taxonomic authorities) (Ates et al., 2008; Woods 2008) is member of monogenetic family of *Paulowniaceae* often related to *Scrophulariaceae* (Woods 2008; Innes 2009) or *Bignoniaceae* (Innes 2009). Based on the flower anatomy, embryo and seed morphology, Paulownia is a member of the *Scrophulariaceae*, family which mainly includes herbaceous species (Innes 2009). The most important species of this genus are *P. albiphloea*, *P. australis*, *P. catalpifolia*, *P. elongata*, *P. fargesii*, *P. fortunei*, *P. ka-wakamii*, and *P. tomentosa* (Yadav etc., 2013).
The hard wood trees of the Paulownia genus originated from China are cultivated since at least 3000 years ago (Bergmann et al., 1997; Ates et al., 2008; Angelov 2010).

Botanic description

Paulownia is a deciduous tree and can reach a height of 20 – 30 m (Innes 2009) under natural conditions and up to 50 m (Navroodi 2013) recorded in China, its origin land. Its diameter can reach 2 m (Innes 2009; Navroodi 2013). Paulownias plant has a tendency to form many branches if it is grown in open space, whereas in the forest it tends to form a straight trunk. Paulownia bark is brown to black, smooth but with visible lenticels in the young tree then gradually are developed vertical cracks together with its growth (Zhao-Hua et al., 1986; El-Showk et al., 2010). Often all the parts except of the old branches are covered with glandular mucigel hair, thick hair and branched hairs or stelate (star shaped). Most of the Paulownia species have pseudo-dikomote ramification which are dried after the wither period (Zhao-Hua et al., 1986).
The rare leaves create a cylindrical crown or an umbrella shape (Zhao-Hua et al., 1986). Leaves at the maturated tree reach the length of 15 – 30 cm and width of 10 – 12 cm (Innes, 2009), with smooth and weaved sides (Zhao-Hua et al., 1986). The new plants have big leaves (Innes, 2009) and long stem, with trowel sides, placed in front of each other or in spiral shape (Zhao-Hua et al., 1986). Paulownia produces C_4 type photosynthesis with a high level of organic matter in their leaves (Woods, 2008).
Flowers are pendicellate with two or five flowers with stems or subsessils (almost jointed in the basis). They are

produced in the axes of the decreasing or small leaves during summer or autumn (Zhao-Hua et al., 1986; El-Showk et al., 2010). The flowers are placed at the apical basis. The calyx is flashy, in bell shape with five lobs uneven triangular. These triangular shaped lobs have the upper main lob bigger and mainly hairy. In several Paulownia species the hairs fall down during anthesis (Zhao-Hua et al., 1986). The big, straight flower up to 15 – 30 cm is compound of tube flowers 5 – 6 cm high. Paulownia enters soon in the reproduction phases, usually after 4 – 5 years but it can reach also 8 – 10 years under normal conditions (Innes 2009). The corolla is big, purple to white, two lips and two lobs to the upper lip and tree elongated lobs to the lower lobs. The bell tube is usually 5 mm from the basis and later is gradually or immediately prolonged (Zhao-Hua et al., 1986).

The fruits have capsules with measurements 2,5 – 4 cm high and 2,5 cm in diameter. Each part of the capsule has two components that contain many small seeds with wings (Innes 2009). The seeds number in the fruit can reach up to 2000 (Yadav et al., 2013) with the length 1,5 – 3 mm (Innes 2009) a gram of seeds contains 5000 small seeds (Yadav et al., 2013).

The root system at Paulovnia is relatively shallow (Innes 2009) or deep (Zhao-Hua et al., 1986; Woods 2008), well developed, depending on the climate-earth conditions (Zhao-Hua et al., 1986; Innes 2009). Upper roots are thin, dichotomously branched and grown in a high density. Suction roots are long, usually 1 – 5 mm in diameter and are expanded up to 60 cm. The development and extension of the root system is affected apparently from the underground water level, physical characteristics of the earth and available nutritive elements (Zhao-Hua et al., 1986). Although they are extended they do not create a strong main root, (Innes 2009). The characteristics of root resistance, dimensional stability and high burning point (Ates et al., 2008; Popović) 400 ºC (Angelov 2010) made Paulownia timber well known in the global market (Ates et al., 2008; Popović). The presence of deep root system linked to the high vegetative growth to support the suction of the nutritive matter quicker than other species, increases the utilization of this species for phytoremediation of the land from heavy metals (Woods, 2008).

