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Review

Cultivation Potential and Uses of Paulownia Wood: A Review

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Abstract: This review aimed to determine the current state of research on the growth conditions and use pertaining to paulownia wood, mainly in European countries where paulownia has been introduced only relatively recently. Several studies carried out on *Paulownia* hybrids have shown significant differences in the growth dynamics of individual clones in their response to local environmental and climatic conditions. For example, dry biomass production yields in the second year of cultivation range from 1.5 t ha^{-1} to as much as 14 t ha^{-1}. This diversity has manifested itself not only in growth characteristics but also in the properties of the wood and the possibilities for its use. Despite having clear similarities to the genus *Paulownia*, the cultivation of species and hybrids under different conditions has produced varying results. The best growing conditions for this wood (that make economic sense) are in the Middle East and Southern Europe. These regions have accumulated the most experience because of the earlier establishment of the crop. Today, paulownia cultivation is dominated by hybrids with selected traits that are propagated mainly in vitro. The most commonly planted hybrids include the clones in vitro 112, Cotevisa 2 and Shan Tong. The growth results and production capacity in central European countries are lower compared to Southern Europe. Experiments on paulownia cultivation are still relatively young, mainly consisting of replicating the cultivation of hybrids developed in Asia or Southern Europe. However, agronomic procedures are being developed and reactions to local climatic conditions are being studied. It is likely that, in the next few years, the profitability of growing paulownia in these regions will become apparent.

Keywords: hybrid; biomass; wood properties; fast-growing; plantation; cultivation

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1. Introduction

Climate change has led to a rapid increase in research into reducing carbon dioxide (CO_2) emissions. One form of reducing CO_2 emissions is the use of alternative energy sources, including biomass. Various forecasts have predicted a steady increase in demand for the use of wood and wood-based materials until at least 2050 [1–5]. There is a rapidly growing interest, worldwide, in fast-growing wood species that can be used for biomass [6–8]. As one of the fastest-growing tree species in the world, the genus *Paulownia* has attracted enormous interest from academia and industry in recent years. Several research programs have been launched and experiments performed in order to verify the possibility of growing and using paulownia wood as a raw material [9–14]. These research programs are being carried out simultaneously across a variety of fields, and their number is growing by the month. On the one hand, this is a positive development, leading to a broad exploration of the possibilities of using paulownia, but on the other hand, numerous limitations are being discovered. Doubts have also been expressed about the previous optimism regarding universal fast-growing species. The genus *Paulownia* is native to China but has quickly gained popularity throughout Asia, the USA, Australia, and Europe [15]. Research on its cultivation has also been conducted in central Africa [16]. The aim of this review was to determine the current state of the research on its growing conditions and areas in which paulownia wood can be used, mainly in European countries and the Middle East, as these areas have seen increased interest in paulownia wood over the last 20 years.

Botanical Description

Paulownia tomentosa (Thunb.) Steud and *P. fortunei* (Seem.) Hemsl. are genera/species of plants that belong to the family Paulowniaceae but that were historically included in the genus *Catalpa* Scop. and the family Scrophulariaceae. Modern genetic research has updated the systematic affiliation of *Paulownia*. Further distinctions were made in the families Scrophulariaceae and Bignoniaceae, leading to the new family Paulowniaceae being separated out, the Paulowniaceae being genetically closer to the Lamiaceae than the Scrophulariaceae [17,18]. There is currently no consensus on the number of species of *Paulownia*, with between six and a dozen species being listed [15,19].

The name 'paulownia' was given to the tree in honor of Anna Pavlovna Romanova, Grand Duchess of Russia, and later, Queen of the Netherlands, who sponsored Philipp von Siebold's second expedition to Japan in 1861 [20,21]. The tree has an umbrella-shaped, low-set crown, and the green parts of the plant are covered with fine hairs. The bark is grey-brown or black, smooth, and covered with numerous lenticels, with vertical cracks appearing with age. The young plant develops large leaves that are 15–30 cm long and 10–20 cm wide (*P. tomentosa*); in older plants, these are smaller [22,23]. Paulownias develop many branches in the wild but will develop a single trunk in close quarters or with specific pruning techniques. Eight years of research into different techniques, including budding branches and pruning development, have yielded varying results. Optimal results have been obtained for moderate-intensity pruning as the best solution for rapid growth in budding branches and the development of an extended trunk [24]. Paulownias have a deep and well-developed root system that forms several branches and usually reaches depths of 2 m. Recorded examples of root systems that are nearly three times as wide as the crown have been reported [23]. Their strong and rapidly growing root systems can also penetrate to greater depths under favorable conditions and can be used, for example, to stabilize landslides [25].

2. Cultivation

2.1. Reproduction

Paulownias reproduce generatively and vegetatively; however, under industrial conditions, reproduction is almost entirely vegetative. Historically, the oldest reproduction method has been via root-splitting, which is also used for natural species [23]. Root-splitting at an early developmental stage—known as the mini-cuttings technique [26]—or activating the rooting process for green cuttings [27] have also been used. However, the primary means of propagation for many clones is via in vitro propagation [28–33]. One of the most important steps in the reproduction phase is the production of a healthy, well-developed root system, so some of the research has focused primarily on this issue [34–36].

2.2. Hybrids

The most commonly cultivated species are *P. tomentosa*, *P. elongata*, *P. fortunei*, *P. taiwaniana*, *P. fargesii*, *P. galbrata* and *P. catalpifolia* [15,37]. In the early introduction of paulownias worldwide, pure botanical species were used. One of the first countries to introduce it on a large scale was the US, with paulownias (*P. tomentosa*) being imported around 1840. Because of its quick growth, it was named "the tree of the future". Over the past 150 years, it has spread throughout the various states, causing a great deal of trouble that has resulted in a heated debate regarding all species of *Paulownia*. *Paulownia tomentosa* has officially been declared an invasive species, so much so that it has been eradicated from many states. More lenient treatment has been given to *P. elongata*, which is not as invasive but is also accepted reluctantly. *Paulownia* in the US has as many opponents as supporters, and discussions regarding the genus are heated because the existing crops make their owners substantial profits [38].

Recent studies have shown that *P. tomentosa* can spread in areas where stands have been damaged by various disasters and disturbances, especially in the canopy [39]. In some countries, certain species of *Paulownia* have been declared dangerous, such as

P. tomentosa, which has been recognized as an invasive species in Austria [40]. The Czech Republic, too, has taken note of it, giving it the status of an alien species requiring constant monitoring [41]. State authorities in Poland have also been cautious about the introduction of paulownias on a mass scale [42]. Natural *Paulownia* species are still being grown throughout Asia, as far as Turkey, but are increasingly being replaced by hybrids. In some countries, such as Bulgaria, hybrids have only gained importance as a potential product after previous attempts to cultivate pure species failed [14,29]. For the production of hybrids, individuals are selected from several popular species that exhibit high productivity and high environmental adaptability, including *P. elongata* × *P. fortunei* [43,44] and *P. fortunei* × *P. tomentosa* [45]. Some of the best-known hybrids are the clones in vitro 112 [10,19,46], Cotevisa 2, Sundsu 11 [47] and Shan Tong [48,49]. Examples of less well-known hybrids include Arctic [37] and the selected genotypes PWCOT-2, PW-105, PWL-1, PWST-33 and PWST-11 [50]. There are also naturally occurring hybrids, such as *P. taiwaniana* from a cross between *P. kawakamii* and *P. fortunei* [51,52]. Sometimes, more unusual hybrids are found, such as the 9501 ((*P. fortunei* × *P. elongate*) × (*P. fortunei* × *P. tomentosa*)) [49]. The paulownia plantations are established at a specific density depending on the end-use. They are usually planted at a spacing of 2 × 1.5 m^2 to 4 × 4 m^2. For biomass production, about 2000–3300 plants/ha are planted, while for timber production, far fewer are planted, about 550–750 trees/ha [10,19]. *Paulownia* hybrids are grown in short, 6–10-year cycles for their roundwood, but these cycles can be even shorter for biomass [10].

2.3. Growth Conditions

The most well-known feature of paulownia is its ability to reach gigantic sizes in a very short time. In China, it has been said of the paulownia that it "looks like a pole in one year, an umbrella in three years and can be cut into boards in five years" [23]. Record-breaking specimens have been described in China, such as the 80-year-old *P. fortunei* growing in Kweichow Province, which reached a height of 49.5 m, a diameter at breast height (DBH) of 202 cm and a wood volume of 34 m^3; another, at 90 years of age, had a 224 cm DBH and 44 m^3 wood volume. Among the younger trees, an 11-year-old *P. fortunei*, grown in the Guangxi Zhuang Autonomous Region of southern China, measured 22 m tall and had a DBH of 75.1 cm with a wood volume of 3.69 m^3. Similar sizes have also been achieved by *P. elongata* [23]. Under native conditions in China, paulownias typically attain a 30–40 cm DBH in 10 years and produce around 0.3–0.5 m^3 of wood, although in optimal conditions, useful wood can be produced in 5–6 years [23]. Using natural species as crops has been a popular undertaking in China and Southeast Asia for centuries. Compared to other species, paulownias perform very well in terms of growth dynamics, even compared to the fastest-growing poplars [53]. Other studies have confirmed that, compared to other fast-growing trees, such as willow, poplar, eucalyptus and red oak, paulownias achieve by far the greatest growth under optimum conditions [54]. These conditions—-especially light levels—-impact photosynthesis, which paulownia growth benefits from under optimal conditions and is limited by unfavorable conditions. This tree requires light intensities of between 20,000 and 30,000 lux for optimal growth [19]. Paulownias perform photosynthesis based on C4-cycle enzymes [15], as opposed to the classical C3-cycle characteristic of most plants [55]. Their greater photosynthetic efficiency in the right conditions enables paulownias to gain weight quickly in a short period. Although C4 mechanisms are present in paulownias, hybrid lines tend to exhibit C3 activity [56]. The activity of enzymes involved in the C4 cycle is highly variable and often limited. Paulownias are greatly affected by their growth and development conditions, especially the stress caused by drought or salinity, for example [55–57]. Through these mechanisms, paulownias can show high adaptation to environmental stress conditions. However, their intensive growth requires a great deal of water—from 1000 to 2000 L per seedling in the first growing season [43]. Studies have emphasized the particular importance of watering in the first months of growth [58,59]. The water supply can also contribute to the production of more leaves and, consequently, increased shoot growth [60]. Paulownias require permeable soil with a pH value above

5 (5–8.9) and an optimum temperature of 15–16 °C. Researchers have pointed out, however, that mass production greatly depends on soil quality, as expressed by the soil quality index [61]. Because of the rapidity of paulownia biomass production, there may be notable changes in the soil. After one year of soil monitoring, it was found that some microbiological parameters had decreased around the trees, which was related to a decrease in the nutrient content [62]. Other researchers have reported similar changes related to soil microbial activity and the soil's microbial community [63]. One proposed solution has been the use of residues produced by the forest biomass industry. This mainly involves the use of pine bark and ash biomass. Soil enriched with these components can maintain a balance between microbial activity and the community [63].

