End use of *Eucalyptus gomphocephala* wood as its traits

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ABSTRACT

The present study was conducted during 2021 in the Forestry and Timber Trees Dept., Hort. Res. Inst., A R C, Giza, Egypt. The study aimed to evaluate biomass and some wood properties of second rotation of *Eucalyptus gomphocephal*a Dehn at age of 22- years- old. And selecting the possibilities of using of *E. gomphocephal*a wood. Mean values of total height, merchantable height, DBH (diameter at breast height), basal area and volume per tree were 19.72 ± 1.42 m, 16.51 ± 0.32 m, 118.49 ± 15.23 cm, 0.40 ± 0.08 m^2 and 3.49 ± 0.48 m^3, respectively. Mean green and dry weight of stem, and branches were (3.54 ± 0.57 and 2.56 ± 0.41), and (0.69 ± 0.18 and 0.60 ± 0.16) ton / tree, respectively. Mean values of wood density were reduced with stem height up. The highest values of strength property of wood as a modulus of rupture (MOR), and compressive strength parallel to grain (C max) were at level 2nd (DBH +2.5 m). The highest values of hardness property as Janka hardness number (JHN) in radial and tangential directions were at 1st level (DBH). At 2nd level, cellulose and lignin were highest values, and reduced with stem height up.

Keywords: *Eucalyptus gomphocephala*- Biomass- Mechanical Properties.

INTRODUCTION

Egypt imports about 1.5-billion-dollar wood, and about 1.5-billion-dollar pulp paper and paper annually (CAPMAS, 2021). At the same time, there are many species of woody exotic trees that good adapted with Egypt environments. These species need to be evaluated for their wood qualities, productivity and suitability for various wood products with commercial value to meet the requirements of the local market. This works to reduce the value of the general budget funds paid to import wood and its products from abroad. Nowadays, eucalyptus is one of the most significant planted hardwoods. They estimate that there are about 20 million hectares of Eucalyptus plantations worldwide, of which 2.4 million ha are in Africa (Hardwood, 2018). The potential uses for Eucalyptus wood are numerous and include plywood panels, laminated wood, sawn timber, posts, telephone and electrical poles, building anchors, cellulose and paper, charcoal, and structural elements of buildings with bendable portions, among other things, (Lahr et al., 2017). The pulp and paper operations mostly source its short fibers from Eucalyptus plantations, which also have good woody properties (Silverio et al. 2007). *Eucalyptus gomphocephala* is one of Eucalyptus species that grows well in new reclaimed lands in Egypt.

Eucalyptus gomphocephala (known commonly as Tuart), Fam. Myrtaceae originates from the Southwest of Australia around Perth (Boland et al., 2006) and it is also found around Adelaide (Capital of South Australia). The species is widely known for outperforming other species such *E. camaldulensis*, on sites with very alkaline soils due to its superior growth performance in winter rainfall areas with dry summer circ umstance. Because of its extreme drought tolerance, it is commonly planted as a shade tree by roadways in South Africa. (National Academy of Sciences, 1980). Tuart is one of the few Eucalyptus sp. known to be well adapted to calcareous alkaline soils (Ruthrof et al., 2002). Species of the genus Eucalyptus have a great capacity for regeneration after harvesting. This capacity is due to the presence of adventitious shoots, as well as lignotubers at the base of the tree, which allow a second rotation managing the sprouts. The large amount of biomass underground from the original tree provides the shoots with a greater reserve and a greater supply of nutrients, allowing a vigorous early growth of sprouts. Coppice management requires the least initial investment and the one that presents less sensitivity to changes in productive variables than the replanting alternatives, Balmelli et al. (2023).

