

ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering

Tome XIV [2016] – Fascicule 4 [November]

ISSN: 1584-2665 [print; online]

ISSN: 1584-2673 [CD-Rom; online]

a free-access multidisciplinary publication
of the Faculty of Engineering Hunedoara



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CONSIDERATIONS ON THE IMPORTANCE OF THE PAULOWNIA TREES PLANTING

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ABSTRACT: In this paper are presented as rich and updated information about the importance and the planting technology of Paulownia trees in order to capitalize the hardwood, with beautiful appearance, clean, smooth, free of knots and with a high degree of machinability, used for the manufacture of sawn wood, for the construction of yachts, light aircrafts, expensive furniture and musical instruments. The paper is aimed to the farmers with larger farms and to the silviculturists which will plant this wonderful trees representing a sustainable source of biofuels, being an energetic plant which grows and is harvested like any tree, which may become firewood, briquettes, pellets and, although burns at higher temperatures, release large amounts of energy and can contribute to solving the global energy crisis

Keywords: Paulownia, biomass, princess tree, phoenix tree

1. INTRODUCTION

The deciduous tree Paulownia, Figure 1, or princess tree, also called “the aluminum of the wood” because of its resistance is a tree with broad crown, thick stems with large leaves and mauve flowers and perfumed [1]. Paulownia tree belongs to the mono generic Paulowniaceae family, related and included in the the family Scrophulariaceae [5].



Figure 1 - Paulownia Plantation [8]

It originated in China, Laos and Vietnam, but it is also grown in other parts of the Far East, especially in Japan and Korea. Paulownia is cultivated in China for at least 3000 years, in the U.S. from 1800 and in Japan since 1970, when the wood has become an export business of billions of dollars. It is very popular in China for reforestations, planting on the roadside and as an ornamental tree, being a hardwood tree, but lightweight and with very fast growth. The timber obtained has a yellowish white color, silvery or light brown, depending on variety, is highly resistant and also aesthetic (fine texture, without knots).

If hundreds of years ago the Chinese planted this tree almost entirely for ornamental purposes, the massive deforestations that occurred in the last two decades, the woodworking industry development, the increasing demand for timber, the emergence and development of more and more plants using biomass for energy production as well as the accelerated growth of the price of wood turns every Paulownia plantation into a real gold mine for its owners [12]. The rapid growth of the Paulownia tree makes it extremely suitable for obtaining of large amounts of biomass (60-80 t/ha) in a short period of time [7].

2. MATERIAL AND METHOD

» Spreading

Ideal for the Paulownia tree is the temperate climate with minimum temperatures between -19°C and $+3.9^{\circ}\text{C}$ (for *Tomentosa* species) and up to -26°C (for *Elongata* species) [2]), and according to [9], the maximum average temperatures may range between 31 and 42.7°C . It is found at altitudes starting about from the sea level, up to about 2400 m [1].

There are over 20-23 species of Paulownia and are similar in terms of appearance and properties of the wood mass, but are scientifically designed and acclimatized to different environmental conditions. Shantong type trees are frost tolerant hybrids, obtained by multiplying in vitro Paulownia *Tomentosa* and Fortune Paulownia species [16]. Shantong hybrid that was developed in China in 1982 can withstand temperatures of minus 29°C and has a faster growth and a higher resistance to drought than the basic species, having a higher capacity for regeneration and production of valuable hardwood timber, being adapted to the weather conditions from Romania. It arrived at this wonderful tree only now, when mankind has realized that the forests are destroyed and the carbon dioxide emissions are extremely high, all this inevitably leading to the gradual and rapid degradation of the planet. The interest for the recycling of the lands polluted by industry, the binding of enormous amount of carbon dioxide and the increasing demand for energetic plants have created the need for attention and researches to be given increasingly higher. In Europe this species has spread through the medium of France, who took over from Japan and not from China, where has its origins and which may contribute to increasing the alternative energy sources, offering a chance to supplement the reserves of the Earth. Such an opportunity is considered to be Paulownia, because, due to its fast growth, the large amount of wood obtained could be used both for heating and for the production of furniture or for the use in the construction.

» Environmental conditions

Paulownia tolerates a wide range of soil types, but nonetheless the deep and fertile soils are required for an optimal growth [1]. Are preferred clay soils sandy and loosened or those loamy, to which the groundwater level is less than 1.5-2 m and where there is no cliff up to a depth of 6 m. Hydric requirements are of 750 mm^3 / year. The trees lose their leaves and may even die after the land was flooded for a short period of 3-5 days. The salty soil and the water can also affect the growth. In order to ensure the maximum growth, the irrigation may be necessary throughout the development cycle. Generally, Paulownia does not tolerate a low level of light, growing the best in the direct sunlight, being it required a daily average temperature of about $24-29^{\circ}\text{C}$ [1].