Paulownias have shown sensitivity to soil salinity, which is often a characteristic of semi-arid regions. Sometimes, this condition can be intensified by the evapotranspiration of the paulownia. This susceptibility is not the same for all *Paulownia* species; it has been recommended that lines of resistant hybrids should be developed [64]. Stress caused by soil salinity can enhance the effect of high light stress, consequently reducing photosynthetic efficiency [65]. The optimum air temperature for rapid paulownia growth is 27 °C but the spectrum of extreme temperatures that they can tolerate is broad, ranging from −25 to 47 °C [19]. However, these values vary by species, the natural tolerance of minimum temperatures being −20 °C for *P. tomentosa*, −15 °C to −18 °C for *P. elongata* and *P. catalpifolia*, and −5 °C to −10 °C for *P. fortunei*, *P. kawakamii* and *P. fargesii*. Introduction experiments conducted in China have resulted in only partial survival at lower temperatures [23]. As hybrids are currently being grown mainly in southern Europe, where severe frosts do not occur, there is no confirmed data on the frost resistance of introduced hybrids. However, some observations have been made on the survival of young seedlings in regions where frosts and freezing occur. Seedling survival in Turkish experiments on seedlings that originated in China was determined to be 60–90%, with one experiment resulting in only a 50% survival rate [66]. In Northern Ireland, where the conditions are quite different, survival ranged from 70% to 95% for hybrids with Spanish origins, except for one study where the survival rate was only 20%, while the survival of hybrids with Moroccan origins ranged from 30% to 33.3% [50]. Some authors have also reported that all their seedlings died in winter. Ulu et al. [66], in one of their experiments, reported that all the seedlings growing in Gölköy, Turkey (at 1400 m) died during the winter of 1999. Other authors have also reported significant numbers of young seedlings that did not survive the winter [67]. Some studies have pointed to frost as being particularly damaging to the growth of young paulownia seedlings when the shoots are green—-that is, at the beginning of winter or during spring frosts. According to the study by Ayan [45], all the top shoots froze in winter. Research carried out in the Czech Republic has shown unsatisfactory growth due to frost in the clone in vitro 112 in the first two years of cultivation [46,68]. Other researchers have recorded heavy snow damage in the winter of 2001 at the Ulubey site in Turkey [66].

Another factor limiting the growth of paulownias is the length of the growing season, which is variable in Central European climate conditions. In comparing the length of the growing season of the *Paulownia* Oxytree (clone in vitro 112) in north-eastern Poland, a 28-day shorter growing season was recorded in 2019 compared to 2018 [69]. Paulownias have very large leaves in their juvenile state, and the stem is not sufficiently woody at that stage, making it susceptible to mechanical damage. Therefore, another damaging factor can be strong winds, which, in open conditions, can destroy an entire plantation [70]. Experiments in New Zealand have shown that young trees and branches are susceptible to damage from wind speeds as low as 40 km hr^{-1}, and that wind can restrict tree growth even after 3–4 years of age [71].

2.4. Diseases

Like any plant, paulownias can get sick and are susceptible to various pathogens. The most well-known disease in paulownia is witches' broom, a condition that has been observed in China for many years [23,72]. Modern studies have determined phytoplasma (a parasite) to be the causal agent of witches' broom, which is potentially transmissible between paulownia trees [73,74]. The mechanism of activity is probably related to gene-expression changes in response to the phytoplasma [75,76]. Some studies have suggested that there may be genetic resistance to the disease in the cultivar *P. tomentosa* × *P. fortunei* [77]. In addition, other diseases have been found, such as *Phytophthora* root and collar rot [78] and rot caused by *Trametes hirsuta* in Serbia [79]. Recent reports have indicated the presence of nematodes (*Meloidogyne hapla*) in the roots of *P. tomentosa* in Poland [80,81].

3. Paulownia Wood Properties and Uses

3.1. Wood Structure

Paulownias have light yellow to light red heartwood. The boundary between the sapwood and heartwood is not clearly defined. The sapwood is very narrow and usually contains one or two annual rings. Annual rings are clearly visible in all cross-sections. The wood has a ring-porous or semi-ring-porous structure. The vessels are either barely visible or are not visible at all, and the tree rays are visible only under magnification [23]. The vessels are oval in shape and can be divided into early-wood vessels and late-wood vessels, the latter being 3 to 10 times smaller. Surrounded by a broad band of parenchyma of varying shapes, the rays are narrow, usually occupying a single row up to 0.5 mm high, although multi-seriate rays do also occur [23,82,83]. The heartwood is sensitive to discoloration. Several factors can cause such color changes, which can be divided into three groups—-chemical discoloration, microbial discoloration and photo-discoloration [84]. The aging of the wood also causes distinct color changes, with natural changes being less obvious than those induced artificially by ultraviolet light or high temperature [85]. It is well known that thermal modification causes similar color changes in other wood species. Suri et al. [86] described these changes in paulownia wood.

3.2. Wood Properties

In terms of their physical and mechanical properties, paulownias are most similar to willows and poplars. However, the findings of many of the works on this subject relate to different crop origins and locations. The experiments that have been carried out often employed different methodological assumptions; therefore, the results are sometimes difficult to compare. Paulownia wood density, with a 12% moisture content, ranges from 220 to 350 kg m^{-3}, but most often oscillates around 270 kg m^{-3} [87–91]. Variability in paulownia wood density is caused mainly by different growth conditions, although this differs between the species *P. tomentosa*, *P. elongata* and *P. fortunei*, with a slightly higher density commonly being attributed to *P. tomentosa* [87,89]. Occasionally, as indicated by certain authors [92], a density of above 400 kg m^{-3} has been measured (Shan Tong, Bulgaria). Paulownia wood static bending strength ranges from 23.98 to 43.56 MPa, depending on the species, while the modulus of elasticity ranges from 2651 to 4917 MPa [44,89,93,94], or even up to 5900 MPa for *P. tomentosa* [87]. In both standing-tree and log tests performed using non-destructive methods, a higher modulus of elasticity has been reported for trees with larger diameters [95].

The physical and mechanical properties of paulownias have been found to be subject to a number of variations during the drying of the sawn timber. Depending on the technological process used, these variations may be either highly significant or non-significant [96]. Paulownias have a high strength-quality factor, which equates to a high strength-to-density ratio. For the Cote-2 hybrid, this has been measured as up to 9.2 km [91]. For specific applications, this is a most useful parameter, especially where very lightweight but robust structures are required, such as in composite construction panels [45,97]. All these data on paulownia wood indicate quite wide variations in the different species' properties; therefore, when talking about paulownia wood, it is important to have a specific species in mind. This issue has been highlighted by Feng et al. [98], who tested 23 clones and demonstrated a phenotypic variation in the wood properties of 11.75% and a genetic variation exceeding 19.04%.

3.3. Traditional Uses of Paulownia Wood

The first descriptions of traditions related to the use of paulownia wood date back to several centuries BCE [21]. The tree was used for religious and medical purposes and was held in high esteem, being associated with birth and death. Many legends have been associated with the tree, mainly in China and Japan. The widespread cultivation of paulownias has been known since the third century CE [23]. Today, the wood is often used because of its popularity and its ability to grow under a wide range of conditions. Paulownia wood is used in plywood, engineered wood (other than construction wood), paper, veneers, hand carvings, clogs, furniture and kitchen items, such as rice pots, water buckets, bowls, spoons and sticks [22,38,99]. A frequently mentioned use for paulownia wood is in the manufacture of musical instruments [22,38,100]. Specific acoustic parameters that are not found in spruce wood may cause it to be replaced by paulownia in some instruments, resulting in new sounds. However, as a material that might be suitable for musical instruments, paulownia wood does not work well as a sound absorber. Paulownias have large vessels, but low through-pore porosity because of the large number of tyloses in the vessels. Therefore, gas permeability is low and sound absorption is poor. This reduces its quality as a soundproofing material compared to balsa or binuang [101]. It also limits the use of paulownia in applications where wood saturation is required [102,103].

One solution to this problem is the thermal modification of the wood. As determined by Kang [104], the gas permeability and sound absorption coefficient of heat-treated *P. tomentosa* increased as a result of heat treatment, depending on the temperature. Kolya and Kang [105] reached a similar conclusion, recommending hydrothermally treated paulownia for sound-absorption boards in housing applications. Yet another method, based on a supercritical CO_2 treatment, has been proposed by Xu et al. [106]. Researchers have shown that this method significantly improves the gas permeability of *P. fortunei* as a result of the reduction in the proportion of cells with tyloses [106]. Tests for suitability in the manufacture of pencils and crayons have also been positive, with tests comparing paulownia (*P. elongata*) wood to poplar (*Populus tremula*) and juniper (*Juniperus excelsa*), which are commonly used in these products, having shown great promise in terms of wood properties [107].