The wood of *E. gomphocephala* is light brown, almost oak-colored, and has a high degree of spiral grain, which caused the boards to twist significantly, Wessels et al. (2016). Traditionally, it has been utilized for keelsons, stern posts, bridge supports, shafts, and wheelwright work. It yields hard, dense, long-lasting wood that is somewhat resistant to termites, (Boland et al., 2006). Banks et al. (1976) Clear wood samples from *E. gomphocephala* trees cultivated in South Africa were evaluated, and the results showed a mean modulus of elasticity (MOE) of 18.3 GPa and a mean modulus of rupture (MOR) of 136 MPa. Wood of *E. gomphocephala* is highly resilient to impacts directed tangentially, but we must constantly exercise caution to avoid dramatically increasing the rate of evaporation during artificial drying in the oven. This will help to avoid the wood from experiencing significant dimensional variations that could negatively impact its mechanical behavior. Although the MOE was still enough for the majority of uses, such as structural or aesthetic grade lumber, it might not be as valuable as high-value species that are usually used for flooring or decking. Research should be done on drying techniques in addition to sawing techniques to lessen twist in boards, Wessels et al. (2016). More energy is absorbed by the wood of *E. gomphocephala* proves that it is more adapted to be usable in the structural construction exhibiting to the high load for example: pit props(Loulidi et al. 2012).

In Egypt, Forestry and Timber Trees Department; Horticulture Research Institute; Agricultural Research Center conducted some studies on *E. gomphocephala* to assess the adaptation to new reclaimed land conditions, where scarce irrigation water, poor soil and difficult climate. Also, planted this species as a wind break in these conditions. Whenever, *E. gomphocephala* has superior growth as compared with *Casuarina* sp. as a wind break. This study focuses on end use of *E. gomphocephala* wood for manufacturing purposes that are compatible with it.

MATERIALS AND METHODS

This study was carried out during 2021 aimed to estimate biomass and some physical, mechanical, and chemical properties of wood at second rotation of *Eucalyptus gomphocephala* Dehn (tuart), belong to Fam. Myrtaceae at age of 22-years - old. And selecting the possibilities of using of *E. gomphocephal*a wood. The trees of this species were planted in new reclaimed land during 1989 at El-Kassasin Horticultural Research Station; Horticulture Research Institute; Agriculture Research Center. Textural class of soil is sandy, and pH 8.1, El-Morshedy et al. (2002). The distance between trees were 5 ×5 m. these trees were cut down for the first time in 1998, the trees grew without intervention and gave from two to five branches.

Selection of trees and parameters of growth determination:

Following the measurement of the diameter at breast height (130 cm above ground level) for the plot of *Eucalyptus gomphocephala* trees to determine the average diameter of the trees, three trees were chosen (based on calculating the average sum of the branch diameters and the average number of branches for each tree). Selected trees were cut at 25 cm above-ground. Aboveground compartments (stem, branches and foliage) were separated in the field, and the following measurements were taken.

Height of tree: A measuring tape was used to measure the merchantable height (from the stump up to 10 cm of stem diameter) of three branches of the tree, as well as the total height of the tree, starting from the stump height (25 cm from ground level to the top) (m/tree). Next, determine each replicate's height mean.

Diameter at breast height: The diameter of the three main branches at the breast height (DBH) of each tree was measured, and these diameters were then summed to give DBH for each replicate.

Above-ground biomass: Following the removal of the trees, the aboveground material was processed at the field into stem wood, branches (up to 0.5 cm in diameter), and foliage (leaves, branches less than 0.5 cm, and fruits). Using a chain saw, the stem (including bark) was separated into successive logs of 2.5 m, in addition to the base ground up to 130 cm diameter (DBH). The green weights were measured in the field for the three main tree branches (stems), branches, and foliage (Kg/tree) using a digital scale with an accuracy of ± 0.1 kg. A 5 cm long disk was cut from each section of stem, and 1.0 kg was removed from the branches and foliage. All of them were then oven dried until their weight remained constant, with the foliage being dried at 70˚C and the stem and branches at 103± 2˚C. Dry mass was determined and recorded to calculate total oven-dry mass of tree. For every component, the percentages of dry and green mass to the total mass above ground were computed. Total above-ground biomass (green and dry) per feddan (density 168 trees) was calculated.