» Features and benefits of the plantation

Paulownia trees are regenerating from the existing root systems, being able to harvest between minimum 3 and maximum 5 turns (cycles 3-4 years) of growth of the wood without the need for replanting, deservedly earning nickname of the Phoenix bird tree.

Its deeply rooted system gives it the possibility of greening the degraded soil surfaces. It has deep pivoting root of 10-12 m whose role is to stabilize soil, saving it of landslides and maintaining the underground water systems. Paulownia trees are resistant to drought, their roots penetrate deep into the soil once fixed looking for water, more than at the surface.

Paulownia leaves are heart-shaped having a diameter of $(15-40)\times 10^{-2}\text{ m}$, being arranged in pairs on opposite branches and having a rapid growth and a huge capacity of absorbing the carbon

dioxide (in a year can absorb 100 tons of CO₂ /ha per plantation) and producing 75 tons of oxygen. They can be used for the manufacture of medicaments (because they contain substances that positively affects the liver, kidney, gallbladder, lung diseases) also for feeding of animals, or as organic fertilizer [3]. In summer, during a hot day it is normal that Paulownia leaves to wilt, this one being a mechanism to avoid the excessive perspiration. If the trees are withered because it is warm but the ground is wet, the leaves will rise again when it cools, in the evening. The fallen leaves in autumn on the ground are rich in nutrients and helps at feeding these trees.

Paulownia leaves have also properties that can be used in the cosmetic industry, for the production of perfumes and creams. Also the flowers can be used for the same purpose, their aroma being one of vanilla or almond. It was demonstrated that this is due to the heliotropine content [13].

One of the most promising applications is the manufacture of bioethanol from cellulose by two methods, namely: using microorganisms especially cultured for this purpose, or by relying on the effect of certain enzymes. It is the fastest growing tree in the world, in the early years may grow about 2-3 m / year [6]. In contrast with other fast-growing trees which have a short life, a healthy Paulownia tree can withstand for 80 to 100 years [3]. It is perfectly ornamental, it has gorgeous flowers flowering abundantly in the spring, before of leaf emergence, with big flowers lilac and beautiful spreading a discreet scent of violets particularly pleasant, being used in manufacture of perfumes. The flowers appear in early spring in bunches long of (10-20)x10⁻² m, with a corolla (petals) tubular in purple nuances, the flower resisting at least a month;

It is a good tree melliferous, being more prolifically than the acacia in the production of honey, the flowers are very appreciated by the bees for the production of honey, which is flavored, light coloured, of about 700-1000 kg of honey / ha, (a single hive producing 10-15 kg of honey of highest quality during the flowering season, compared to that of acacia) [7];

Due to the existing hairs to the underside of the leaves and of the the stem, the tree is a good sound absorber. Banish the insects, absorbs the noise and dust (a hectare of plantation cancels an annual quantity of 48 tons of dust and air pollutants) [3];

The fruit is a dry capsule containing 1200-2300 of small seeds, with fins, having the mass of 1000 grains of 0.15 g and germinating power of 80-90% [9]. The seeds, which contain a highly valued oil in the Far East, enters in the manufacturing of varnishes used for the impregnation of various materials [9]. Paulownia produces seeds after the age of 8 years, into a gram of Paulownia seeds existing about 6000 pieces, and a mature tree can produces 20 million seeds [15]. Autumn is the best season for harvesting the seed of Paulownia. The optimum temperature for seed germination is of 26°C. These are sown on the surface and are covered with a thin layer of soil or may to be not covered at all. Soil has to be moist, but not in excess. Paulownia seeds need light and oxygen to germinate. Can be used the natural light or the artificial light. The time of germination of the Paulownia seeds is between 7 and 21 days;

The wood is resistant to twisting (grows straight, clean and smooth), is resistant to contraction (no splits, no cracks) and to deformations, it is stable during the modifications of humidity. feels few downsizing or dilatations compared to most other types of wood, It has a fine texture, which makes from Paulownia a tree with exceptional wood for boats, pallets, household furniture, as well as plywood, houses, prefabs, semi-products and internal panels for construction [2];

Recently this tree has received a great attention for its beneficial environmental properties and was presented as a possible solution to the problem of deforestation at globally level, issue that is central to the debate on climate change, plantations representing a certain good forestry protection belt;