Paulownia utilization

Within natural conditions in 10 years Paulownia develops a trunk with diameter of 30 – 40 cm, measured 1,2 m from the earth, producing a volume of 0,3 – 0,5 m^3 (Yadav et al., 2013; Ates et al., 2008). According Ates et al., (2008) and Angelov (2010), each Paulownia tree aged 5 – 7 years old can generate 1 m^3 timber in a surface with density of 2000 plants/ha, offering a total production of 330 t/ha. In the areas planted with a smaller number of plants per surface unit can reach a production of 150 t/ha.

Paulownia trunk is light, strong, dries quickly, aesthetically pleasant, with light colour that do not change, easily workable and suitable for carvings and isolations (Yadav et al., 2013; Ates et al., 2008; Akyildiz et al., 2010), without junctions and a soft surface, with a specific mass of 0,35 g/cm^3 (Ates et al., 2008; Akyildiz et al., 2010). Paulownia timber has low thermo conductivity (0,063 – 0,086 kcal/m hr C) and natural resistance against fire and damages (El-Showk et al., 2010), it is resistant against the wood worms and termites because of the high content of tannins (Angelov 2010).

Because of the fast growth and the high cellulose concentration up to 440 g cellulose/kg (Yadav et al., 2013) Paulownia timber is estimated to be adequate for its usage to the cellulose pulp industry and also as solid biofuels (Yadav et al., 2013; Ates et al., 2008).

Flowers and leaves of Paulownia are a good source of fats, sugars and proteins for the cattle nourishment. The nitrogen compound to the Paulownia leaves can be compared with that of several leguminous family plants. They have the same nutritious values as alfalfa, and are suitable for the nutrition of the cattle specially sheep and goats especially in combination with wheat straw or silage (Woods, 2008; Angelov, 2010). Paulownia leaves are utilized as green fertilizer as compote. (Yadav et al., 2013). A tree aged 8 – 10 years produces about 100 kg green compound (leaves) about 2,8 – 3 % N and 0,4 K (Woods 2008).

Paulownia has a high coefficient of carbon fixation (Lawrence 2011), the biomass fast growth demands a high quantity of CO_2 absorbing about 1250 t/ha/year (Bikfalvi 2013). A tree absorbs about 22 kg CO_2 and exhale 6 kg O_2 in a year, obtaining so far the purification of thousands of cubic meters of air (Angelov 2010).

To Paulownia plantations the earth carbon contain is increased as the result of the accumulation of the organic matter from fallen leaves, whereas the wide root system plays an important role to the continuous distrait of carbon in earth (Lawrence 2011) and the retention of the underground water (Bikfalvi 2013). Paulownia can be truncated 4 – 5 times and its growth improves the earth which distinguishes it as sustainable compared to other biomass systems (Lawrence 2011).

Table 1. Chemical compound of the Paulownia leaf (El-Showk et al., 2010)

Compounds	In %
Organic matter	91,4
Proteins	22,6
N	2,8 – 3,0
K	0,4
P	0,6
Ca	2,1
Fe	0,6
Zn	0,9
Metabolisation energy	15 – 18 MJ/kg

High flourish of Paulownia is a good source in the production of the honey (Yadav et al., 2013; Woods 2008), obtaining honey production up to 700 kg/ha/year (Bikfalvi 2013). The honey has a light colour and a high quality, even higher than acacia. It is specially used to treat respiratory disorders, lung problems and digestive system (Angelov 2010).

The tea and syrup extracted from the Paulownia flowers affect positively the liver and spleen problems and also bronchitis. Recently the flowers are used to the cosmetic industry for perfumes, creams etc. production. (Angelov 2010).

Cultivation requirements

Paulownia consumes about 2000 litters of water per tree to reach a production of 4,3 t/ha during the first cut (García-Morote et al., 2014).