3.4. Pulp Industry

The utility of *P. tomentosa* in the pulp industry was pointed out decades ago in the US; however, researchers have stressed that paulownia fibers are short and are only suitable for certain grades of paper [108]. Contemporary research has verified this knowledge in a broader context. As determined by San et al. [44], based on a study conducted on a 3-year paulownia plantation, the fiber sizes take on values typical of the deciduous species useful in this industry. However, it is always important to bear in mind the specific species in question because, while the fiber lengths of the various species of *Paulownia* are similar, ranging from around 0.82 to 1.002 mm, the thickness of the cell wall varies considerably. For example, the average thickness of the fiber cell wall can vary from 3.8 to 8.6 µm between the different species of *Paulownia* [44]. Its high cellulose content (47.85%) makes it useful for the pulp industry, as indicated by Popovic and Radosevic [109], who also, however, noted that the chemical composition differed between the various species. Similar relationships and the suitability of *Paulownia* for cellulose production have also been pointed out in other studies [110–112], whereas in later studies, the biorefinery of paulownia wood has been improved in order to obtain lignocellulosic biomass for fuels, solvents and chemicals, etc. [113]. Due to paulownia wood's short production cycles, both the stem and branch wood can be used, although the latter is of lower value and is often accompanied by reaction wood; however, this can be used in paper, nanocellulose, charcoal and other applications [82,114,115].

3.5. Energy Goals

Nowadays, paulownia plantations oriented toward biomass production are gaining in popularity [12]. This tree can produce as much biomass in a year as other species can in a few years [47]. Suitable hybrids work best in this field, but the differences between the hybrids and the regions where the experiments were carried out are quite significant. Studies have shown that, for example, the clone Cotevisia 2, grown in Spain, has 1.8 times the productivity of the clone Suntzu 11. However, in two locations out of the six studied, it was Suntzu that yielded higher productivity. Both clones in the 2-year experiment showed record productivity in the Villanueva del Río y Minas region (Sevilla province, Spain), where between 7.2 and 14 t of dry matter were harvested per hectare (i.e., 3.2 and 7.4 t of C, respectively). The same clones in another region of Spain (Cordoba) showed productivity ranging from 1.7 to 2.3 t of dry matter [47]. By comparison, a 16-year experiment conducted on *P. tomentosa* in Asia yielded 38.8 t C ha^{-1}, while a 21-year experiment yielded over 105 t C ha^{-1} [90]. The experience of other researchers has also indicated that biomass production greatly depends on the hybrid used for the crop. As an example, Berdon et al. [10] determined very poor productivity from clone X1 compared to three others (112, COT2 and L1) based on a 3-year experiment conducted in southern Spain. Baier et al. [116], in a study conducted near Lake Issyk-Kul (Kyrgyzstan), demonstrated biomass production of between 1.52 and 3.41 kg per tree per season, with water consumption of between 433 and 613 l. Gyuleva et al. [117], reporting on a 5-year experiment that compared the productivity of two paulownias introduced into Bulgaria, showed that the best results came from the southwestern part of the country. *Paulownia tomentosa* had higher productivity of 3.479 t ha^{-1} (oven-dried biomass) after 2 years of growth and 36.995 t ha^{-1} after 4 years, while the productivity of *P. elongata* × *P. fortunei* was 2.730 t ha^{-1} after 2 years and 19.964 t ha^{-1} after 4 years. On degraded soils, paulownias show a very low growth rate. In a 3-year study in Spain, a biomass yield of *P. fortunei* of only 3.34 t ha^{-1} was achieved, which was very low compared to the parallel-grown *Eucalyptus globulus* (40.4 t ha^{-1}) [118].

As a tree with a high growth rate but low wood density, paulownias do not perform well at producing efficient fuel. A comparison of pellets, in terms of European standards, produced from young *P. elongata* × *P. fortunei* plantations showed their poor quality compared to *Pinus radiata* and *Eucalyptus nitens* pellets [119]. In another study, however, evaluating the production of briquettes and pellets from sawdust, satisfactory energy effects were obtained for *P. tomentosa* and *P. elongata* [120]. It may be appropriate to first apply biomass torrefaction, as proposed by Świechowski et al. [121,122], in order to get a better starting quality for fuel production. The calorific value of paulownia alone is close to that of the energy species already grown in Europe. The tested hybrids (9501 and Shan Tong) produced only slightly lower gross calorific values of 19.5 MJ kg^{-1} (hybrid 9501) and 19.6 MJ kg^{-1} (Shan Tong) than willow (19.9 MJ kg^{-1}) and poplar (19.8 MJ kg^{-1}). By contrast, the OXI hybrid (19.2 MJ kg^{-1}) had a lower calorific value [123]. Similar values have been provided by Zachar et al. [124] for *P. tomentosa* (19.71 MJ kg^{-1}).

However, today's economies require much more rapid results than are obtainable from years of observation during various experiments. To some extent, this process can be, and has been, accelerated by building mathematical models and forecasting crop development under different local conditions. As experience has shown, such models have a great future and can highlight favorable vs. unfavorable phenomena at an early stage. Stankova et al. [125,126] showed using a model that variability in dendromass production depended on the species and crop type, with variability ranging from 0.3 to 4.5 t ha^{-1} of dry matter. They also proved that most biomass is accumulated in the trunk, and only 35% of juvenile trees have branches. However, modeling faces several problems due to the complexity of the criteria that can affect forecasting, although the models are constantly developing. This is especially true for biomass planning and the forecasting of wood properties [90,127–130]. In a recent analysis, Iran, which has some experience in introducing paulownia cultivation, forecast the capacity for paulownia cultivation in an area of 160,000 km^2 [128,129]. Introducing paulownias as an important element in biomass production needs particular consideration in countries with favorable conditions for the growth of hybrids that may be competitive with native species. Research in this area is ongoing in Spain [131,132], Romania [133], Portugal [9], Italy [134], Iran [129], Kyrgyzstan [135], Serbia [54], Ukraine [136,137] and Northern Ireland [15,50], among others.

3.6. Other Modern Uses

There is currently much research being conducted that is aimed at furthering the use of paulownia wood in the production of wood plastics and composites [97,138,139] and in the production of biopolymers [140]. Paulownia wood also performs well in the production of blockboards, which act as a core layer between veneers [141], and as an ingredient for the production of lightweight particleboards [142,143]. It can also be subjected to thermal modification [144–146] or can be improved by other methods, such as high-pressure treatment, which works well for low-density woods such as paulownia [147,148]. Paulownia wood can undergo pyrolysis and conversion to gases as an energy source [149] and can be used as a feedstock for bioethanol production [13,150]. Work is also underway to examine the use of paulownia waste as a substrate for producing biohydrogen [151]. In addition to the wood, the remaining parts of the plant, such as the leaves and flowers, can be used for medicinal purposes [152–157] and as a food source for animals [153,158–160].

Attempts to use *Paulownia* species for the phytoremediation of heavy metals in contaminated soils have indicated a significant accumulation of metals, such as copper, zinc and cadmium, although this was due to their high biomass productivity rather than their metal accumulation potential [161,162]. Another study found a significant difference in lead and zinc accumulations between different hybrids [163].

4. Summary

Based on the literature review presented here, it can be concluded that the main purpose of growing paulownia in short cycles is to produce woody biomass for the energy and pulp industries, as well as for other industries related to wood processing, the creation of wood composites and biopolymers, and wood gasification, etc. To a minor extent, research is ongoing into the use of other parts of the plant, such as the leaves and flowers, in the pharmaceutical industry or for animal feed. The traditional uses of wood for furniture-making and wider mechanical processing is rather limited by the natural occurrence of *Paulownia* species and the locations where paulownia trees reach large dimensions. Experience has shown that pure species, such as *P. tomentosa* and even *P. fortunei*, are invasive so only some hybrids have been accepted into mass cultivation. Considering the regions involved, the best conditions for the growth of *Paulownia* hybrids are in southern Europe, particularly Spain, Portugal, Italy and the Balkans, and in Middle Eastern countries such as Turkey and Iran, where conditions are also much better than in countries further north. The number of positive experiences indicates great potential, which, however, varies strongly locally.

The reported technical parameters, chemical composition, requirements for growing conditions and biomass production differ significantly between different species and hybrids. The values obtained from the published studies sometimes differ by up to several dozen percent. Each time, a trial should determine the suitability of the selected species or hybrid for each specific purpose. Experiments in Central and Eastern Europe are still in the early stages due to the late migration of paulownias to these areas. However, there are already indications of lower production efficiency than in southern Europe. Several factors contribute to this finding, the most important being the shorter growing season, which significantly reduces seedling growth and biomass production. The second is low temperatures and frosts in spring and autumn. This does not rule out the possibility of introducing paulownias into this region of Europe, but further research is required, mainly to improve cultivation methods in order to best adapt the tree to the specific climatic conditions. The use of appropriate frost protection and various agrotechnical treatments can aid in this. *Paulownia* and its hybrids offer a serious alternative to many native tree species in Europe, but it is not a completely universal species and requires further research, variety selection and improved cultivation methods for introduction into production in specific regions.

