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RESEARCH ON THE EVOLUTION OF THE PHYSICAL AND MECHANICAL PARAMETERS OF *PAULOWNIA* FIBER UNDER DIFFERENT PLANTING AND FERTILIZATION CONDITIONS

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Abstract

Two factors are directly involved in obtaining superior wood in quantitative and qualitative aspects, respectively an optimal consumption of nutrients (macro and micro-elements) and the optimal plants density at the surface unit. In this context, the present research have been made in order to establish the influence degree of the planting and the fertilization scheme on the physical and mechanical properties that restore the value from the point of view of wood quality to Pauownia ssp. Experimental results showed that best of all the fibers harvested from the experimental variants where the planting schemes of 5x5 m or 6x6 m were used and were administered 40 kg/ha Polyfeed 14-14-28+2MgO+ME by fertirigation during the vegetation period of the plants, the balanced ratio between the nutrients giving to the plants increased resistance to the mechanical factors action.

Key words: *Paulownia ssp., plants density, fertirigation, fiber's quality, physical parameters, mechanical parameters.*

INTRODUCTION

The *Paulownia* tree originates in Asian countries (China, Vietnam), and is still widely cultivated in East Asia. The *Paulownia* genus, included in the Paulowniaceae family by the latest genetic research, includes several species, between 6 and 12 depending on the accepted taxonomic classification, the best known species being *Paulownia tomentosa*, *P. elongata* and *P. fortunei* (Jakubowski, 2022). The tree was brought to Europe at the beginning of the 19th century, imported by the Dutch East India Company, the name "paulownia" or "princess tree" being given in honor of Queen Anna Pavlovna of the Netherlands, daughter of Tsar Paul I of Russia. In the last decades, Paulownia was introduced in more than 40 countries, from various continents: North America, Australia, South America, etc.

Although initially *Paulownia* was cultivated in Europe as an ornamental tree, today it is used for many other purposes, as a result of the many interesting characteristics of this plant and the advantages of the culture (Jiménez & Rodríguez, 2003). The irrational deforestation at the planetary level in the last decades has serious consequences regarding the increase in carbon emissions and visible climate changes (Hamdan et Houri, 2022). Many countries, including the EU, have launched several initiatives to reduce carbon emissions, in which forests play an essential role, being large CO_2 sinks (Haldar and Shethi, 2021). Due to the rapid growth, *Paulownia* tree culture can be a very efficient solution for reforestation projects, including the very high rate of carbon absorption, due to the well-developed leaf system (40 tons of CO_2/ha/year) (Jensen, 2016).

On the other hand, thanks to the very well developed root system, the culture of these trees can protect the land against soil erosion and the stabilization of landslides, even contributing to improving the quality and fertility of the soil, thanks to the ability to fix nitrogen (Gyuleva, 2008).

Due to the rapid growth, the *Paulownia* culture is suitable for the production of biomass (Jose et Bardhan, 2012), used not only as a source of energy (biofuels), but also as a use of wood, the growth of the biomass of a *Paulownia* plantation being higher by about 30% compared to poplar and willow, e.g. *Paulownia* wood is much lighter compared to other

species, having an average density of 260 kg/m^3 (Barbu et al., 2022).
Paulownia is the solution of the future in forestry, which replaces the beautiful forests of formerly felled mercilessly due to lack, indifference or simply to enrich many (House et al., 2002). This plant dates back to 1049 BC and we find it registered in Asia as a high quality wood production for the construction of boats and houses. In China, about 3 million ha have been planted in the last 60 years. Due to the abusive destruction of forests and the need for timber worldwide *Paulownia* is an alternative that offers timber quality in optimum time, starting with 3-4 years for biomass and 5-10 years for construction wood, which another tree species cannot offer (Dobrinoiu et al., 2018; Haldar and Sethi, 2021). It absorbs very well the nitrates of the soil and the carbon dioxide in the air, offering freshness and tenderness through its appearance and behavior. Due to its elasticity it can be planted as a curtain against the wind, the blizzard on the edge of roads, airports, the protection of isolated villages from the open field (withstands over 80 km/h wind speed without breaking) (Kaymakci et al., 2013).
The wood has a great capacity for modeling and handling, being able to be used in the furniture industry (as solid wood or veneer) or in the manufacture of musical instruments, these being known by instrument manufacturers in Asia as having special acoustic properties. The wood can be successfully used in the timber industry, being resistant to rotting and termite attack, due to the fact that it is rich in tannins. The low weight of *Paulownia* wood makes it very suitable for the manufacture of light wooden structures, for example for aircraft structures or for other parts where weight is essential (Kaymakci et al., 2013). The research carried out on this "new" woody species, in the last period of time, had as main purpose, the creation of a clone with the best performance from the point of view of the productive potential, the parental material being quite heterogeneous and being represented only by species pure (Fokina et al., 2020).
So far there are several clones available, some of which are more suitable for biomass production, while others are suitable for wood production (Dubova et al., 2019).
Regarding the latter destination, despite the fact that the species has a very rapid growth, the harvesting of the stems depends on the type of wood we want to obtain, that is its size at the cubicle (Koman et al., 2017).
The physical-mechanical properties of the wood of the same species can vary by up to 30% and these variations can be considered frequent (Jakubowski, 2022), for these it is recommended to study the properties of a wood for each area of origin, cutting age determining its quality.