Stem volume calculation: Using a measuring tape, the stem diameter and length between specific intervals along the stem of each tree were recorded in order to calculate the stem volume (outside bark), using Samilian׳s formula (De Gier, 2003). The volume of each section was determined and they were summed to give the total volume of stem (m^3/ tree). Total volume yield per feddan was calculated by multiple numbers of trees per feddan (density 168 trees) by the mean volume of tree stem.

Basal area: Basal area at 130 cm above-ground level (DBH) was calculated for three main branches of each tree then summed (m^2/tree).

Wood samples: Two disks at 2.5 and 7.5 m of total height tree after DBH, and the first disk obtained at DBH (diameter at breast height) were the three 40 cm long sectioned disks that were dried at 103 ± 2˚C to constant weight.

Physical properties of wood: Density of wood was calculated as the ratio of oven-dry weight to green volume, determined through the water displacement method (Barnett and Jeronimidis, 2003)**.**

Mechanical properties of wood: samples of wood were cut into rectangular sections with dimensions of 2 × 2 × 30 cm according to British Standard Specifications (1957). Dimensions of specimens were 2 × 2 × 30 cm over a span length of 28 cm for Static Bending Test (MOR), 2 × 2 × 3 cm for Compressive Strength Parallel to grain (Cmax) and 2 × 2 × 6 cm for Janka Hardness Test (JHN). Mechanical testes were carried out using Amsler Universal Testing Machine (Model, DBZF 120). Percentage of moisture content of test specimens ranged from 11.50 to 15.41 %. These properties had determined by wood and wood products testing laboratory, Forestry department, Faculty of Agriculture, Alexandria University.

Chemical analysis of wood: Hemicellulose, cellulose and lignin were determined using the method of Goering and Van Soest (1970).

Physical and mechanical properties and chemical analysis of wood determined at three levels of height of stem (level 1 = diameter at breast high (DBH), level 2 = DBH + 2.5 m, level 3 = DBH + 7.5 m).

Statistical Analysis: The SPSS software program was utilized to determine the general statistical description, which included the average and standard deviation, for the various biomass and wood property metrics. The percentage distribution of the tree's biomass components-its stem, branches, and foliage-was computed from the total amount of above-ground biomass that is green and dry.

RESULTS AND DISCUSSIONS

Biomass parameters of *Eucalyptus gomphocephala* of second rotation at age 22 - years- old:

Means and standard deviations for *Eucalyptus gomphocephala* of second rotation at age 22 years old, including total and merchantable height of tree (m), DBH (diameter at breast height) (cm), basal area (m^2)/tree, and volume (m^3)/tree.

These parameters presented in **(Table 1)**. Mean value of total height was 19.72 ± 1.42 m, merchantable height was 16.51 ± 0.32 m, diameter at breast height was 118.49 ± 15.23 cm, basal area was 0.40 ±0.08 $m^{2,}$ and volume was 3.49 ± 0.48 m^3. At the same plot of this study since1998, in the Research Farm of El-Kassasin, El-Morshedy et al. (2002) indicated that, the highest value of DBH and the total height had obtained for *E. gomphocephala* (27.9 ± 1.67 cm) and (18.84 ±1.38 m), respectively. This was in a comparative study among eight tree species (*Casuarina glauca*, *C. equisetifolia, Eucalyptus citriodora*, *E. gomphocephala*, *Khaya senegalensis*, *Swietenia mahagoni*, *Cupressus sempervirens and Taxodium distichum*).

Table (1). Biomass parameters of *Eucalyptus gomphocephala* of second rotation at age 22-year-old.

Parameters of growth	Mean values	Standard deviation
Total height of tree (m)	19.72	1.42±
Merchantable height of tree (m)	16.51	0.32±
Diameter at breast height (cm)	118.49	15.23±
Basal area (m^2)	0.40	0.08±
Volume (m^3)	3.49	0.48±

Merchantable height and volume (from the stump up to 10 cm stem diameter)
Diameter at breast height = Sum of the diameters of the main branches of the tree.

Green and dry weight of the stem, branches, foliage and total above-ground biomass (ton/tree) of the second rotation at the age of 22- year-old of *Eucalyptus gomphocephala*.