Paulownia has a high adaptability with land climacteric conditions, as shown in the table 2. In the Mediterranean climate conditions the Paulownia production is negatively affected by the high evapotranspiration but not from the rainfalls and temperatures (García-Morote et al., 2014).

This species is very adaptable and widely dispersed. It has a natural distribution from the tropical zones till the ones with moderated climate. And to the zones where the annual rainfalls are between 500 to 2000 mm and a high from the sea level up to 2400 m (Navroodi 2013). The adequate conditions for the Paulownia cultivation are attained in a height of 200 – 1300 m above the sea level with an average of the annual temperature 15 – 23ºC and annual rainfalls 1400 – 2800 mm (Navroodi 2013).

Paulownia is not affected from pests and diseases; the plant is very flexible and usually not affected by diseases (El-Showk et al., 2010).

Table 2. Cultivation requirements of Paulownia

Temperature	-25 – 47ºC Optimal 27ºC	Paulownia Bulletin; El-Showk et al., 2010
Water	500 - 2000 mm (700 mm during vegetative growth or over 150 mm/month)	Zhao-Hua et al., 1986; Lawrence 2011; Paulownia Bulletin; El-Showk et al., 2010; Bio Tree LTD
Sea level height	÷ 2400 m (preferred under 750 – 800 m)	Bio Tree LTD; Zhao-Hua et al., 1986; Navroodi 2013
Soil		
Soil temperature	15 – 16ºC	García-Morote et al., 2014; Bio Tree LTD
Soil pH	5,0 – 8,9	García-Morote et al., 2014; Navroodi 2013; Angelov 2010; El-Showk et al., 2010
Clay	< 25 – 30 %	García-Morote et al., 2014; Bio Tree LTD
Total porosity	> 50 %	Bio Tree LTD
Salinity	< 1%	Bio Tree LTD
Light norm	20000 – 30000 lux	Bio Tree LTD

Biomass production

The timber production in the short cutting cultivations through planting of the fast growth energetic crop guides toward preservation of natural ecosystems. The usage of exotic plants for this reason can be adequate because usually they show a good productive potential to the new cultivation lands (Navroodi 2013).

The main advantage of the biomass utilization for fuel is its resilience capability. Timber biomass of the forestry modified for the high content of cellulose and hemicellulose can be the main source of ethanol production. Analyses of the Paulownia timber compound show that it contains: 14,0 % extract, 50,55 % cellulose, 21,36 % lignin, 131,6 % hemicellulose and 0,49 % ash (Yadav et al., 2013). The presence of lignin, hemicelluloses and cellulose in Paulownia timber is comparable with the ones of hard woods (Ates et al., 2008). Because of the high compound of cellulose, Paulownia pulp can be utilized for the ethanol production, which is a renewable bio carburant that reduces the emission of the greenhouse gases to the environment (Woods 2008). American researchers have created new thermo-chemical and biotechnological technologies from which can be extracted 511 litters ethanol from 1 ton dry mass, this is the reason why Paulownia is considered as "oil well" (Angelov 2010).

Paulownia is a very fast growing plant, trees can reach 4 – 6 m only during the first year (after cuting) growing further 2 – 3 m during the second year, to reach a diameter of 20 – 25 cm of the trunk on chest height at four year (Navroodi 2013).

Calorific value of Paulownia biomass is higher than that of coal (and forest biomass) (Table 3), lower with air pollutants as sulphur (Table 4), lower compound compared to other biomasses and the fast growth factor and the renewable factor make this plant suitable for environmental profitability (Lawrence 2011). Paulownia wood has the advantage of being light reducing therefore the transportation cost compared to other woods. Paulownia can be cut at least 4 – 5 times and its growth improves the soil quality better than other biomass systems.

Paulownia, as energy source, is utilized to produce the pellet (as solid combustible) and other adequate forms for biofuel, utilizing this way every part of the plant (Angelov 2010).