MATERIALS AND METHODS

The experiement was carried out in a 5-year-old *Paulownia* plantation in the specific soil-climatique condition of Tulcea county and the fundamental purpose of the experiment was to verify the influence of the different technological links (planting density and fertilization scheme) on increasing the technological characteristics of the wood obtained at harvest.
The objectives of the research were:
- determination of the physical properties of the fibers belonging to *Paulownia* plants aged 5 years;
- determination of the mechanical properties of the fibers belonging to *Paulownia* plants aged 5 years.

The exeperiment been placed in the field in a bifactorial experience type, in subdivided plots with three repetitions, the experimental factors tested in the study being the following:
FACTOR A: plants density at the unit surface, with the follow graduations:
- a1 - equidistant planting at 4.00 m x 4 m, with a density of 625 plants per hectare (Control);
- a2 - equidistant planting at 5.00 m x 5.00 m, with a density of 400 plants per hectare;
- a3 - equidistant planting at 6.00 m x 6.00 m, with a density of 277.7 plants per hectare.

FACTOR B: scheme of fertilizing, with the follow graduations:
- b1 - unfertirigated (Control);
- b2 - fertirigated with 40 kg/ha Polyfeed 14-14-28 + 2MgO + ME;
- b3 - fertirigated with 40 kg/ha Bonus K-Energy (10-5-38 + 6% S + 3% Mg + B + Mn).

The analysis and interpretation of the experimental results was performed by the method of analysis of variance, according to the method of subdivided plots.

Table 1. The dimensions of the samples according to the norm

Species properties			Height (mm)	Amplitude (mm)	Length (mm)
Moisture content by drying		UNE EN 13183-1:03			
Moisture content by resistance hygrometer		UNE EN 13183-2:03			
Specific weight		UNE 56 531:77	20	20	25 ±
Hygroscopicity		UNE 56 532:77	20	20	40
Linear and volumetric contraction		UNE 56 533:77	20	20	40
Determination of hardness		UNE 56 534:77	20	20	40
Determination of axial compression		UNE 56 535:77	20	20	60
Resistance to dynamic bending		UNE 56 536:77	20	20	300
Resistance to static bending		UNE 56 537:77	20	20	300
Tensile strength perpendicular to fiber	radial	UNE 56 538:78	20	20	70
	tangential	UNE 56 538:78	20	20	70
Splitting resistance		UNE 56 539:78	20	20	70
Resistance to perpendicular compression on fibers		UNE 56 542:88	50	50	150

In order that the values obtained in the characterization are comparable with the results of other tests, the methodology used was indicated in the norm tested (Table 1).

The determinations regarding the physical and mechanical properties of the fibers were made with small samples, without defects that harm the values of a certain property of the wood.

In order to determine the size of the specimens, the criterion of the Spanish norm described in the UNE norms was followed, which uses specimens with the section dimensions of 20 x 20 mm^2 for most physical and mechanical tests, except for the resistance to the cutting force and compression perpendicular to the fiber, for which the norms of the UNE establish samples with 50 x 50 mm^2 section.

The samples were collected from the experimental group, from *Paulownia* plants aged 5 years, using destructive plant samples, separately for each experimental variant.

In order to obtain the specimens, with the dimensions specified in the regulations in force, the stems were cut in the laboratory workshop, according to the specific method for determining each physical and mechanical parameter followed.

The specimens needed to test the physical-mechanical properties of *Paulownia* fibers were obtained from the 3-year-old plant stems, from a unit of 60 cm in length, from which the specimens were subsequently made, by sectioning to the dimensions provided in the regulations according to Figure 1.

The pieces contain marrow and young wood were eliminated being cut in half, resulting in slabs with a section of 2 x 2 cm^2 and the axis parallel to the axis of the trunk. From these chips were obtained the test pieces used to test the physical and mechanical parameters of the fiber.

Also, specimens with a section of 5 x 5 cm^2 and 15 cm in length were obtained on which tests were performed on fiber resistance to perpendicular compression and parallel cutting (splitting).