It has a very good fire resistance, having a high ignition temperature of 420-430°C compared with the average of hardwoods at which the ignition temperature is of 220-225° C;

Paulownia is an exotic tree from which are used all parts of the tree [5] as the trunk, leaves, flowers and seeds (figure 2), the whole tree with its remarkable growth being a treasure for environmentalists. From the Paulownia Shan Tong approx. 70% can be used for the manufacturing of timber, and 30% for the production of pellets, briquettes or biomass for the factories that use gasification in order to obtain green energy [11];

As firewood performs very well, having a calorific power of 15407 kJ/kg (3680 kcal/kg) [3]. For instance, the calorific power released by 2 kg of Paulownia wood is equal to that released by 1 liter of diesel oil and is comparable with the types of coal quality [4].

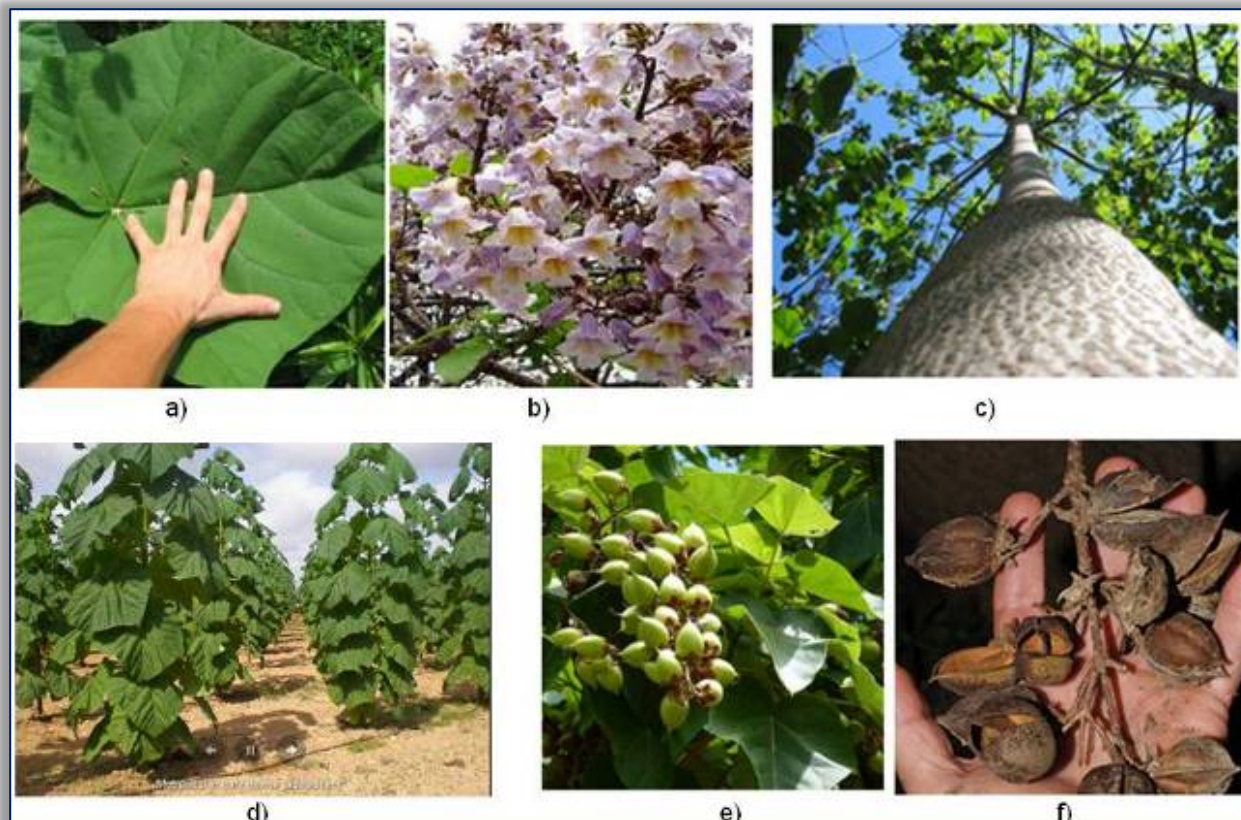


Figure 2 - Components of Paulownia tree [8]. a - leaves; b - flowers;
c, d - trunk; e - capsules with green seed ; f - capsules with dry seed

It is a light wood (2 times lighter than oak, with a density of 300-330 kg/m³) and it is 2 times more resistant to fire than usual beech wood, being a wood with a very low humidity degree (15%), itself being not affected by moisture. It is a very good insulator, it is easy to dry (the outdoor drying being performed in a time of 30-60 days without curving, deforming, bursting or cracking) and shows a high degree of processability being also known as the “aluminum timber”. From tree bark are produced special paints. It has low silicon content and reduces a lot the processing tools attrition, bringing sentient savings in the production process.