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References

1. Sikkema, R.; Proskurina, S.; Banja, M.; Vakkilainen, E. How Can Solid Biomass Contribute to the EU's Renewable Energy Targets in 2020, 2030 and What Are the GHG Drivers and Safeguards in Energy- and Forestry Sectors? *Renew. Energy* **2021**, *165*, 758–772. [CrossRef]
2. Jamil, K.; Liu, D.; Gul, R.F.; Hussain, Z.; Mohsin, M.; Qin, G.; Khan, F.U. Do Remittance and Renewable Energy Affect CO_2 Emissions? An Empirical Evidence from Selected G-20 Countries. *Energy Environ.* **2021**. [CrossRef]
3. Kirikkaleli, D.; Güngör, H.; Adebayo, T.S. Consumption-Based Carbon Emissions, Renewable Energy Consumption, Financial Development and Economic Growth in Chile. *Bus. Strategy Environ.* **2022**, *31*, 1123–1137. [CrossRef]
4. Haldar, A.; Sethi, N. Effect of Institutional Quality and Renewable Energy Consumption on CO_2 Emissions−an Empirical Investigation for Developing Countries. *Environ. Sci. Pollut. Res.* **2021**, *28*, 15485–15503. [CrossRef] [PubMed]
5. Kircher, M. Economic Trends in the Transition into a Circular Bioeconomy. *J. Risk Financ. Manag.* **2022**, *15*, 44. [CrossRef]
6. Hamdan, H.Z.; Houri, A.F. CO_2 Sequestration by Propagation of the Fast-Growing *Azolla* Spp. *Environ. Sci. Pollut. Res.* **2022**, *29*, 16912–16924. [CrossRef] [PubMed]
7. Tyśkiewicz, K.; Konkol, M.; Kowalski, R.; Rój, E.; Warmiński, K.; Krzyżaniak, M.; Gil, Ł.; Stolarski, M.J. Characterization of Bioactive Compounds in the Biomass of Black Locust, Poplar and Willow. *Trees* **2019**, *33*, 1235–1263. [CrossRef]
8. Ols, C.; Bontemps, J.-D. Pure and Even-Aged Forestry of Fast-Growing Conifers under Climate Change: On the Need for a Silvicultural Paradigm Shift. *Environ. Res. Lett.* **2021**, *16*, 024030. [CrossRef]
9. Abreu, M.; Reis, A.; Moura, P.; Fernando, A.L.; Luís, A.; Quental, L.; Patinha, P.; Gírio, F. Evaluation of the Potential of Biomass to Energy in Portugal—Conclusions from the CONVERTE Project. *Energies* **2020**, *13*, 937. [CrossRef]
10. Berdón Berdón, J.; Montero Calvo, A.J.; Royano Barroso, L.; Parralejo Alcobendas, A.I.; González Cortés, J. Study of Paulownia's Biomass Production in Mérida (Badajoz), Southwestern Spain. *Environ. Ecol. Res* **2017**, *5*, 521–527. [CrossRef]
11. Dubova, O.; Voitovych, O.; Boika, O. Paulownia Tomentosa–New Species for the Industrial Landscaping. *Curr. Trends Nat. Sci.* **2019**, *8*, 19–24.
12. Magar, L.B.; Khadka, S.; Joshi, J.R.R.; Pokharel, U.; Rana, N.; Thapa, P.; Sharma, K.R.S.R.; Khadka, U.; Marasini, B.P.; Parajuli, N. Total Biomass Carbon Sequestration Ability under the Changing Climatic Condition by *Paulownia tomentosa* Steud. *Int. J. Appl. Sci. Biotechnol.* **2018**, *6*, 220–226. [CrossRef]
13. Yavorov, N.; Petrin, S.; Valchev, I.; Nenkova, S. Potential of Fast Growing Poplar, Willow and Paulownia for Bioenergy Production. *Bulg. Chem. Commun.* **2015**, *47*, 5–9.
14. Gyuleva, V. Project 'Establishment of geographical plantations of *Paulownia elongata* hybrids in Bulgaria'—contract No37 with State Agency of Forests (2007-2010). *News Bulg. Acad. Sci.* **2008**, *12*, 2–4.
15. Woods, V.B. *Paulownia as a Novel Biomass Crop for Northern Ireland?* Occasional publication No. 7; Global Research Unit AFBI Hillsborough, Agri-Food and Biosciences Institute: Hillsborough, UK, 2008.
16. Muthuri, C.W.; Ong, C.K.; Black, C.R.; Mati, B.M.; Ngumi, V.W.; van Noordwijk, M. Modelling the Effects of Leafing Phenology on Growth and Water Use by Selected Agroforestry Tree Species in Semi-Arid Kenya. *Land Use Water Resour. Res.* **2004**, *4*, 1–11. [CrossRef]
17. Kirkham, T.; Fay, M.F. 645. *Paulownia Kawakamii. Curtis's Bot. Mag.* **2009**, *26*, 111–119. [CrossRef]
18. Olmstead, R.G.; Pamphilis, C.W.; de Wolfe, A.D.; Young, N.D.; Elisons, W.J.; Reeves, P.A. Disintegration of the Scrophulariaceae. *Am. J. Bot.* **2001**, *88*, 348–361. [CrossRef] [PubMed]
19. Icka, P.; Damo, R.; Icka, E. *Paulownia tomentosa*, a Fast Growing Timber. *Ann. Valahia Univ. Targoviste Agric.* **2016**, *10*, 14–19. [CrossRef]
20. Christenhusz, M.J.M.; Fay, M.F.; Chase, M.W. *Plants of the World: An Illustrated Encyclopedia of Vascular Plants. Richmond*; Kew Publishing, The University of Chicago Press: Chicago, IL, USA, 2017; p. 581.
21. Nagata, T.; DuVal, A.; Schmull, M.; Tchernaja, T.A.; Crane, P.R. *Paulownia tomentosa*: A Chinese Plant in Japan. *Curtis's Bot. Mag.* **2013**, *30*, 261–274. [CrossRef]
22. Innes, R.J. *Paulownia tomentosa*. In: Fire Effects Information System (Online). US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. 2009. Available online: https://www.fs.fed.us/database/feis/plants/tree/pautom/all.html (accessed on 22 April 2022).
23. Zhu, Z.-H.; Chao, C.-J.; Lu, X.-Y.; Xiong, Y.G. *Paulownia in China: Cultivation and Utilization*; Asian Network for Biological Sciences and International Development Research Centre: Beijing, China, 1986.