The physical tests were performed on 20 x 20 x 40 mm samples, in which the weights and linear dimensions (radial, tangential and longitudinal) were measured, under different humidity conditions. From the obtained values, the physical and mechanical properties were calculated, according to the specific standard of each determined parameter.

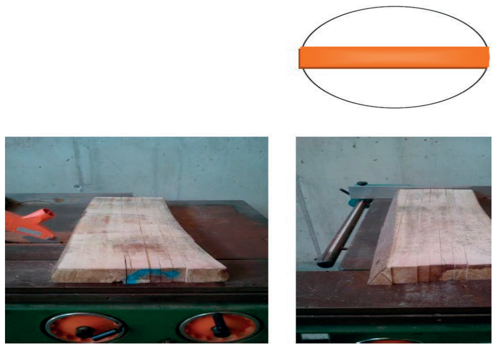

Figure 1. Preparation of the specimens for determination of physical-mechanical parameters

Determination of moisture content of fiber by drying: UNE EN 13183-1: 03. The protocol of work: Weigh the specimen, then dry it at a temperature of 103 ± 2ºC until the

difference between two successive weighings at intervals of 2 hours is less than 0.1%. Resample the sample (Figure 2).
Equipment needed to determination: SCALTEC Digital Scale 2200 X 0.01gr (CET.LAB.003.01); 72 l SELECTA THEROVEN 2000W cooker (CET.LAB.005.01); 300 mm crystal dryer (CET.LAB.006.01)

Figure 2. Determining of specific humidity and weight

Determination of specific weight: UNE 56 531: 77. The protocol of work: Weigh the specimen, measure its size and then calculate it to obtain the specific weight in g/cm^3. Repeat the procedure in anhydrous state. Equipment needed to determine: SCALTEC Digital Scale 2200 X 0.01gr (CET.LAB.003.01); 72 l SELECTA THEROVEN 2000W cooker (CET.LAB.005.01); 300 mm crystal dryer (CET.LAB.006.01)
Determination of fiber hygroscopicity: UNE 56 532: 77. The protocol of work: It is calculated from the values of the coefficient of volumetric contraction and the specific weight of the sample.
Determination of linear and volumetric fiber contraction: UNE 56 533: 77 20. The protocol of work: Fully insert the specimen into the water, at room temperature, until it exceeds the saturation humidity, after which the dimensions of the specimen are measured and its volume is calculated. Leave the specimen at room temperature until it reaches the hygroscopic equilibrium after which again the dimensions of the specimen are measured and its volume is calculated. Dry the specimen at a temperature of 103 ± 2ºC until the difference in weight between two successive weighing at 2-hour intervals is less than 0.1% (Figure 2). Measure the sample size in anhydrous state and calculate its volume. Equipment needed to determine: SCALTEC Digital Scale 2200 X 0.01gr (CET.LAB.003.01); Digital jack (S225) (CET.LAB.004.01); 72 l SELECTA THEROVEN 2000W cooker (CET.LAB.005.01); 300 mm crystal dryer (CET.LAB.006.01)
Determination of fiber hardness: UNE 56 534: 77.

Figure 3. Determining the physical hardness of the fiber

The protocol of work Place the specimen in the weight machine with the radial part up, then operate the load until it reaches 100 kg per cm width, in the case of very soft timber until it reaches 50 kg and multiply by 2, the deformation obtained (Figure 3). The Hardness is calculated and the Hardness Rate is obtained. Equipment needed to determine: Weight machine (CET. LAB.010.01).
Determination of fiber resistance to linear compression: UNE 56 535: 77. The protocol of work: Place the lumber specimen in the weight machine, with the longitudinal direction of the fibers perpendicular to the plates of the weight press. Apply the weight at a uniform rate from 200 to 300 kg/cm^2 per minute, until breaking (Figure 4).

Figure 4. Determining of fiber resistance to linear compression

The resistance to axial compression is calculated. Equipment needed to determine: Weight machine (CET. LAB.010.01).

Determination of fiber resistance to dynamic bending: UNE 56 536: 77. The protocol of work: Place the specimen in the weight machine, at a distance of 24 cm between the supports, with the radial side up.

Figure 5. Determining of fiber resistance to bending

The hammer of the machine falls from a height of 1000 mm ± 1 mm (Figure 5). The dynamic bending resistance is then calculated. Equipment needed to determine: Weight machine (CET. LAB.010.01).

Determination of tensile strength perpendicular to fiber: UNE 56 538: 78. The protocol of work: Fix the specimen between the traction machine guides and then apply traction weight, until it breaks (Figure 6). Thereafter, the tensile strength perpendicular to the fiber and the adhesion rate are calculated. Equipment needed to determine: Weight machine (CET. LAB.010.01).