Mean values and standard deviation of green and dry weight of stem, branches and foliage of second rotation of *E. gomphocephala* **(Table 2)** were (3.54 ± 0.57) and (2.56 ± 0.41), (0.69 ± 0.18) and (0.60 ± 0.16) and (0.41 ± 0.03) and (0.19 ± 0.02) ton/ tree, respectively. Mean values and standard deviation of green and dry weight of Total above-ground biomass are 4.63 ± 0.78 and 3.34 ± 0.59 ton/ tree, respectively. Eucalyptus grows quickly, reaching a maximum annual growth rate of 10 m and monthly growth rates of up to 1 m. It is one of the three fastest-growing tree species worldwide. Therefore, the cornerstone of attaining *Eucalyptus* growth-change monitoring and exact management is methods to rapidly and precisely obtain the aboveground biomass (AGB) of Eucalyptus in various growth stages at a low cost, can have a significant impact on eucalyptus plantation planning, management, and policy formation. (Liu et al., 2023).

Table (2). Green and dry weight of the stem, branches, foliage and total above- ground biomass (ton/tree) of the second rotation at the age of 22- year-old of *Eucalyptus gomphocephala*.

Parameters	Green weight (ton/tree)	Dry weight (ton/tree)
Stem	3.54 ± 0.57	2.56 ± 0.41
Branches	0.69 ± 0.18	0.60 ± 0.16
Foliage	0.41 ± 0.03	0.19 ± 0.02
Total above-ground biomass	4.63 ± 0.78	3.34 ± 0.59

Mean values ± standard deviation

Distribution of biomass components as a percentage from the total green and dry above-ground biomass (AGB) of *Eucalyptus gomphocephala.*

Distribution of biomass components as a percentage from total green and dry above-ground biomass of *E. gomphocephala* presented in **(Fig. 1)** The highest percentage of the green and dry biomass components was tree stem (76.37 and 76.50%). However, it reduced for branches and foliage (14.83 and 17.90%), (8.81 and 5.63%), respectively. In the same stand at the age of 9 years, the distribution of total above-ground biomass in green and dry state was (67.51, 10.75 and 21.74%) and (70.01, 10.93 and 19.06%) for stem, branches and foliage of *E. gomphocephala*, Abd El-Kader (2000). The stem and branches ratios were greater of second rotation at age of 22–years-old than at age 9-years–old. On The contrary, the ratio foliage of second rotation at age 22-years-old was less than at age of 9 years. The mature wood increases and juvenile wood decreases with increase age of trees. It is possible to take advantage of trees at a young age, whether during thinning or in the case of intensive agriculture in the manufacture of pulp or paper. Because juvenile wood increases with tree height, it will make up a larger proportion of complete trees. By using better technology and combining juvenile wood with adult or wood from different species, the pulp and paper industry was able to adapt to the shorter fibers and thinner cell walls of juvenile wood, Bendtsen and Senft (1986). *E. gomphocephala* showed a similarly large stem volume, but the lowest vessel fraction. Therefore, it had the highest density and largest biomass as compared with *Eucalyptus grandis* × *E. camaldulensis* hybrid, and *E. cladocalyx*, Lundqvist et al. (2017). The proportion of stem biomass increased with increasing tree age, and the biomass proportion of branches and leaves decreased with increasing tree age, Deng et al. (2023).