24. Wu, L.; Wang, B.; Qiao, J.; Zhou, H.; Wen, R.; Xue, J.; Li, Z. Effects of Trunk-Extension Pruning at Different Intensities on the Growth and Trunk Form of *Paulownia tortunei*. *For. Ecol. Manag.* **2014**, *327*, 128–135. [CrossRef]
25. Huseinovic, S.; Osmanović, Z.; Bektić, S.; Ahmetbegović, S. *Paulownia elongata* Sy Hu in Function of Improving the Quality of the Environment. *Period. Eng. Nat. Sci.* **2017**, *5*, 117–123. Available online: http://pen.ius.edu.ba/index.php/pen/article/view/83 (accessed on 22 April 2022). [CrossRef]
26. Stuepp, C.A.; Zuffellato-Ribas, K.C.; Koehler, H.S.; Wendling, I. Rooting mini-cuttings of *Paulownia fortunei var. mikado* derived from clonal mini-garden. *Rev. Árvore* **2015**, *39*, 497–504. [CrossRef]
27. Temirov, J.; Shukurova, G.; Klichov, I. Study on the Influence of Stimulants on the Rooting of the Paulownia (*Paulownia*) and Tulip (*Liriodendron tulipifera*) Trees during the Propagation by Cuttings. *IOP Conf. Ser. Earth Environ. Sci.* **2021**, *939*, 012059. [CrossRef]
28. Bergmann, B.A.; Whetten, R. In Vitro Rooting and Early Greenhouse Growth of Micropropagated *Paulownia elongata* Shoots. *New For.* **1998**, *15*, 127–138. [CrossRef]
29. Gyuleva, V. Micropropagation of Hybryd Paulownia from Long-Term Preserved Seeds. *Silva Balcan.* **2010**, *11*, 45–58.
30. Magar, L.B.; Shrestha, N.; Khadka, S.; Joshi, J.R.; Acharya, J.; Gyanwali, G.C.; Marasini, B.P.; Rajbahak, S.; Parajuli, N. Challenges and Opportunity of in Vitro Propagation of *Paulownia tomentosa* Steud for Commercial Production in Nepal. *Int. J. Appl. Sci. Biotechnol.* **2016**, *4*, 155–160. [CrossRef]
31. Luca, R.; Crisan, M.; Botau, D. The Role of Nitrobenzoic Acid Derivatives on Callus Induction and Plant Regeneration in Paulownia Shan Tong. *Bull. UASVM Anim. Sci. Biotechnol.* **2016**, *73*, 2. [CrossRef]
32. Pożoga, M.; Olewnicki, D.; Jabłońska, L. In Vitro Propagation Protocols and Variable Cost Comparison in Commercial Production for *Paulownia tomentosa* × *Paulownia fortunei* Hybrid as a Renewable Energy Source. *Appl. Sci.* **2019**, *9*, 2272. [CrossRef]
33. Mohamad, M.E.; Awad, A.A.; Majrashi, A.; Esadek, O.A.A.; El-Saadony, M.T.; Saad, A.M.; Gendy, A.S. In Vitro Study on the Effect of Cytokines and Auxins Addition to Growth Medium on the Micropropagation and Rooting of *Paulownia* Species (Paulownia Hybrid and *Paulownia tomentosa*). *Saudi J. Biol. Sci.* **2021**, *29*, 1598–1603. [CrossRef]
34. Saiju, H.K.; Bajracharya, A.; Rajbahak, B.; Ghimire, S. Comparative Study of Growth Statistics of Two Species of Paulownia and Optimization of Rooting Methods. *Nepal J. Biotechnol.* **2018**, *6*, 11–15. Available online: https://www.nepjol.info/index.php/NJB/article/download/22330/19016 (accessed on 22 April 2022). [CrossRef]
35. Filipova, L.; Matskevych, V.; Karpuk, L.; Andriievsky, V.; Vrublevsky, A.; Pavlichenko, A.; Krupa, N. Features of Pavlovnia Plants Post-Septic Adaptation. In Proceedings of the Multidisciplinary Conference for Young Researchers, Bila Tserkva, Ukraine, 22 November 2019; Available online: http://193.138.93.8/handle/BNAU/3293 (accessed on 22 April 2022).
36. Filipova, L.; Matskevych, V.; Karpuk, L.; Stadnyk, A.; Andriievsky, V.; Vrublevsky, A.; Krupa, N.; Pavlichenko, A. Features of Rooting Paulownia in Vitro. *Egypt. J. Chem.* **2019**, *62*, 57–63. [CrossRef]
37. Jensen, J.B. An Investigation into the Suitability of Paulownia as an Agroforestry Species for UK & NW European Farming Systems. Master's Thesis, Department of Agriculture & Business Management, Scotland's Rural College, Edinburgh, UK, 2016. [CrossRef]
38. Snow, W.A. Ornamental, Crop, or Invasive? The History of the Empress Tree (*Paulownia*) in the USA. *For. Trees Livelihoods* **2015**, *24*, 85–96. [CrossRef]
39. Chongpinitchai, A.R.; Williams, R.A. The Response of the Invasive Princess Tree (*Paulownia tomentosa*) to Wildland Fire and Other Disturbances in an Appalachian Hardwood Forest. *Glob. Ecol. Conserv.* **2021**, *29*, e01734. [CrossRef]
40. Essl, F. From ornamental to detrimental? The incipient invasion of Central Europe by *Paulownia tomentosa*. *Preslia* **2007**, *79*, 377–389.
41. Pergl, J.; Sádlo, J.; Petrusek, A.; Laštůuvka, Z.; Musil, J.; Perglova, I.; Šanda, R.; Šefrová, H.; Šíma, J.; Vohralik, V. Black, Grey and Watch Lists of Alien Species in the Czech Republic Based on Environmental Impacts and Management Strategy. *NeoBiota* **2016**, *28*, 1. [CrossRef]
42. Jakubowski, M.; Tomczak, A.; Jelonek, T.; Grzywiński, W. The use of wood and the possibility of planting trees of the *Paulownia* genus. *Acta Sci. Pol. Silv. Colendar. Ratio Ind. Lignar.* **2018**, *17*, 291–297.
43. García-Morote, F.A.; López-Serrano, F.R.; Martínez-García, E.; Andrés-Abellán, M.; Dadi, T.; Candel, D.; Rubio, E.; Lucas-Borja, M.E. Stem Biomass Production of *Paulownia elongata* × *P. fortunei* under Low Irrigation in a Semi-Arid Environment. *Forests* **2014**, *5*, 2505–2520. [CrossRef]
44. San, H.P.; Long, L.K.; Zhang, C.Z.; Hui, T.C.; Seng, W.Y.; Lin, F.S.; Hun, A.T.; Fong, W.K. Anatomical Features, Fiber Morphological, Physical and Mechanical Properties of Three Years Old New Hybrid Paulownia: Green Paulownia. *Res. J. For.* **2016**, *10*, 30–35. [CrossRef]
45. Ayan, S.; Sıvacıoğlu, A.; Bilir, N. Growth Variation of Paulownia Sieb. and Zucc. Species and Origins at the Nursery Stage in Kastamonu-Turkey. *J. Environ. Biol.* **2006**, *27*, 499–504. [PubMed]
46. Kadlec, J.; Novosadová, K.; Pokornỳ, R. Preliminary Results from a Plantation of Semi-Arid Hybrid of Paulownia Clone in Vitro 112®under Conditions of the Czech Republic from the First Two Years. *Balt. For.* **2021**, *27*. [CrossRef]
47. Zuazo, V.H.D.; Bocanegra, J.A.J.; Torres, F.P.; Pleguezuelo, C.R.R.; Martínez, J.R.F. Biomass Yield Potential of Paulownia Trees in a Semi-Arid Mediterranean Environment (S Spain). *Int. J. Renew. Energy Res. IJRER* **2013**, *3*, 789–793.
48. Luca, R.; Camen, D.; Danci, M.; Petolescu, C. Research Regarding the Influence of Culture Conditions upon the Main Physiological Indices at Paulownia Shan Tong. *J. Hortic. For. Biotechnol.* **2014**, *18*, 74–77.
49. Sedlar, T.; Šefc, B.; Drvodelić, D.; Jambreković, B.; Kučinić, M.; Ištok, I. Physical Properties of Juvenile Wood of Two Paulownia Hybrids. *Drv. Ind. Znan. Časopis Pitanja Drv. Tehnol.* **2020**, *71*, 179–184. [CrossRef]

50. Olave, R.; Forbes, G.; Muñoz, F.; Lyons, G. Survival, Early Growth and Chemical Characteristics of Paulownia Trees for Potential Biomass Production in a Cool Temperate Climate. *Ir. For.* **2015**, *72*, 42–57.
51. Wang, W.Y.; Pai, R.C.; Lai, C.C.; Lin, T.P. Molecular Evidence for the Hybrid Origin of *Paulownia taiwaniana* Based on RAPD Markers and RFLP of Chloroplast DNA. *Theoret. Appl. Genet.* **1994**, *89*, 271–275. [CrossRef] [PubMed]
52. Wang, H.W.; Duan, J.M.; Zhang, P.; Cheng, Y.Q.; Wu, J.W.; Wang, G.Z. Microsatellite Markers in *Paulownia kawakamii* (Scrophulariaceae) and Cross-Amplification in Other Paulownia Species. *Genet. Mol. Res.* **2013**, *12*, 3750–3754. [CrossRef] [PubMed]
53. Navroodi, I.H. Comparison of Growth and Wood Production of *Populus deltoides* and *Paulownia fortunei* in Guilan Province (Iran). *Ind. J. Sci. Technol.* **2013**, *6*, 84–88. [CrossRef]
54. Janjić, Z.; Janjić, M. Paulownia, Characteristics and Perspectives of Its Exploitation. *Innov. Woodwork. Ind. Eng. Des.* **2019**, *16*, 34–41.
55. Sage, R.F.; Sultmanis, S. Why Are There No C4 Forests? *J. Plant Physiol.* **2016**, *203*, 55–68. [CrossRef] [PubMed]
56. Ivanova, K.; Georgieva, T.; Markovska, Y. A possible role of C4 photosynthetic enzymes in tolerance of two paulownia hybrid lines to salinity. *Annu. L'université Sofia* **2016**, *101*, 132–140.
57. Wang, J.; Wang, H.; Deng, T.; Liu, Z.; Wang, X. Time-Coursed Transcriptome Analysis Identifies Key Expressional Regulation in Growth Cessation and Dormancy Induced by Short Days in Paulownia. *Sci. Rep.* **2019**, *9*, 16602. [CrossRef] [PubMed]
58. Rad, J.E.; Mirkala, S.R.M. Irrigation Effects on Diameter Growth of 2-Year-Old *Paulownia tomentosa* Saplings. *J. For. Res.* **2015**, *26*, 153–157. [CrossRef]
59. Ptach, W.; Langowski, A.; Rolbiecki, R.; Rolbiecki, S.; Jagosz, B.; Grybauskienė, V.; Kokoszewski, M. The Influence of Irrigation on the Growth of Paulownia Trees at the First Year of Cultivation in a Light Soil. In Proceedings of the 8th International Scientific Conference Rural Development, Kaunas, Lithuania, 23–24 November 2017; pp. 763–768. [CrossRef]
60. Langowski, A.; Rolbiecki, R.; Rolbiecki, S.; Ptach, W.; Wrobel, P. Effect of sprinkler irrigation on growth of paulownia Shan Tong trees at first two years of cultivation in light soil. In Proceedings of the 18th International Scientific Conference Engineering for Rural Development, Jelgava, Latvia, 22–24 May 2019. [CrossRef]
61. Tu, J.; Wang, B.; McGrouther, K.; Wang, H.; Ma, T.; Qiao, J.; Wu, L. Soil Quality Assessment under Different *Paulownia fortunei* Plantations in Mid-Subtropical China. *J. Soils Sediments* **2017**, *17*, 2371–2382. [CrossRef]
62. Woźniak, M.; Gałązka, A.; Siebielec, G.; Frąc, M. Can the Biological Activity of Abandoned Soils Be Changed by the Growth of *Paulownia elongata* × *Paulownia fortunei*?—Preliminary Study on a Young Tree Plantation. *Agriculture* **2022**, *12*, 128. [CrossRef]
63. Moreno, J.L.; Bastida, F.; Ondoño, S.; García, C.; Andrés-Abellán, M.; López-Serrano, F.R. Agro-Forestry Management of Paulownia Plantations and Their Impact on Soil Biological Quality: The Effects of Fertilization and Irrigation Treatments. *Appl. Soil Ecol.* **2017**, *117–118*, 46–56. [CrossRef]
64. Ivanova, K.; Geneva, M.; Anev, S.; Georgieva, T.; Tzvetkova, N.; Stancheva, I.; Markovska, Y. Effect of Soil Salinity on Morphology and Gas Exchange of Two Paulownia Hybrids. *Agrofor. Syst.* **2019**, *93*, 929–935. [CrossRef]
65. Stefanov, M.; Yotsova, E.; Markovska, Y.; Apostolova, E.L. Effect of High Light Intensity on the Photosynthetic Apparatus of Two Hybrid Lines of Paulownia Grown on Soils with Different Salinity. *Photosynthetica* **2018**, *56*, 832–840. [CrossRef]
66. Ulu, F.; Çetiner, Ş.; Eren, N.; Ayan, S. Results of the Field Stage in Third Year of Species and Provenances Trials of *Paulownia* Sieb. &Zucc. in Eastern Black Sea Region. *Kast. Univ.* **2005**. Available online: http://earsiv.kastamonu.edu.tr:8080/jspui/handle/123456789/344 (accessed on 21 April 2021).
67. Smarul, N.; Tomczak, K.; Tomczak, A.; Jakubowski, M. Growth of paulownia 'Shan Tong' seedlings at the Forest Experimental Station in Murowana Goślina in 2017 (In Polish). *Studia I Mater. CEPL* **2018**, *20*, 158–165.
68. Kadlec, J.; Novosadová, K.; Pokorný, R. Impact of Different Pruning Practices on Height Growth of Paulownia Clon in Vitro 112®. *Forests* **2022**, *13*, 317. [CrossRef]
69. Lisowski, J.; Porwisiak, H. Oxytree tree biometric features (paulownia clon in vitro 112) after third and fourth years of cultivation. *Zesz. Nauk. WSA W Łomży Res. Books WSA Łomża* **2020**, *41*, 41–48.
70. Jakubowski, M.; Dobroczyński, M. Density of Wood of 2year Paulownia Plantation Damaged by Wind in Poland. *For. Lett.* **2020**, *113*, 8–11. Available online: http://www.forestryletters.pl/index.php/forestryletters/article/view/77 (accessed on 22 April 2021).
71. Barton, I.L.; Nicholas, I.D.; Ecroyd, C.E. *Paulownia. Forest Research Bulletin*; New Zealand Forest Research Institute: Rotoura, New Zeland, 2007.
72. Tokushige, Y. Witches-Broom of Paulownia Tomentosa L. *J. Fac. Agric. Kyushu Univ.* **1951**, *10*, 45–67. [CrossRef]
73. Yue, H.N.; Wu, Y.F.; Shi, Y.Z.; Wu, K.K.; Li, Y.R. First Report of Paulownia Witches'-Broom Phytoplasma in China. *Plant Dis.* **2008**, *92*, 1134. [CrossRef]
74. Gao, R.; Zhang, G.-M.; Lan, Y.-F.; Zhu, T.-S.; Yu, X.-Q.; Zhu, X.-P.; Li, X.-D. Molecular Characterization of Phytoplasma Associated with Rose Witches'-Broom in China. *J. Phytopathol.* **2008**, *156*, 93–98. [CrossRef]
75. Cao, X.; Fan, G.; Deng, M.; Zhao, Z.; Dong, Y. Identification of Genes Related to Paulownia Witches' Broom by AFLP and MSAP. *Int. J. Mol. Sci.* **2014**, *15*, 14669–14683. [CrossRef]
76. Cao, Y.; Sun, G.; Zhai, X.; Xu, P.; Ma, L.; Deng, M.; Zhao, Z.; Yang, H.; Dong, Y.; Shang, Z.; et al. Genomic Insights into the Fast Growth of Paulownias and the Formation of Paulownia Witches' Broom. *Mol. Plant* **2021**, *14*, 1668–1682. [CrossRef]
77. Du, T.; Wang, Y.; Hu, Q.-X.; Chen, J.; Liu, S.; Huang, W.-J.; Lin, M.-L. Transgenic Paulownia Expressing Shiva-1 Gene Has Increased Resistance to Paulownia Witches' Broom Disease. *J. Integr. Plant Biol.* **2005**, *47*, 1500–1506. [CrossRef]