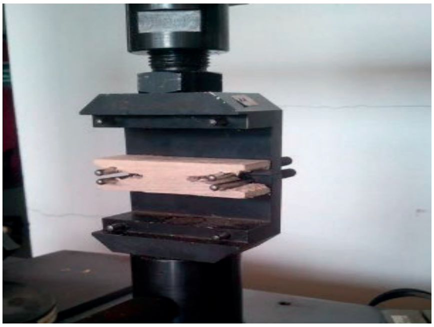

Figure 6. Determining of the tensile strength perpendicular to the fiber

Determination of fiber resistance to splitting: UNE 56 539: 78. How to work: The specimen is fastened between the trusses (jaws) of the traction machine and then the traction weight is applied until breaking. Split resistance and breaking rate are calculated. Equipment needed to determine: Weight machine (CET. LAB.010.01).

Determination of resistance to perpendicular compression of fibers: UNE 56 542: 88. How to work: Place the specimen in the weight machine. The tensile weight is applied until it is broken and the resistance to perpendicular compression of the fiber is calculated. Equipment needed to determine: Weight machine (CET. LAB.010.01).

RESULTS AND DISCUSSIONS

Results and discussion regarding physical characteristics of *Paulownia*'s fibers

Analyzing the quality of *Paulownia* fibers, in terms of their density at 12% humidity (Table 2), due to the influence of the two experimental factors studied (planting density and fertilization scheme), it is observed that the values of this physical parameter of quality registered values between 209 kg/m^3, minimum value obtained in the case of experimental variant a2b2, variant in which the planting scheme was 5x5 m, the plants benefiting during the vegetation period by the contribution of 40 kg/ha POLYFEED 14- 14-28+2MgO+ME and 257 kg/m^3, maximum value recorded for the experimental variant in which the planting scheme of 4x4 m was practiced, under non-fertilization conditions (a1b1-Control).

By increasing the nutrient space of the plants, supported by the optimal supply with their nutrients, an inversely proportional increase of the fiber density is observed. Thus, if we make a comparison between the experimental variant taken as a control (a1b1) and the rest of the experimental variants, there are recorded differences that varied between -6 kg/m^3 and -48 kg/m^3, with statistically insignificant assurance (-), to the a3b1 variant, significantly negative (o), at a2b1 and very significantly negative (ooo), at the rest of the experimental variants.

The same situation is found after determining the anhydrous and saturated density of the analyzed *Paulownia* fibers. Thus, the values of anhydrous fiber density ranged from 187 kg/m^3 (a2b2) to 224 kg/m^3 (a1b1-Control), the values of this physical indicator increasing directly in proportion to the decrease of the plant nutrition space and decreasing inversely with the increase the distance between plants and the administration of fertilizers.

Table 2. Fiber density, as a result of the combined action of experimental factors

Experimental Variants	Density at 12% (kg/m^3)	Difference (kg/m^3)	Anhydrous density (kg/m^3)	Difference (kg/m^3)	Saturated density (kg/m^3)	Difference (kg/m^3)	Semnification		
a1b1 (Control)	257	Control	224	Control	445	Control	-	-	-
a1b2	217	-40	198	-26	413	-32	ooo	ooo	ooo
a1b3	229	-28	209	-15	428	-17	ooo	oo	o
a2b1	245	-12	221	-3	416	-29	o	-	oo
a2b2	209	-48	187	-37	385	-60	ooo	ooo	ooo
a2b3	227	-30	192	-32	403	-42	ooo	ooo	ooo
a3b1	251	-6	219	-10	438	-7	-	-	-
a3b2	213	-44	197	-27	407	-38	ooo	ooo	ooo
a3b3	222	-35	212	-12	426	-19	ooo	o	o
DL5% =9.3; DL1% = 13.6; DL0.1% = 21.4 DL5% =11.2; DL1% = 18.7; DL0.1% = 25.6 DL5% =15.1; DL1% = 24.3; DL0.1% = 31.3									

The difference from the control variant was between -3 kg/m^3 (a2b1) and - 37 kg/m^3 (a2b2), with statistically insignificant assurance (-) in the case of experimental variants (a2b1 and a3b1), significantly negative (o), in the variant a3b3, distinctly significant negative to the experimental variant a1b3 and very significantly negative (ooo), to the rest of the experimental variants tested within the experiment. The saturated fiber density had values between 385 kg/m^3, the minimum value obtained under the conditions of the 5 x 5 m planting scheme, against the background of fertilization with Polyfeed 14-14-28+2MgO+ME, at a dose of 40 kg/ha and 445 kg/m^3 (a2b2), maximum recorded in the case of the control variant (a1b1), with the differences recorded being between -7 kg/m^3 and -60 kg/m^3, having insignificant statistical assurance (-), in the variant a3b1, significantly negative (o), at a1b3 and a3b3, distinctly significant negative (oo), at a2b1 and very significantly negative (ooo), for the rest of the experimental variants analyzed.