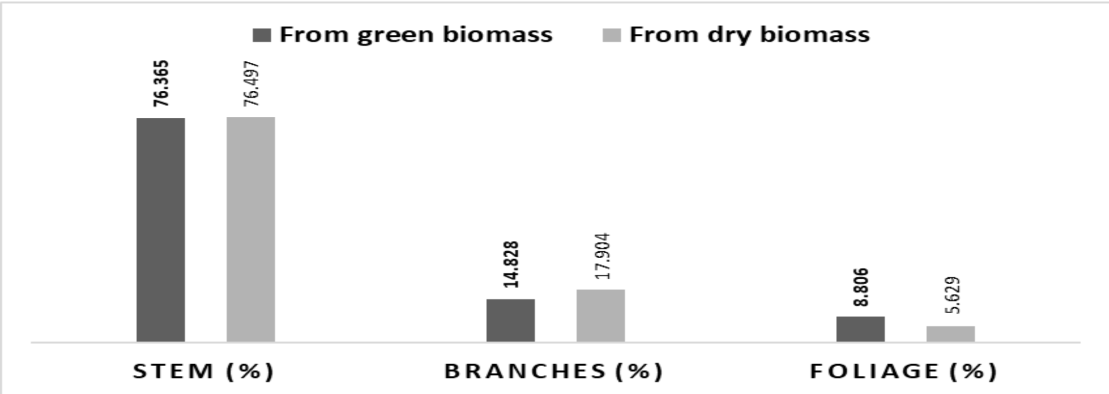

Fig. (1). Distribution of biomass components as a percentage from the total green and dry above-ground biomass (AGB) of *Eucalyptus gomphocephala.*

Total above-ground biomass of *Eucalyptus gomphocephala*:

Data presented in **Table (3)** indicated that, production of biomass (ton/ feddan) for stem, branches and total above-ground biomass in green and dry weight. Also, total volume of stem outside bark (m^3/ feddan) of *E. gomphocephala* of second rotation at age of 22 -years-old. Green biomass of stem and branches were 594.38 and 115.42 (t/f). The monetary value of a ton for green biomass of stem and branches of *E. gomphocephala* is estimated at about 64 and 32 US dollars. The cash value for feddan obtained of second rotation at age of 22 -years-old 41733.76 US dollars.

Table (3). Total above-ground biomass in green and dry state (ton/ feddan) and total volume of stem (m^3/ feddan) of *Eucalyptus gomphocephala* of second rotation at age 22-year-old.

Growth traits	Mean values	Standard deviation
Green biomass of stem (t/f)	594.38	96.04±
Green biomass of branches (t/f)	115.42	30.12±
Green biomass of foliage (t/f)	68.60	5.63±
Total green biomass (t/f)	778.40	131.78±
Dry biomass of stem (t/f)	429.24	69.41±
Dry biomass of branches (t/f)	100.41	26.24 ±
Dry biomass of foliage ((t/f))	31.53	2.67±
Total dry biomass (t/f)	561.18	98.32±
Total volume of stem (m^3/f)	585.93	80.02±

t/f = ton/ feddan, m^3/f =cubic meters/ feddan,

***Eucalyptus gomphocephala* wood traits:**

Data presented in **Table (4)** showed that, mean values and standard deviation of wood density of *E. gomphocephala* were reduced from the level of DBH to the height of stem up. The values of these properties at DBH were 0.86 ± 0.03 g. cm^3, and at the levels of 2, and 3 were (0.83 ± 0.08 g. cm^3), and (0.71 ± 0.06 g. cm^3), respectively. The average density of the cross-sections from breast height to the sample location above it increased slightly in *E. gomphocephala*. This is a sign that the wood is transitioning from juvenility to maturity for both radially and longitudinally along the stem, Lundqvist et al. (2017).

The very high density of its wood may make this species good for use in processing multiple end products where products that can benefit for the high density, such as biofuel chips, are one of the end products together with lumber, Wessels et al. (2016). From bottom to top, juvenility rises, and as it does, density falls. The density demonstrated a declining trend towards the upper portion due to the maturity of the wood tissues in the lower portion. This suggests that where great strength is needed for structural requirements, butt end logs' high-density timber should be utilized, Getahun et al. (2014).

Table (4). Wood density (g. cm^3), modulus of rupture (MOR), compressive strength (C max) and Janka Hardness test (JHN) in radial and tangential directions (R and T) at different level of stem height for *Eucalyptus gomphocephala*.