3. RESULTS ON THE CULTIVATION TECHNOLOGY

» Land preparation

Sapling planting technologies (in greenhouses and tree nurseries) as well as the monitoring of their behavior into experimental crops, starting from the harvesting of the seeds, performing tests of germination, planting, maintenance (weeding of weeds and soil mobilization), irrigation, pricking-out, etc., are not the subject of this paper, of these technologies being engaged the experimental research resorts. This material merely offer information related from preparing the ground, Paulownia seedlings or cuttings planting and the maintenance of the culture up to its harvest.

Choice of the place to establish plantations of Paulownia involves the identification of a land with a sunny exposure (SE, S, SV), with well drained soil, with a slight slope, preferring sites sheltered from cold winds in winter.

The land is plowed deep in autumn at $(35-40) \times 10^{-2}$ m and then is worked with the rotary hoe or is applied a disking tillage, after which can be applied herbicides for weeds, and at 3 weeks after the application of herbicides the saplings can be planted [10].

The application of NPK fertilizers (in ratios of 14:10:20 or 12:10:18), as basic fertilization is recommended of course [12]. If using a borer with a diameter of 60 cm and carry out holes at the depth of $(60-100) \times 10^{-2}$ m, it is possible to no longer carry out the plowing in autumn [13].

» Planting

Planting of the 1 year saplings, having a minimum diameter at the base of the stem of 1.0 cm, must be made in holes of at least $(30 \times 30 \times 30) \times 10^{-2}$ m in soil sloppy in the fall [9], or at a depth of one meter and a diameter of 30×10^{-2} m [12], after which the holes are filled with a mixture of peat, osmocote (a coated fertilizer containing nitrogen, phosphorus, potassium and

micronutrients, elements that are available to the plant on a longer period of time) and other fertilizers according to the soil analysis. The hole can be completed when planting with a mixture of soil with manure, sand, peat and forest land, and on the bottom of the hole (to achieve a good drainage), will put a little gravel [14]. Half of the soil fertilized with the aforementioned mixture must be introduced into the hole until the hole reaches a depth of $(30-40) \times 10^{-2}$ m [13], some authors recommending to put 100 grams of artificial fertilizer and of 10 kg of cattle manure instead of this mixture [15].

If it is planted in a position with windy slightly higher, then it is necessary to put a tutor for support in the early years of growth and formation.

Paulownia tree must be ordered 10 weeks before the desired time of planting, because it requires 8 weeks for the early stage of growth, which is realized in specially designed greenhouses. The interval of two weeks is required for delivering the product depending on where planting will be done (eg hill, plain, mountain) [6].

Paulownia does not support acidic soils, the pH value must be at least 5.5, the optimum being between 6.1 and 7.8 [13].

The water requirement in the summer months is about. 50 liters / tree, but if it is placed at planting a quantity of 20 grams of hydrogel into the ground, then will put only half of this amount of water [16].

The planting of the saplings is done in straight rows, at a distance of 4 m between plants on row. The ideal period for planting is in spring, after the last frosts, so that the plant to have the time to form a lignified root as strong throughout the spring, summer and autumn [12]. Place the roots in the hole so that the top of the stem must be at the ground level or with $(2-3) \times 10^{-2}$ m over it [13]. After planting, for a better anchoring, are made around the sapling mounds (ridges) of soil with the height between $(15-20) \times 10^{-2}$ m. It is particularly important that when planting to have a sapling with a well developed root and with a stem lignified in an as high proportion [12]. The accelerated rythm of grothof these shrubs is due their pivoting root, that reaches 10-12 m in depth, but the plant will not have the capacity to develop and grow independently than from the second or the third year. The periods suitable for planting the cuttings is from November to late April, iar puietul trebuie plantat de la sfârșitul lunii aprilie până la începutul lunii august [13].

It is recommended the planting for the wood production, at the distance between trees in the row and between rows according to the following matrix (planting schemes): 4 m x 4 m - in order to ensure a density of 630 trees/ha (in which case the first exploitation is performed at 4 years).