Table 3. The hygroscopicity of the fibers, as a result of the combined action of the experimental factors

Experimental Variants	Hygroscopicity (kg/m^3)	Difference (kg/m^3)	Semnification
a1b1 (Control)	1.29	Control	-
a1b2	1.37	0.08	xx
a1b3	1.54	0.25	xxx
a2b1	1.25	-0.04	o
a2b2	1.07	-0.22	ooo
a2b3	1.32	0.03	x
a3b1	1.31	0.02	-
a3b2	1.13	-0.16	ooo
a3b3	1.42	0.13	xxx
DL5% =0.03; DL1% = 0.05; DL0.1% = 0.11			

From the point of view of fiber hygroscopicity (Table 3), there was a great variability of the values of this physical parameter between the 9 experimental variants taken in the study, values that varied from 1.07 kg/m^3, in the case of the experimental variant in which planting was done according to the planting scheme 5x5 m, the plants benefiting from phase fertilization with Polyfeed 14-14-28+2MgO+ME, at a dose of 40 kg/ha (a2b2) and 1.54 kg/m^3, maximum value of to this indicator obtained by the mature variant where the planting scheme of 4 x 4 m was practiced, under conditions of non-fertilization of the plants (a1b1). Overall, it was observed that the hygroscopicity of *Paulownia* fibers decreases inversely with the increase of the plant nutrition space, with differences from the control variant, statistically insured, very significant negative (ooo) in the variants a2b2 and a3b2, significantly negative (o), at a2b1, insignificant (-), at variant a3b2, significantly positive (x), for variant a2b3, distinctly significant positive (xx), at experimental variant a1b2 and very significantly positive (xxx) at variants a1b3 and a3b3.

The same variability between the experimental variants was also recorded after determining the degree of contraction of the fibers (Table 4). Thus, the volumetric contraction of the fibers was between 7.7% and 9.2%, by practicing the planting scheme of 4 x 4 m, 6.7% and 7.9% in the case of the 5 x 5 m planting scheme, respectively between 7.1% and 8.8% by using the 6 x 6 m planting scheme, the smallest values of this physical indicator being recorded under conditions of non-fertilization of the plants, regardless of the planting density.

Table 4. Fiber contraction as a result of the combined action of experimental factors

Experimental Variants	Volumetric contraction (%)	Difference (%)	Linear contraction (%)	Difference (%)	Semnification	
a1b1 (Control)	7.7	Control	4.2	Control	-	-
a1b2	8.6	0.9	4.7	0.5	xxx	xxx
a1b3	9.2	1.5	5.1	0.9	xxx	xxx
a2b1	6.7	-1.0	3.8	-0.4	ooo	ooo
a2b2	7.1	-0.6	4.1	-0.1	ooo	ooo
a2b3	7.9	0.2	4.3	0.1	ooo	xxx
a3b1	7.1	-0.6	4.1	-0.1	ooo	ooo
a3b2	8.2	0.5	4.5	0.3	xxx	xxx
a3b3	8.8	1.1	4.8	0.6	xxx	xxx
DL5% =0.01; DL1% = 0.03; DL0.1% = 0.05 DL5% =0.02; DL1% = 0.04; DL0.1% = 0.06						

Analyzing *Paulownia* fibers in terms of resistance to linear contraction, we obtained values of this physical parameter of fiber quality ranging from 4.2% to 5.1% by using the 4x4 m planting scheme, between 3.8% and 4.3%, when the planting was done at a distance between 5x5 m plants and between 4.1% and 4.8% after practicing the 6 x 6 m planting scheme, with differences compared to the control variant that had statistical assurance from very significant negative (ooo), in the case of experimental variants a2b1, a2b2, a3b1, to very significant positive (xxx), to the rest of the experimental variants tested in the experiment. The values of the fiber hardness indices (Table 5) showed a very high variability between the experimental variants taken into study, both under the influence of planting density and under the aspect of plant supply in nutrients, with indices between 0.02 and 0.15, the lowest hardness level being recorded after planting at a distance of 5 x 5 m, under conditions of non-fertilization (a2b1).

Compared with the control variant (a1b1), the other experimental variants recorded very significant negative differences (ooo), in the experimental variants a2b1, a2b2, a2b3, a3b1, significantly negative (o), in the a3b2 variant, significantly positive (x), at variant a1b2, distinctly significant positive (xx), in the case of variant a3b3 and very significantly positive (xxx), in the experimental variant a1b3. The radial hardness at the dimension of the *Paulownia* fibers tested had values between 2.09 and 2.16, under the conditions of the 4 x 4 m, 1.79 and 1.95 planting scheme, following the 5 x 5 m planting scheme, respectively between 1.96 and 2.12 by planting at a distance of 6 x 6 m, with differences from the control which had very negative statistical assurance, in the case of experimental variants a2b1, a2b2, a2b3 and a3b1, insignificant (-), for experimental variants a1b2 and a3b2, significantly positive (x), for variant a3b3 and distinctly positive (xx), in the experimental variant a1b3.