Table 3. Calorific value of different combustibles

Combustible	kJ/g	Thermochemical energy kal/g
Paulownia	**20,90**	**4,99**
Poplar	17,62	4,21
Beech	14	3,43
Oak	19,42	4.64
Fir	16	3,82
Straw crops	15	3,58
Olives cores	19,87	4,74
Ethanol	47	11,23
Natural gas	49,99	11,95
Diesel	41,48	10,00
Coal	14,64	3,50

Table 4. Gas emission in kg gas/1000 ton dry matter (Angelov 2010)

Emitted gas	Paulownia	Coal	Diesel
SO	0	1750	277
NO	0	1550	5250
CO	0	7	0
CH_4	0	7	0
CO_2	187	550	775
Other hazardous substances	0	140	2800

According Angelov 2010, the Paulownia advantages as a plant to produce bio-carburant are:

- Paulownia can grow in sandy and poor soil; therefore it does not compete with agriculture crop for the fertile land.
- Paulownia cultivation does not require much care and has low cost.
- Replanting is not required. After the cutting the plants are fast regenerated, roots lifespan is approximately 70 years and can support the growth about 8 – 9 cuttings with vegetative cycle about 8 years.

Nowadays is researchers are working for the production of new cultivars with high productivity. Spanish researchers created Paulownia clones in Vitro 112® (since 2003 from Paulownia elongata x fortunei) and Paulownia cotevisa 2, hybrid clones that have a high resistance against extreme temperatures between -25 to 45ºC and high quality timber (Cuomo 2014). These hybrids play an important role in the timber production for industry and for incineration (Bikfalvi 2013). Clone Paulownia in Vitro 112® and Paulownia Cotevisa 2 have a faster growth compared to other varieties of Paulownia obtaining a diameter of 25 – 30 cm and a height of 15 – 20 m (~ 0,3 m^3/tree) since the third year. This reduces the harvest time every 3 years and increases the productivity. This plant although that is very adaptable to every climacteric condition is considered, as non-invasive plant (Bikfalvi). For the biomass production is recommended more dense sowing for timber production (550-750 trees/ha). The biomass plants are preferred with a density of 2000 plants/ha, in Bulgaria are planted plantations for biomass with density of 3000 - 3300 plants/ha in distances 3,3 x 1 m and 2 x 1,5 m respectively. The species is considered suitable for the improvement of the abandoned agriculture lands or for land rehabilitation, where the main intention is focused to the biomass production.

3. RESULTS AND DISSCUTIONS

PAULOWNIA TO KORÇA REGION

For more than ten years is tented to insert in Albania the Paulownia plant through projects or interested individuals. Only during the recent 3 – 4 years these attempts are intensified creating several plantations with Paulownia mainly to the western lowland (Shkodër, Lezhë) and also in Korça region. The study of the regionalization of Paulownia in Korça region is interested because of the climacteric characteristics of this region.

Korça region is located in a height of 800 m over the sea level defined by the literature as the border of optimal growth (Table 2). Korça region is poor in precipitations with an average of 750 mm per year and about 20 % of them falls during the period that corresponds with the vegetative growth of Paulownia which demands high amounts of water.

Korça region is recognized for its cold winter where the temperatures reach -25ºC. The study in described in this paper is done in a nursery garden close to Cangonj (Devoll) village in the propriety of the company Gjelbërimi shpk, with centre in Korça.

The company Gjelbërimi shpk exercises its activity in the sector of production and selling the decorative plants including flowers and trees. According its own demand the company imported from France in 2014 300 seedlings of *Paulownia tomentosa*. The seedlings were planted in a surface of 500 m^2 in a distance of 1 x 1 m for the production of decorative seedlings. The land where the seedlings were planted is in a height of 850 m over the sea level. During the spring 2015 was performed the technical cut "seedlings enforcement" and further the necessary services to obtain a healthy seedling. After the cutting, the plants have growing quickly. The growth of new soot was quick and with high intensity (Figure 1). By the end of vegetative growth by 2015 were performed several biometric measurements (Table 5), and the most interesting indicators are the average plant height of 4,25 m and the trunk diameter on chest height by 5,22 cm, which are close to the literature data for the seedlings of the same age.