78. Aloi, F.; Riolo, M.; La Spada, F.; Bentivenga, G.; Moricca, S.; Santilli, E.; Pane, A.; Faedda, R.; Cacciola, S.O. Phytophthora Root and Collar Rot of Paulownia, a New Disease for Europe. *Forests* **2021**, *12*, 1664. [CrossRef]
79. Milenković, I.; Tomšovský, M.; Karadžić, D.; Veselinović, M. Decline of *Paulownia tomentosa* Caused by *Trametes hirsuta* in Serbia. *For. Pathol.* **2018**, *48*, e12438. [CrossRef]
80. Skwiercz, A.; Dobosz, R.; Flis, L.; Damszel, M.; Litwińczuk, W. First Report of Meloidogyne Hapla on *Paulownia tomentosa* in Poland. *Acta Soc. Bot. Pol.* **2019**, *88*, 3628. [CrossRef]
81. Skwiercz, A.T.; Zapałowska, A.; Litwińczuk, W.; Stefanovska, T.; Puchalski, C. Plant Parasitic Nematodes on *Paulownia tomentosa* in Poland. *Preprints* **2020**, 2020010047. [CrossRef]
82. Qi, Y.; Jang, J.H.; Park, S.H.; Kim, N.H. Anatomical and Physical Characteristics of Korean Paulownia (*Paulownia coreana*) Branch Wood. *J. Korean Wood Sci. Technol.* **2014**, *42*, 510–515.
83. Qi, Y.; Jang, J.; Hidayat, W.; Lee, A.; Park, S.; Lee, S.; Kim, N. Anatomical Characteristics of *Paulownia tomentosa* Root Wood. *J. Korean Wood Sci. Technol.* **2016**, *44*, 157–165. [CrossRef]
84. Gao, W. Review on the Discoloration Treatment Technology of Paulownia Wood. *J. Phys. Conf. Ser.* **2019**, *1213*, 052040. [CrossRef]
85. Liu, X.Y.; Timar, M.C.; Varodi, A.M.; Yi, S.L. Effects of Ageing on the Color and Surface Chemistry of Paulownia Wood (*P. Elongata*) from Fast Growing Crops. *BioResources* **2016**, *11*, 9400–9420. [CrossRef]
86. Suri, I.F.; Kim, J.H.; Purusatama, B.D.; Yang, G.U.; Prasetia, D.; Lee, S.H.; Hidayat, W.; Febrianto, F.; Park, B.H.; Kim, N.H. Comparison of the Color and Weight Change in *Paulownia tomentosa* and *Pinus koraiensis* Wood Heat-Treated in Hot Oil and Hot Air. *BioResources* **2021**, *16*, 5574–5585. [CrossRef]
87. Akyildiz, M.H.; Kol Sahin, H. Some Technological Properties and Uses of Paulownia (*Paulownia tomentosa* Steud.) Wood. *J. Environ. Biol.* **2010**, *31*, 351–355.
88. Kozakiewicz, P.; Laskowka, A.; Ciołek, S. A Study of Selected Features of Shan Tong Variety of Plantation Paulownia and Its Wood Properties. *Ann. Wars. Univ. Life Sci. SGGW For. Wood Technol.* **2020**, *111*, 116–123. [CrossRef]
89. Kaymakci, A.; Bektas, I.; Bal, B. Some Mechanical Properties of Paulownia (*Paulownia elongata*) Wood. In Proceedings of the International Caucasian Forestry Symposium, Artvin, Turkey, 24–26 September 2013; pp. 24–26.
90. Joshi, N.R.; Karki, S.; Adhikari, M.D.; Udas, E.; Sherpa, S.; Karki, B.S.; Chettri, N.; Kotru, R.; Ning, W. *Development of Allometric Equations for Paulownia tomentosa (Thunb) to Estimate Biomass and Carbon Stocks: An Assessment from the ICIMOD Knowledge Park, Godavari, Nepal*; International Centre for Integrated Mountain Development: Kathmandu, Nepal, 2015.
91. Lachowicz, H.; Giedrowicz, A. Characteristics of the technical properties of Paulownia COTE- 2 wood. *Sylwan* **2020**, *164*, 414–423.
92. Bardarov, N.; Popovska, T. Examination of the properties of local origin paulownia wood. (*Paulownia* sp. Siebold & Zucc.). Housing provision as an element of the quality of life in the regions of Bulgaria. *Manag. Sustain. Dev.* **2017**, *63*, 75–78.
93. Koman, S.; Feher, S.; Vityi, A. Physical and Mechanical Properties of *Paulownia tomentosa* Wood Planted in Hungaria. *Wood Res.* **2017**, *62*, 335–340.
94. Koman, S.; Feher, S. Physical and Mechanical Properties of Paulownia Clone in Vitro 112. *Eur. J. Wood Wood Prod.* **2020**, *78*, 421–423. [CrossRef]
95. Madhoushi, M.; Boskabadi, Z. Relationship between the Dynamic and Static Modulus of Elasticity in Standing Trees and Sawn Lumbers of *Paulownia fortune* Planted in Iran. *Maderas. Cienc. Y Tecnol.* **2019**, *21*, 35–44. [CrossRef]
96. Miri Tari, S.M.; Habibzade, S.; Taghiyari, H.R. Effects of Drying Schedules on Physical and Mechanical Properties in Paulownia Wood. *Dry. Technol.* **2015**, *33*, 1981–1990. [CrossRef]
97. Sobhani, M.; Khazaeian, A.; Tabarsa, T.; Shakeri, A. Evaluation of Physical and Mechanical Properties of Paulownia Wood Core and Fiberglass Surfaces Sandwich Panel. *Key Eng. Mater.* **2011**, *471–472*, 85–90. [CrossRef]
98. Feng, Y.; Cui, L.; Zhao, Y.; Qiao, J.; Wang, B.; Yang, C.; Zhou, H.; Chang, D. Comprehensive Selection of the Wood Properties of Paulownia Clones Grown in the Hilly Region of Southern China. *BioResources* **2020**, *15*, 1098–1111. [CrossRef]
99. Latib, H.A.; Liat, L.C.; Ratnasingam, J.; Law, E.L.; Azim, A.A.A.; Mariapan, M.; Natkuncaran, J. Suitability of Paulownia Wood from Malaysia for Furniture Application. *BioResources* **2020**, *15*, 4727–4737. [CrossRef]
100. Sidan, L.; Liu, Z.; Liu, Y.; Yu, H.; Yinglai, H. Acoustic Vibration Properties of Wood for Musical Instrument Based on FFT of Adding Windows. In Proceedings of the 2010 International Conference on Mechanical and Electrical Technology, Singapore, 10–12 September 2010; pp. 370–373.
101. Jang, E.-S.; Kang, C.-W. Sound Absorption Characteristics of Three Species (Binuang, Balsa and Paulownia) of Low Density Hardwood. *Holzforschung* **2021**, *75*, 1115–1124. [CrossRef]
102. Marzbani, P.; Saraeyan, A.; Mohammadnia-afrouzi, Y.; Azim-mohseni, M. Statistical Modeling of Weight and Dimensions Changes of *Paulownia fortunei* and *Pseudotsuga menziesii* Sapwood. *Adv. Environ. Biol.* **2014**, *8*, 440–445.
103. Taghiyari, H.R.; Kalantari, A.; Ghorbani, M.; Bavaneghi, F.; Akhtari, M. Effects of Fungal Exposure on Air and Liquid Permeability of Nanosilver- and Nanozincoxide-Impregnated Paulownia Wood. *Int. Biodeterior. Biodegrad.* **2015**, *105*, 51–57. [CrossRef]
104. Kang, C.-W.; Jang, E.-S.; Jang, S.-S.; Cho, J.-I.; Kim, N.-H. Effect of Heat Treatment on the Gas Permeability, Sound Absorption Coefficient, and Sound Transmission Loss of *Paulownia tomentosa* Wood. *J. Korean Wood Sci. Technol.* **2019**, *47*, 644–654. [CrossRef]
105. Kolya, H.; Kang, C.-W. Hygrothermal Treated Paulownia Hardwood Reveals Enhanced Sound Absorption Coefficient: An Effective and Facile Approach. *Appl. Acoust.* **2021**, *174*, 107758. [CrossRef]
106. Xu, H.; Taghiyari, H.R.; Clauson, M.; Milota, M.R.; Morrell, J.J. Effect of Supercritical Carbon Dioxide Treatment on Gas Permeability of Paulownia Fortunei Heartwood and Sapwood. *Wood Fiber. Sci.* **2019**, *51*, 1–5. [CrossRef]