Table 5. The radial hardness of the fibers, as a result of the combined action of the experimental factors

Experimental Variants	Radial hardness (index)				Semnification	
	N	Difference	Share	Difference		
a1b1 (Control)	0.09	Control	2.09	Control	-	-
a1b2	0.12	0.03	2.11	0.02	x	-
a1b3	0.15	0.06	2.16	0.07	xxx	xx
a2b1	0.02	-0.07	1.79	-0.3	ooo	ooo
a2b2	0.04	-0.05	1.83	-0.26	ooo	ooo
a2b3	0.07	-0.02	1.95	-0.14	ooo	ooo
a3b1	0.05	-0.04	1.96	-0.13	ooo	ooo
a3b2	0.10	0.01	2.08	-0.01	o	-
a3b3	0.12	0.03	2.12	0.03	xx	x
DL5% =0.01; DL1% = 0.03; DL0.1% = 0.05 DL5% =0.03; DL1% = 0.06; DL0.1% = 0.09						

Results and discussion regarding the mechanical characteristics of *Paulownia*'s fibers.

The two experimental factors studied (planting density and fertilization scheme) significantly influenced the mechanical characteristics of the *Paulownia* fibers subjected to the analyzes, with a high variability of them (Table 6). Thus, following the determination of the axial compression of the fibers belonging to the strains harvested from the 9 experimental variants taken in the study, it was found that at the humidity of 12% of the samples values were recorded that varied between 193 kg/cm^2, minimum value recorded in the case of the strains from the experimental variant a2b2 (5x5 m, fertilized with 40 kg/ha Polyfeed 14-14-28+2MgO+ME) and 223 kg/cm^2 in the case of the control variant (4x4 m, unfertilized), with differences from the control which they had very significant negative insurance (ooo), under the conditions of the 5 x 5 m planting scheme, regardless of the fertilizer administered.

This, it justifies us to affirm that, from the point of view of this parameter, the nutritional status of the *Paulownia* plants had a direct impact on the values recorded by this parameter of fiber quality. In the experimental variant a3b2, the differences from the control variant (a1b1) were significantly negative (o) whereas, the rest of the experimental variants have insignificant statistical assurance (-) compared to the control variant.

The influence of the fertilization scheme on the degree of axial compression of the fibers was even more evident when this mechanical parameter was determined at the level of the static quota of the fibers, the values obtained following the determinations varying within quite wide limits, respectively from 7.8 kg/cm^2, under the conditions of administration of 40 kg/ha Polyfeed 14-14-28 + 2MgO + ME, against the background of the planting scheme 5x5m (a2b2), up to 8.8 kg/cm^2, under the conditions of the control variant in which it was planted 4 x 4 m planting scheme, under conditions of non-fertilization of plants (a1b1). Compared with the control variant (a1b1), the rest of the experimental variants recorded very significant negative differences (ooo), except for the experimental variants in which the *Paulownia* plants were planted at a distance of 4 x 4 m, variants where the differences were insignificant (-), respectively significantly negative (o).

Table 6. Axial fiber compression as a result of the combined action of experimental factors

Experimental Variants	Axial compresion (kg/cm^2)		Difference (kg/cm^2)		Semnification	
	Value at 12%	Static share	Value at 12%	Static share		
a1b1 (Control)	223	8.8	Control	Control	-	-
a1b2	216	8.4	-7	-0.4	-	o
a1b3	219	8.7	-4	-0.1	-	-
a2b1	211	8.1	-12	-0.7	ooo	ooo
a2b2	193	7.8	-30	-1.0	ooo	ooo
a2b3	203	7.9	-20	-0.9	ooo	ooo
a3b1	221	8.3	-2	-0.5	-	ooo
a3b2	214	7.9	-9	-0.9	o	ooo
a3b3	217	8.1	-6	-0.7	-	ooo
DL5% = 7.39; DL1% = 12.64; DL0.1% = 16.82 DL5% =0.21; DL1% = 0.46; DL0.1% = 0.64						

The results of the determinations regarding the behavior of *Paulownia* fibers at dynamic and static bending are centralized in Table 7.