Figure 1. Paulownia growth after the cut for seedlings enforcement

From this study was highlighted that in the Korçës region (Devoll region) there are 3 – 4 individuals of Paulownia planted since 13 years ago in the garden of a house located in the Bilisht town, about 870 m over the sea level (Figure 2). The trees have a height over 10 m and a diameter of 38 – 40 cm on chest height, similar measurements with the ones on the literature. These plants can fructify (Figure 3a) showing that they have found optimal conditions for their growth and development. The seeds obtained from these trees are planted in the seedbed of the company Gjelbërimi shpk, and 400 seedlings from these seeds (Figure 3b) are transplanted to the seedbed during the springtime 2015 (seedlings distances 1 x 1 m). The growth and development of the seedlings was normal and almost the same with the growth observed to the imported seedlings. This study observed not only the performance of acclimatisation of Paulownia to Korça region, the other objective was to observe the seedlings production with seeds from "inland" plants and the comparison of their growth and development with other imported seedlings reducing the seedlings cost. Preparation of the seedlings, planting and replanting of the plantations is considered relatively easy and with low cost for maintenance free of negative impact in the environment which is confirmed from the data of this very study. Although as far as the study is in its first steps it is early to generate complete conclusions about the sustainability of the species in all aspects of its cultivation.

Table 5. Biometric measurements of Paulownia in the first year after the cut for seedling reinforcement

Tree height	4,25 ± 0,20 m
Trunk diameter (1.2 m from earth)	5,22 ± 0,40 cm
Leaf length	60,05 ± 0,90 cm
Leaf width	60,10 ± 0,62 cm
Diameter of the leaf stem	2,45 ± 0,17 cm
Stem length	44,8 ± 1.30 cm

Figure 2. (a) Paulownia tree in Korça region, September 2015. (b) Paulownia timber from the tree grown in Korça region (fig 2.a), July 2016

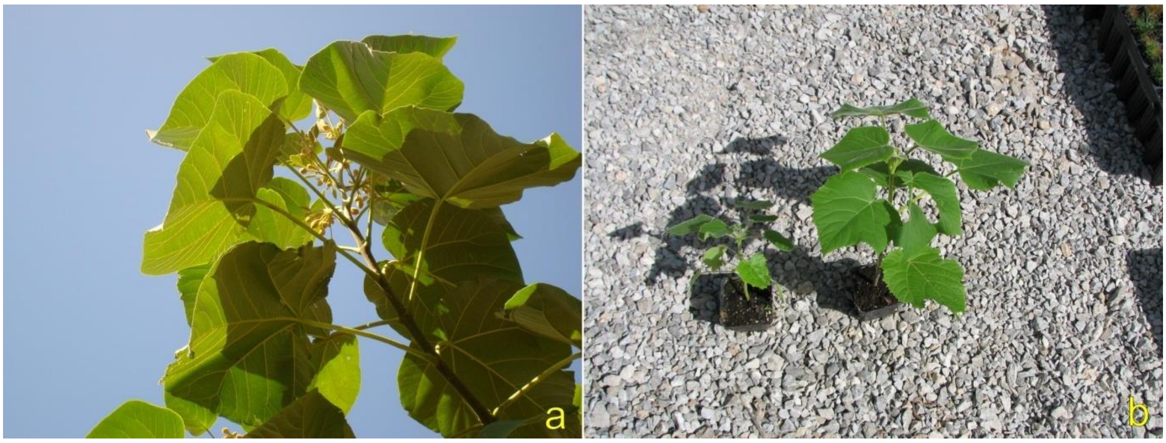

Figure 3. (a)Paulownia fruits on Korça region, (b) Paulownia seedlings produced from seeds of exemplars in Korça region

The study is on-going and will generate more complete data. To generate complete conclusions that will support the idea to grow the trees for biomass and bioenergy. The study will continue to observe the planting in different distances of seedlings and also other marginal land. The first results are promising that the results of the study will be implemented into practice.

4. CONCLUSIONS

This study about the *Paulownia* regionalization started from the company Gjelbërimi shpk as the only one in the Korça region. This specie is little known and its cultivation in the region and the utilization of the biomass will generate new perspectives in the development of the very region.

Paulownia biomass is a renewable source for energy and neutral carbon.