107. Kaygin, B.; Kaplan, D.; Aydemir, D. Paulownia Tree as an Alternative Raw Material for Pencil Manufacturing. *BioResources* **2015**, *10*, 3426–3433. [CrossRef]
108. Olson, J.R.; Carpenter, S.B. Specific Gravity, Fiber Length, and Extractive Content of Young Paulownia. *Wood Fiber Sci.* **1985**, *17*, 428–438.
109. Popović, J.; Radošević, G. Paulownia Elongata, S.Y. Hu–Anatomical and Chemical Properties of Wood Fibers. *Prerada Drv.* **2011**, *9*, 15–22.
110. Ates, S.; Ni, Y.; Akgul, M.; Tozluoglu, A. Characterization and Evaluation of *Paulownia elongota* as a Raw Material for Paper Production. *Afr. J. Biotechnol.* **2008**, *7*, 4153–4158.
111. Ashori, A.; Nourbakhsh, A. Studies on Iranian Cultivated Paulownia—a Potential Source of Fibrous Raw Material for Paperindustry. *Eur. J. Wood Prod.* **2009**, *67*, 323–327. [CrossRef]
112. Vilotić, D.; Popović, J.; Mitrović, S.; Šijačić-Nikolić, M.; Ocokoljić, M.; Novović, J.; Veselinović, M. Dimensions of Mechanical Fibres in *Paulownia elongata* S. Y. Hu Wood from Different Habitats. *Drv. Ind. Znan. Časopis Za Pitanja Drv. Tehnol.* **2015**, *66*, 229–234. [CrossRef]
113. Gong, C.; Bujanovic, B.M. Impact of Hot-Water Extraction on Acetone-Water Oxygen Delignification of *Paulownia* Spp. and Lignin Recovery. *Energies* **2014**, *7*, 857–873. [CrossRef]
114. Qi, Y.; Jang, J.-H.; Hidayat, W.; Lee, A.-H.; Lee, S.-H.; Chae, H.-M.; Kim, N.-H. Carbonization of Reaction Wood from *Paulownia tomentosa* and Pinus Densiflora Branch Woods. *Wood Sci. Technol.* **2016**, *50*, 973–987. [CrossRef]
115. Qi, Y.; Yang, C.; Hidayat, W.; Jang, J.-H.; Kim, N.-H. Solid Bioenergy Properties of *Paulownia tomentosa* Grown in Korea. *J. Korean Wood Sci. Technol.* **2016**, *44*, 890–896. [CrossRef]
116. Baier, C.; Thevs, N.; Villwock, D.; Emileva, B.; Fischer, S. Water Productivity of *Paulownia tomentosa x fortunei* (Shan Tong) in a Plantation at Lake Issyk-Kul, Kyrgyzstan, Central Asia. *Trees* **2021**, *35*, 1627–1637. [CrossRef]
117. Gyuleva, V.; Stankova, T.; Zhiyanski, M.; Andonova, E. Five Years Growth of *Paulownia* on Two Sites in Bulgaria. *For. Sci.* **2021**, *1*, 11–22.
118. Madejón, P.; Alaejos, J.; García-Álbala, J.; Fernández, M.; Madejón, E. Three-Year Study of Fast-Growing Trees in Degraded Soils Amended with Composts: Effects on Soil Fertility and Productivity. *J. Environ. Manag.* **2016**, *169*, 18–26. [CrossRef] [PubMed]
119. Pegoretti Leite de Souza, H.J.; Muñoz, F.; Mendonça, R.T.; Sáez, K.; Olave, R.; Segura, C.; de Souza, D.P.L.; de Paula Protásio, T.; Rodríguez-Soalleiro, R. Influence of Lignin Distribution, Physicochemical Characteristics and Microstructure on the Quality of Biofuel Pellets Made from Four Different Types of Biomass. *Renew. Energy* **2021**, *163*, 1802–1816. [CrossRef]
120. Spirchez, C.; Japalela, V.; Lunguleasa, A.; Buduroi, D. Analysis of Briquettes and Pellets Obtained from Two Types of Paulownia (*Paulownia tomentosa and Paulownia elongata*) Sawdust. *BioResources* **2021**, *16*, 5083–5095. [CrossRef]
121. Świechowski, K.; Liszewski, M.; Bąbelewski, P.; Koziel, J.A.; Białowiec, A. Fuel Properties of Torrefied Biomass from Pruning of Oxytree. *Data* **2019**, *4*, 55. [CrossRef]
122. Świechowski, K.; Liszewski, M.; Bąbelewski, P.; Koziel, J.A.; Białowiec, A. Oxytree Pruned Biomass Torrefaction: Mathematical Models of the Influence of Temperature and Residence Time on Fuel Properties Improvement. *Materials* **2019**, *12*, 2228. [CrossRef]
123. Vusić, D.; Migalić, M.; Zečić, Ž.; Trkmić, M.; Bešlić, A.; Drvodelić, D. Fuel Properties of Paulownia Biomass. In Proceedings of the Natural Resources, Green Technology and Sustainable Development/3-GREEN, Zagreb, Croatia, 5–8 June 2018; pp. 126–130. Available online: https://urn.nsk.hr/urn:nbn:hr:108:838890 (accessed on 22 April 2022).
124. Zachar, M.; Lieskovský, M.; Majlingová, A.; Mitterová, I. Comparison of Thermal Properties of the Fast-Growing Tree Species and Energy Crop Species to Be Used as a Renewable and Energy-Efficient Resource. *J. Therm. Anal. Calorim.* **2018**, *134*, 543–548. [CrossRef]
125. Stankova, T.; Gyuleva, V.; Dimitrov, D.N.; Hristova, H.; Andonova, E. Above Dendromass Estimation of Juvenile *Paulownia* Sp. *Glas. Šumarskog Fak. Univ. U Banjoj Luci* **2016**, *24*, 5–18.
126. Stankova, T.; Gyuleva, V.; Dimitrov, D.N.; Popov, E. Allometric Relationships for Estimation of Aboveground Woody Biomass of Two Clones Paulownia at Juvenile Age. *Nauka Gorata* **2019**, *55*, 43–54.
127. Perpiña, C.; Martínez-Llario, J.C.; Pérez-Navarro, Á. Multicriteria Assessment in GIS Environments for Siting Biomass Plants. *Land Use Policy* **2013**, *31*, 326–335. [CrossRef]
128. Galán-Martín, Á.; Pozo, C.; Guillén-Gosálbez, G.; Antón Vallejo, A.; Jiménez Esteller, L. Multi-Stage Linear Programming Model for Optimizing Cropping Plan Decisions under the New Common Agricultural Policy. *Land Use Policy* **2015**, *48*, 515–524. [CrossRef]
129. Abbasi, M.; Pishvaee, M.S.; Bairamzadeh, S. Land Suitability Assessment for Paulownia Cultivation Using Combined GIS and Z-Number DEA: A Case Study. *Comput. Electron. Agric.* **2020**, *176*, 105666. [CrossRef]
130. Palma, A.; Loaiza, J.M.; Díaz, M.J.; García, J.C.; Giráldez, I.; López, F. Tagasaste, Leucaena and Paulownia: Three Industrial Crops for Energy and Hemicelluloses Production. *Biotechnol. Biofuels* **2021**, *14*, 89. [CrossRef]
131. Pleguezuelo, C.R.R.; Zuazo, V.H.D.; Bielders, C.; Bocanegra, J.A.J.; PereaTorres, F.; Martínez, J.R.F. Bioenergy Farming Using Woody Crops. A Review. *Agron. Sustain. Dev.* **2015**, *35*, 95–119. [CrossRef]
132. Parra-Lopez, C.; Sayadi, S.; Duran-Zuzáo, V.H. Production and Use of Biomass from Short-Rotation Plantations in Andalusia, Southern Spain: Limitations and Opportunities. *New Medit.* **2015**, *14*, 40–49.