The investment is about 3,000 euro/ha, at which are added the costs for preparing the land (plowing, milling or disking, digging holes, etc), the maintenance expenses (comprising the activities of: fertilization, pruning and removing weeds, harvesting and storage), as well as those of irrigation, that can vary depending on the irrigation system (flow on ditches, drip irrigation or mobile) [12].

In case when the plantation is intended exclusively for the production of biomass, the distance between trees on row and between rows is of 2 m x 0.5 m or of 1 m x 1 m, in order to ensure a density of 1600 trees/ha, but the this variant involves an investment of around 8000 euros/ha, at which are added te the above mentioned expenses.

» **Watering**

Pour about 10 liters of water (watering is not necessary if the Paulownia is planted in the fall). If the soil is too dry, especially in depth, is recommended a watering (irrigation) of supply, with at least 200-250 m³ of water/ha ($20-25$ l/m²), with 24-48 hours before of planting. The water reserve in the soil at the moment of planting is a critical aspect of the success of a Paulownia plantation.

» **Ridging**

Formation of ground in layers raised (ridges) is optional, but it has advantages such as: a better drainage, ensuring a greater depths of the soil layer for rootand faster warming of the soil in early spring.

» **Weeding and removing the grass**

Now comes the most fragile phase of the tree, when it is still young but the grass grows and if it is not removed (generally by hand or by herbicides), the tree can be suffocated by it [13]. It is well to remove the weeds around the young trees within a radius of $(30-40) \times 10^{-2}$ m. This phase represents the greatest danger of attack with Mamestra Brassicae or with Trialeudores vaporariorum, which can be treated three times in their early growth phase. In spring and at

early summer, insects can appear on the Paulownia trees, particularly caterpillars, This does not mean serious problems, and if necessary, it may be treated with the known pesticides used also to fruit trees. When trees grow more than 1 m (they grow between $(5-10) \times 10^{-2}$ m per day), the bugs can no longer attack. Till reaches at least 1.5 m, it should be protected from insects. Removal of weeds is necessary for the trunk grows straight, without branches to at least 8 m. The lack of branches guarantees the quality of the wood.

Even if it is planted in autumn or spring, the Paulownia cuttings begin their rise from mid-April to early May. Of course, the temperature plays a very important role. It is possible that the young trees to flourish prematurely because of the early heat. At cold there is the risk of freezing, the Paulownia defeat the cold and is budding again, this process slowing their growth, but did not kill them. After the danger of frost has passed, usually grow two offshoots. It must grow 10×10^{-2} m and then will be cut the weakest. This is the way that is formed the tree trunk. It is extremely important (if planting Paulownia for wood), not to let the buds to grow, because the Paulownia tree will become a bush.

It is recommended that in the areas where the temperature variations between seasons are very high, the saplings to be covered with straws during the winter, and during the summer to have the bark painted white, to be protected from solar rays [15].

» Irrigation

After planting, the constant supply with water is also an essential problem. The recommended watering way is the drip irrigation, carried out using the dropping lines (or pipes). The regime sustained of watering (flooding 2 times per week with a minimum of 10 l/plant in the first months after planting), in conjunction with the phasal fertilization, ensure obtaining of a sustained growth regime, especially in the early stages of vegetation. This type of watering (abundant) is preferable to short frequent watering. In the following years after developing their own root system, the amount of water may be reduced, being necessary the irrigation of the culture only during the very dry periods.

» Fertilization

Paulownia requires autumnal fertilization and several additional fertilization throughout the year. In autumn, if there is the possibility to place at the base of the stem several shovels of manure, during the winter it will decompose and provide a good nutrition in the next year, and in the spring will spread fertilizer with slow release near the stem [14]. In order to ensure a good growth, Paulownia needs a soil rich in nutrients, fed strong in the vegetative period, especially with nitrogen-rich fertilizer.

» Hoeing

As cultivation measures, the soil will be maintained free of weeds by hoeing or using herbicides. It is very important to keep the soil free of weeds, especially in the first year of vegetation (due to competition for the resources of water and nutrients). If the soil is clean, a superficial hoeing at $(2-5) \times 10^{-2}$ m depth applied monthly is enough.

» Pruning (cutting) the saplings

In November, with the first signs of rime, the tree will enter into a dormant period, the leaves will dry and the entire stem will be cut from the base, in order to forcing the pivoting root of the plant to develop as quickly [12].