The collected data are encouraging for the regionalization of the Paulownia in Korça region, although the performance of the study will indicate about the possibilities for using Paulownia as a bioenergetics alternative with high values for the environment.

5. REFERENCES

[1] Akyildiz M. Hakan, Hamiyet Sahin Kol "Some technological properties and uses of paulownia (Paulownia tomentosa Steud.) wood". Journal of Environmental Biology Triveni Enterprises, Lucknow (India) **2010**.

[2] Angelov Boyan "Paulownia the tree of future" **2010** Velboy Ltd. Bulgaria.

[3] Ates Saim, Yonghao Ni, Mehmet Akgul, Ayhan Tozluoglu "Characterization and evaluation of *Paulownia elongota* as a raw material for paper production" African Journal of Biotechnology Vol. 7 (22), pp. 4153-4158, 19 November, **2008.**

[4] Bergmann, B.A., Rubin, A.R. and Campbell, C.R. **1997**. Potential of *Paulownia* elongata tress for swine waste utilization. *American Society of Agricultural Engineers*, 40 (6): 1733-1738.

[5] Bikfalvi Martin "The intelligent tree" Paulownia GreenE Romania **2013**.

[6] Bio Tree LTD "Short rotation cycles, good practices, directions and instructions" Good Practices and Instructions.

[7] Cuomo Francesco "Progetto clone in vitro 112® La nuova grande opportunita per líagricoltura" AGRIinnovazioni **2014.**

[8] Durán Zuazo Víctor Hugo, Juan Antonio Jiménez Bocanegra, Francisco Perea Torres, Carmen Rocío Rodríguez Pleguezuelo, José Ramón Francia Martínez Biomass "Yield Potential of Paulownia Trees in a Semi-Arid Mediterranean Environment (S Spain)" International Journal of Renewable Energy Research Vol.3, No.4, **2013.**

[9] El-Showk Sedeer, El-Showk Nabil "The paulownia tree an alternative for sustainable forestry" **2003.**

[10] Francisco Antonio García-Morote, Francisco Ramón López-Serrano, Eduardo Martínez-García, Manuela Andrés-Abellán, Tarek Dadi, David Candel, Eva Rubio and Manuel Esteban Lucas-Borja. "Stem Biomass Production of *Paulownia elongata* × *P. fortune* under Low Irrigation in a Semi-Arid Environment" *Forests* **2014**, *5*, 2505-2520.

[11] Innes, Robin J. **2009**. "Paulownia tomentosa. In: Fire Effects Information System" [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer).

[12] Lawrence James S. "Paulownia Biomass Production" **2011** TGG ~ toadgully.com.au

[13] Navroodi Iraj Hassanzad "Comparison of growth and wood production of *Populus deltoides* and *Paulownia fortunei* in Guilan province (Iran)" Indian Journal of Science and Technology Vol: 6 Issue: 2 February **2013.**

[14] Paulownia Bulletin ≠ 3 advices and instructions "Paulownia for biomass production" BIO TREE LTD Bulgaria .

[15] Popović Jasmina, Gordana Radošević *"Paulownia elongata* S. Y. HU - anatomical and chemical properties of wood fibers" Faculty of Forestry, Kneza Višeslava 1, Belgrade/Serbia.

[16] Woods V.B. "*Paulownia* as a novel biomass crop for Northern Ireland?" AFBI (Agri-Food and bioscience Institute) Occasional publication No. 7, **2008.**

[17] Yadav Niraj Kumarmangalam, Brajesh Nanda Vaidya, Kyle Henderson, Jennifer Frost Lee, Whitley Marshay Stewart, Sadanand Arun Dhekney, Nirmal Joshee. "A Review of *Paulownia* Biotechnology: A Short Rotation, Fast Growing Multipurpose Bioenergy Tree" *American Journal of Plant Sciences*, 2013, 4, 2070-2082 Published Online November **2013.**

[18] Zhao-Hua Zhu, Ching-Ju Chao, Xin-Yu Lu, Xiong Yao Gao "Paulownia in China: cultivation and utilization" Published by Asian network for biological sciences and international development research centre **1986.**