133. Livia, B.R.; Maxim, A.; Odagiu, A.; Balint, C.; Hartagan, R.M. Paulownia Sp. Used as an Energetic Plant, for the Phytoremediation of Soils and in Agroforestry Systems. *ProEnvironment* **2018**, *11*, 76–85. Available online: http://journals.usamvcluj.ro/index.php/promediu/article/view/13206 (accessed on 22 April 2022).
134. Testa, R.; Schifani, G.; Rizzo, G.; Migliore, G. Assessing the Economic Profitability of Paulownia as a Biomass Crop in Southern Mediterranean Area. *J. Clean. Prod.* **2022**, *336*, 130426. [CrossRef]
135. Thevs, N.; Baier, C.; Aliev, K. Water Productivity of Poplar and Paulownia on Two Sites in Kyrgyzstan, Central Asia. *J. Water Resour. Prot.* **2021**, *13*, 293. [CrossRef]
136. Morozova, I.; Oechsner, H.; Roik, M.; Hülsemann, B.; Lemmer, A. Assessment of Areal Methane Yields from Energy Crops in Ukraine, Best Practices. *Appl. Sci.* **2020**, *10*, 4431. [CrossRef]
137. Kaletnik, G.; Pryshliak, N.; Tokarchuk, D. Potential of Production of Energy Crops in Ukraine and Their Processing on Solid Biofuels. *Ecol. Eng. Environ. Technol.* **2021**, *22*, 59–70. [CrossRef]
138. Khanjanzadeh, H.; Bahmani, A.A.; Rafighi, A.; Tabarsa, T. Utilization of Bio-Waste Cotton (*Gossypium hirsutum* L.) Stalks and Underutilized Paulownia (*Paulownia fortunie*) in Wood-Based Composite Particleboard. *Afr. J. Biotechnol.* **2012**, *11*, 8045–8050. [CrossRef]
139. Ebrahimi, H.; Vaziri, V.; Faraji, F.; Aminian, H.; Jamalirad, L. The Effect of Using PET to Paulownia Strands on Physical and Mechanical Properties of OSB. *For. Wood Prod.* **2021**, *74*, 371–382. [CrossRef]
140. Rodríguez-Seoane, P.; Domínguez, H.; Torres, M.D. Mechanical Characterization of Biopolymer-Based Hydrogels Enriched with Paulownia Extracts Recovered Using a Green Technique. *Appl. Sci.* **2020**, *10*, 8439. [CrossRef]
141. Nelis, P.A.; Henke, O.; Mai, C. Comparison of Blockboards with Core Layers Made of Kiri (*Paulownia* Spp.) and of Spruce (*Picea abies*) Regarding Mechanical Properties. *Eur. J. Wood Wood Prod.* **2019**, *77*, 323–326. [CrossRef]
142. Nelis, P.A.; Michaelis, F.; Krause, K.C.; Mai, C. Kiri Wood (*Paulownia tomentosa*): Can It Improve the Performance of Particleboards? *Eur. J. Wood Prod.* **2018**, *76*, 445–453. [CrossRef]
143. Nelis, P.A.; Mai, C. The Influence of Low-Density (*Paulownia* Spp.) and High-Density (*Fagus sylvatica* L.) Wood Species on Various Characteristics of Light and Medium-Density Three-Layered Particleboards. *Wood Mater. Sci. Eng.* **2021**, *16*, 21–26. [CrossRef]
144. Kim, Y.K.; Kwon, G.J.; Kim, A.R.; Lee, H.S.; Purusatama, B.; Lee, S.H.; Kang, C.W.; Kim, N.H. Effects of Heat Treatment on the Characteristics of Royal Paulownia (*Paulownia tomentosa* (Thunb.) Steud.) Wood Grown in Korea. *J. Korean Wood Sci. Technol.* **2018**, *46*, 511–526. [CrossRef]
145. Esmailpour, A.; Taghiyari, H.R.; Golchin, M.; Avramidis, S. On the Fluid Permeability of Heat Treated Paulownia Wood. *Int. Wood Prod. J.* **2019**, *10*, 55–63. [CrossRef]
146. Candan, Z.; Gonultas, O.; Gorgun, H.V.; Unsal, O. Examining Parameters of Surface Quality Performance of Paulownia Wood Materials Modified by Thermal Compression Technique. *Drv. Ind.* **2021**, *72*, 231–236. [CrossRef]
147. Li, H.; Jiang, X.; Ramaswamy, H.S.; Zhu, S.; Yu, Y. High-Pressure Treatment Effects on Density Profile, Surface Roughness, Hardness, and Abrasion Resistance of Paulownia Wood Boards. *Trans. ASABE* **2018**, *61*, 1181–1188. [CrossRef]
148. Yu, Y.; Jiang, X.; Ramaswamy, H.S.; Zhu, S.; Li, H. Effect of High-Pressure Densification on Moisture Sorption Properties of Paulownia Wood. *BioResources* **2018**, *13*, 2473–2486. [CrossRef]
149. Chen, L.; Wang, S.; Meng, H.; Wu, Z.; Zhao, J. Study on Gas Products Distributions During Fast Co-Pyrolysis of Paulownia Wood and PET at High Temperature. *Energy Procedia* **2017**, *105*, 391–397. [CrossRef]
150. Domínguez, E.; Río, P.G.; del Romaní, A.; Garrote, G.; Domingues, L. Hemicellulosic Bioethanol Production from Fast-Growing Paulownia Biomass. *Processes* **2021**, *9*, 173. [CrossRef]
151. Zhang, Q.; Jin, P.; Li, Y.; Zhang, Z.; Zhang, H.; Ru, G.; Jiang, D.; Jing, Y.; Zhang, X. Analysis of the Characteristics of Paulownia Lignocellulose and Hydrogen Production Potential via Photo Fermentation. *Bioresour. Technol.* **2022**, *344*, 126361. [CrossRef]
152. He, T.; Vaidya, B.N.; Perry, Z.D.; Parajuli, P.; Joshee, N. Paulownia as a Medicinal Tree: Traditional Uses and Current Advances. *Eur. J. Med. Plants* **2016**, *14*, 1–15. [CrossRef]
153. Huang, H.; Szumacher-Strabel, M.; Patra, A.K.; Ślusarczyk, S.; Lechniak, D.; Vazirigohar, M.; Varadyova, Z.; Kozłowska, M.; Cieślak, A. Chemical and Phytochemical Composition, in Vitro Ruminal Fermentation, Methane Production, and Nutrient Degradability of Fresh and Ensiled Paulownia Hybrid Leaves. *Anim. Feed. Sci. Technol.* **2021**, *279*, 115038. [CrossRef]
154. Adach, W.; Żuchowski, J.; Moniuszko-Szajwaj, B.; Szumacher-Strabel, M.; Stochmal, A.; Olas, B.; Cieslak, A. In Vitro Antiplatelet Activity of Extract and Its Fractions of Paulownia Clone in Vitro 112 Leaves. *Biomed. Pharmacother.* **2021**, *137*, 111301. [CrossRef] [PubMed]
155. Dżugan, M.; Miłek, M.; Grabek-Lejko, D.; Hęclik, J.; Jacek, B.; Litwińczuk, W. Antioxidant Activity, Polyphenolic Profiles and Antibacterial Properties of Leaf Extract of Various *Paulownia* Spp. Clones. *Agronomy* **2021**, *11*, 2001. [CrossRef]
156. Stochmal, A.; Moniuszko-Szajwaj, B.; Zuchowski, J.; Pecio, Ł.; Kontek, B.; Szumacher-Strabel, M.; Olas, B.; Cieslak, A. Qualitative and Quantitative Analysis of Secondary Metabolites in Morphological Parts of Paulownia Clon In Vitro 112®and Their Anticoagulant Properties in Whole Human Blood. *Molecules* **2022**, *27*, 980. [CrossRef] [PubMed]
157. Yang, H.; Zhang, P.; Xu, X.; Chen, X.; Liu, Q.; Jiang, C. The Enhanced Immunological Activity of *Paulownia tomentosa* Flower Polysaccharide on Newcastle Disease Vaccine in Chicken. *Biosci. Rep.* **2019**, *39*, BSR20190224. [CrossRef] [PubMed]
158. Al-Sagheer, A.A.; Abd El-Hack, M.E.; Alagawany, M.; Naiel, M.A.; Mahgoub, S.A.; Badr, M.M.; Hussein, E.O.S.; Alowaimer, A.N.; Swelum, A.A. Paulownia Leaves as A New Feed Resource: Chemical Composition and Effects on Growth, Carcasses, Digestibility, Blood Biochemistry, and Intestinal Bacterial Populations of Growing Rabbits. *Animals* **2019**, *9*, 95. [CrossRef] [PubMed]

159. Ganchev, G.; Ilchev, A.; Koleva, A. Digestibility and Energy Content of Paulownia (*Paulownia elongata* SY Hu) Leaves. *Agric. Sci. Technol.* **2019**, *11*, 307–310.
160. Alagawany, M.; Farag, M.R.; Sahfi, M.E.; Elnesr, S.S.; Alqaisi, O.; El-Kassas, S.; Al-wajeeh, A.S.; Taha, A.E.; Abd, E.; Hack, M.E. Phytochemical Characteristics of Paulownia Trees Wastes and Its Use as Unconventional Feedstuff in Animal Feed. *Anim. Biotechnol.* **2020**, 1–8. [CrossRef]
161. Miladinova-Georgieva, K.; Geneva, M.; Markovska, Y. Effects of EDTA and Citrate Addition to the Soil on C4 Photosynthetic Enzymes and Biochemical Indicators for Heavy Metal Tolerance in Two Paulownia Hybrids. *Genet. Plant Physiol.* **2018**, *8*, 68–81.
162. Miladinova-Georgieva, K.; Ivanova, K.; Georgieva, T.; Geneva, M.; Petrov, P.; Stancheva, I.; Markovska, Y. EDTA and Citrate Impact on Heavy Metals Phytoremediation Using Paulownia Hybrids. *Int. J. Environ. Pollut.* **2018**, *63*, 31–46. [CrossRef]
163. Tzvetkova, N.; Miladinova, K.; Ivanova, K.; Georgieva, T.; Geneva, M.; Markovska, Y. Possibility for Using of Two Paulownia Lines as a Tool for Remediation of Heavy Metal Contaminated Soil. *J. Environ. Biol.* **2015**, *36*, 145.