The resistance of Paulownia fibers to mechanical bending recorded values between 0.09 kp/cm^2 and 0.20 kp/cm^2, under planting conditions at a distance of 4 x 4 m, between 0.06 kp/cm^2 and 0.11 kp/cm^2, in following the planting at 5 x 5 m and between 0.08 kp/cm^2 and 0.19 kp/cm^2 by practicing the 6 x 6 m planting scheme, best behaving at the action of the mechanical bending forces the specimens collected from the experimental variants where the distance between plants were 5 and 6 m respectively and the plants benefited during the vegetation period from a balanced supply with nutrients (a2b2, a2b3 and a3b2), nutrients that significantly increased the elasticity of the fibers.

Table 7. The bending resistance of the fibers, as a result of the combined action of the experimental factors

Experimental Variants	Dinamic bending (kp/cm^2)	Difference (kp/cm^2)	Static bending at 12% (kp/cm^2)	Difference (kp/cm^2)	Semnification	
a1b1 (Control)	0.20	Control	371	Control	-	-
a1b2	0.09	-0.11	352	-19	ooo	ooo
a1b3	0.18	-0.02	365	-6	o	o
a2b1	0.11	-0.09	348	-23	ooo	ooo
a2b2	0.06	-0.14	337	-34	ooo	ooo
a2b3	0.09	-0.11	345	-26	ooo	ooo
a3b1	0.19	-0.01	369	-2	o	-
a3b2	0.08	-0.12	348	-23	ooo	ooo
a3b3	0.14	-0.06	362	-9	o	oo
DL5% =0.01; DL1% = 0.04; DL0.1% = 0.07 DL5% =4.39; DL1% = 7.64; DL0.1% = 8.89						

The differences, compared to the variant taken as an experimental control (a1b1) had a statistically significant negative assurance (o), in the case of the experimental variants a1b3, a3b1 and a3b3, differences that became very significantly negative (ooo) in the case of the samples from the experimental variants. which plant density was 400 plants/ha and 40 kg/ha were administered Polyfeed 14-14-28+2MgO+ME, respectively Bonus K-Energy (10-5-38+6%S+3%Mg+B+Mn), the fibers showing in these situations increased elasticity.

Regarding the resistance of the fibers to the static bending, at their 12% humidity, the recorded values ranged from 337 kp/cm^2 to 371 kp/cm^2, with differences compared to the very negative control variant (ooo) in the experimental variants a1b2, a2b1, a2b2, a2b3 and a3b3, distinctly significant negative (oo), a3b3, significant negative (o), a1b3 and insignificant (-), in the experimental variant a3b1.

Table 8. The tensile strength of the fibers, as a result of the combined action of the experimental factors

Experimental Variants	Fiber traction at 12%				Semnification	
	Tangential (kp/cm^2)	Difference (kp/cm^2)	Radial (kp/cm^2)	Difference (kp/cm^2)		
a1b1 (Control)	10.91	Control	11.23	Control	-	-
a1b2	10.81	-0.10	11.17	-0.06	ooo	ooo
a1b3	10.83	-0.08	11.19	-0.04	oo	oo
a2b1	10.82	-0.09	11.18	-0.05	ooo	oo
a2b2	10.67	-0.24	11.07	-0.16	ooo	ooo
a2b3	10.71	-0.20	11.11	-0.12	ooo	ooo
a3b1	10.94	0.03	11.20	-0.03	xx	o
a3b2	10.86	-0.05	11.15	-0.08	oo	ooo
a3b3	10.88	-0.03	11.19	-0.04	oo	oo
DL5% =0.02; DL1% = 0.03; DL0.1% = 0.09 DL5% =0.02; DL1% = 0.04; DL0.1% = 0.06						

From a statistical point of view, compared to the control variant (a1b1), there were very significant negative differences (ooo) in the experimental variants a1b2, a2b1, a2b2 and a2b3, distinctly significant negative (oo), in the variants a1b3, a3b2, and a3b3, distinctly significant positive (xx), in the experimental variant a3b1, variant in which fibers with lower tensile strength were obtained, compared to the rest of the experimental variants.

The same situation was founded when was analyzed the results of the determinations related to the fiber resistance to radial traction, the values of this parameter being between 11.07 kp/cm^2 and 11.23 kp/cm^2 (Table 8), the fibers of the highest quality, in terms of their resistance to mechanical actions, being obtained under the conditions of fertilization of plants with a dose of Polyfeed 14-14-28+2MgO+ME, regardless of the density of the plants, the differences from the control of the experience (a1b1) having a very negative statistical assurance (ooo).

CONCLUSIONS

In terms of fiber density, the lightest wood, with high quality fibers, was obtained under the conditions of planting schemes 5x5m and 6x6 m, against the background of 40 kg/ha Polyfeed 14-14-28+2MgO+ME and BONUS K-ENERGY (10-5-38+6%S+3%Mg+B+Mn).