The ideal time for pruning the saplings at base of their stem, is in the period of vegetative rest (in late autumn, in winter and in early spring), because in November, instead of cutting the stem will create a surplus of sap [12]. Because this tender strain with tubular structure is hollow inside, and following the cold and the upcoming low temperatures, this sap will freeze and will turn into a stopper.

The ice stopper will descend through the tubular stem remained and will arrive shortly at the root, phenomenon that can be fatal for Paulownia tree. After making this cut in autumn is recommended carrying out a bed over the remaining trunk consisting of sawdust, soil and protective foil. It marks the place and in the spring the trunk is uncovered [7].

» Cutting the lateral branches

The main trunk is vertical having branches growing at an angle of 45-60 degrees from the stem, and the width of rich crown can reach at over 8 m [12]. To obtain a quality wood, with a straight trunk, beautiful, the trees are cleaned every year to a height of approx. two meters, by cutting the the lateral branches as close to the stem [15]. Above the leaves, the trunk will be cut taking care

not to tear the leaves, because otherwise will remain traces on the trunk which can reduce its value.

» Harvesting the trees

The harvesting of the trees starts after 3-4 years depending on the purpose for which were planted and the growing conditions, but due to the high growth rate, the crops intended for biomass can be harvested regularly, at very short intervals. Following the cutting of trees can be obtained a volume of timber of the highest quality of approximately 0.3 to 0.7 m³/plant (depending if harvesting is done at 4, respectively 9 years after planting), what it provides about 200 to 500 m³/ha of timber Paulownia, to which is added the rest of the branches used for the production of biomass 30-50%.

In the case of Paulownia trees cultivated for timber, after 3-5 cycles of cutting (about 15 years), the plantation must be renewed with young saplings, because both the quality of the wood material and especially the growth of the trees initially planted will decline. The growth rate and the volume of wood produced since the year 4 of life is presented in Table 1 [6].

Table 1. The growth rate [6]

The growth rate / approx. 6 months	Height [m]	Diameter [m]
1 year	2 ... 3	4 ... 6)x10 ⁻²
2 years	4 ... 5	(8 ... 10)x10 ⁻²
3 years (approx. 0.3 m ³)	10 ... 12	(15 ... 20)x10 ⁻²
6 years (approx. 0.5 m ³)	15 ... 20	(24 ... 30)x10 ⁻²
9 years (approx. 0.7 m ³)	18 ... 22	(35 ... 40)x10 ⁻²
	20 ... 25	(45 ... 55)x10 ⁻²

Initial investment in the trees planted at a distance of 4 x 4 m (to provide a density of 630 trees / ha), and revenues from the 3rd year of the potting (the 4th year after planting) and up to the extraction of the roots made in the 10th year after planting are shown in Table 2 [6].

Table 2. Investments and incomes [6]

Initial investment in trees planted at a distance of 4x4 m (density 630 pcs./ha)	Income in the 3rd year	Income in the 6th year	Income in the 9th year	Income in the 10th year
3,000 € +vat	30,000 €/ha	60,000 €/ha	90,000 €/ha	9,000 € extracting roots/ha

4. CONCLUSIONS

Because of the many advantages and potential benefits in agriculture, environment and industry offered by Paulownia tree planting, they represent a sustainable source of biofuel which can help solve the global energy crisis. The main product obtained is the hardwood, which is light, resistant and easily machinable, having a very good commercial value.

It is the fastest growing trees in the world, which can to grow by 2-3 m / year in the early years, gaining tremendous popularity and because it regenerates quickly, is a good melliferous tree (being more prolific than acacia at the honey production) and an excellent plant for carbon sequestration and oxygen release, contributing to the slow down effect of global warming which we are facing and being a possible solution to the problem of global deforestation.

Compliance with planting and maintenance technology of the Paulownia leads to obtaining of high productions of high quality of wood mass (200 m³/ha when the plantation is harvested in cycles of 3 years, except for the first harvest which is made at 4 years after planting), or of 500 m³/ha when the plantation is harvested after 10 years after planting), as well as to the production of large amounts of biomass in a short period of time.

Note

This paper is based on the paper presented at ISB-INMA TEH' 2015 International Symposium (Agricultural and Mechanical Engineering), organized by „Politehnica” University of Bucharest - Faculty of Biotechnical Systems Engineering, National Institute of Research-Development for Machines and Installations Designed to Agriculture and Food Industry - INMA Bucharest, EurAgEng - European Society of Agricultural Engineers and Romanian Society of Agricultural Engineers - SIMAR, in Bucharest, ROMANIA, between 29 - 31 October, 2015, referred here as [17].

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– International Journal of Engineering



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