The hygroscopicity of *Paulownia* fibers increased directly in proportion to the reduction of the nutrition space of the plants, regardless of the type of fertilizer administered to the plants during the vegetation period, fibers of the highest quality being obtained on the basis of the administration of 40 kg/ha Polyfeed 14-14-28+2MgO+ME under the conditions of the 5x5 m planting scheme.

The volumetric and linear contraction of the fibers increased directly in proportion to the increase of the plant nutrition space and the quantity of nutrients available to the plants in order to stimulate the physiological processes of growths and their development.

The radial hardness of the fibers increased directly in proportion to the dose of fertilizer administered during the vegetation period of the *Paulownia* plants and conversely proportional to the increase in the available nutrition space to the plants.

By achieving a planting density of 400 plants/ha (5x5 m) and ensuring a balanced nutrition with nutrients of *Paulownia* plants, the mechanical properties of the fibers, in particular the elasticity and the resistance of the fibers to dynamic and static bending, are significantly improved.

The tensile strength of the fibers was influenced to a lesser extent by the planting scheme used in the experimental field, having a direct impact on the fiber quality from the point of view of this indicator having the optimum supply of plants throughout the vegetation period with the indispensable nutrients their growth and development, elements that are easily accessible to plants, easily assimilated and in a balanced ratio.

REFERENCES

Barbu, M.C., Buresova, K., Tudor, E.M., Petutschnigg, A. (2022). *Physical and Mechanical Properties of Paulownia tomentosa x elongata Sawn Wood from Spanish, Bulgarian and Serbian Plantations*. Forests 2022, 13, 1543. *https://doi.org/10.3390/f13101543*

Dobrinoiu, R.V., Dănăilă-Guidea, S.M., Ivan, R., Filip, C.E., Sprio, F.M. (2018). *Researches concerning the influence of technological links on dendrometric parameters to Paulownia Ssp.* Agriculture for Life, Life for Agriculture" Conference Proceedings, Sciendo-DE GRUYTER Poland, Online ISSN 2601-6222, 1(1), p. 290–297 DOI: https://doi.org/10.2478/alife-2018-0043

Dubova, O., Voitovych, O., Boika, O. (2019). *Paulownia Tomentosa-New Species for the Industrial Landscaping*. Current Trends in Natural Sciences, 8(16), 19–24.

Fokina, A., Satarova, T., Denysiuk, K., Kharytonov, M., Babenko, M., Rula, I., 2020. *Biotechnological approaches to Paulownia in vitro propagation and in vivo adaptation*. Scientific Bulletin. Series F. Biotechnologies, Vol. XXIV, ISSN 2285-1364, 167-176. https://biotechnologyjournal.usamv.ro/pdf/2020/issue_1/Art23.pdf

Gyuleva, V. (2008). Project '*Establishment of geographical plantations of Paulownia elongata hybrids in Bulgaria*'- Contract No37 with State Agency of Forests (2007-2010). News Bulgarian Academy of Sciences, 12(64), 2–4.

Haldar, A., Sethi, N. (2021). *Effect of Institutional Quality and Renewable Energy Consumption on CO2 Emissions-an Empirical Investigation for Developing Countries*. Environmental Science and Pollution Research, 28, 15485–15503. DOI: https://doi.org/10.1007/ s11356-020-11532-2

Hamdan, H.Z. & Houri, A.F. (2022). *CO2 Sequestration by Propagation of the Fast-Growing Azolla Spp*. Environmental Science and Pollution Research, 29, 16912–16924. DOI: https://doi.org/10.1007/s11356-021-16986-6.

House, J.I., Colin Prentice, I. and Le Quere, C. (2002). *Maximum impacts of future reforestation or deforestation on atmospheric CO_2. Global Change Biology* 8(11): 1047- 1052. DOI: 10.1046/j.1365-2486.2002.00536.x

Jakubowski, M. (2022). *Cultivation Potential and Uses of Paulownia Wood: A Review*. Forests, 13(5), 668. DOI: https://doi.org/10.3390/f13050668

Jiménez, L. & Rodríguez, A. (2003). *La Paulownia como materia prima para la fabricación de papel*. Química Teórica y Aplicada 516: 100-105.

Jensen, J.B. (2016). *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, p.213. DOI: 10.13140/RG.2.2.31955.78882

Jose, S. and Bardhan, S. (2012). *Agroforestry for biomass production and carbon sequestration: an overview*. *Agroforestry Systems 86*:(2). 105-111. DOI: 10.1007/s10457-012-9573-X

Kaymakci, A., Bektas, I., Bal, B. (2013). *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.

Koman, S., Feher, S., Vityi, A. (2017). *Physical and Mechanical Properties of Paulownia tomentosa Wood Planted in Hungaria*. Wood Res. 2017, 62, 335–340.