Property	Level No.	1	2	3
Wood density (g. cm^3)		**0.86 ± 0.03**	**0.83 ± 0.08**	**0.71 ± 0.06**
MOR (MPa)		**72.18 ± 12.45**	**105.96 ±10.77**	**59.86 ± 23.39**
C max (MPa)		**51.78 ± 3.64**	**55.71 ± 2.60**	**51.34 ± 4.41**
JHN (N)	**R**	**5.42 ± 0.66**	**4.98 ± 0.39**	**4.56 ± 0.81**
	T	**6.98 ± 0.89**	**6.19 ± 1.47**	**5.03 ± 0.53**

Mean values ± standard deviation, level No. = position of sample on height of stem, level No.1= DBH, level No. 2 = DBH+2.5 m, level No. 3 = DBH+7.5. m, Pa = pascal, unit that determination of perpendicular force on unit of area, 1 Pa= $1N/m^2$, MPa = 10^6 Pa, N = Newton.

Concerning the strength property of *E. gomphocephala* wood at different levels of stem **(Table 4)** as a modulus of rupture (MOR), and compressive strength (C max), the highest mean values at level 2nd (DBH +2.5 m) 105.96 ±10.77 MPa and 55.71 ±2.60 MPa, respectively. However, the lowest mean values of both properties at level 3th (DBH +7.5 m) 59.86 ±23.39 MPa and 51.34 ±4.41 MPa, respectively. The moderate mean values at level 1st (DBH) 72.18 ±12.45 MPa, and 51.78 ±3.64 MPa, respectively. Hardness property as Janka hardness number (JHN) in radial and tangential directions, the highest mean values at level 1st (DBH) 5.42 ±0.66 and 6.98 ±0.89 (N), respectively. While, Hardness property of wood of *E. gomphocephala* reduced with headed up the stem. Mean values of JHN at level 2nd (4.98 ±0.39 and 6.19 ±1.47 (N) followed by level 3th (4.56 ±0.81 and 5.03 ±0.53 (N), respectively.

Data in **Table (4)** concluded that, *E. gomphocephala* wood have a high density, that decreased with the direction to the top of tree stem. Because wood density has a significant positive link with strength, elasticity, and hardness, it is also a crucial wood feature when producing solid wood products, Balatinecz et al. (2014). There was an increase in modulus of rupture (MOR), and compressive strength (C max) at level 2nd, (DBH +2.5 m), this may be attributed to an increase of cellulose and lignin percentages at the same level from height of stem. However, there was a decrease in density of wood, MOR, C max and hardness at level 3th (DBH +7.5 m), which is accompanied by a decrease in the percentage of cellulose and lignin. Its strength and hardness of its fibers makes us shed light to exploit it to produce solid wood products such as timber of structural construction. We can explain why the wood from the base had the best mechanical properties, and based on the results, we can conclude that using the wood from the base for furniture is preferable to using top wood because the base wood had lower vessel number values and higher vessel wall thickness and fiber wall thickness values. On the other side, the wood from the told may be utilized to produce ethanol and furfural, Abdel-Aal and Hammad (2009).

Chemical analysis of *Eucalyptus gomphocephala* wood:

Data presented in **Table (5)** showed that, the content of *E. gomphocephala* wood from cellulose and lignin at level 2nd (DBH +2.5 m), were highest values (45.12 and 30.75 %), respectively, while, its lowest value in hemicellulose (20.00 %). At level 3th (DBH +7.5 m), cellulose and lignin percentages were lowest values (35.41 and 23.73%), while hemicellulose increased (27%). However, at level 1st (DBH), cellulose and lignin percentages were moderate values between level 2nd and 3th (39.60 and 27.30 %).

Table (5). Cellulose, hemicellulose, and lignin (%) at different level of stem height for *Eucalyptus gomphocephala* of second rotation at age 22-year-old.

Property \ Level No.	1	2	3
Cellulose (%)	39.60	45.12	35.41
Hemicellulose (%)	27.00	20.00	27.00
Lignin (%)	27.30	30.75	23.73

Level No. = position of sample on height of stem, level No.1= DBH, level No. 2=DBH+2.5m, level No. 3=DBH+7.5m.

Many authors have reached such results; the quality of wood substance of which the cell walls are built is not constant despite the practically unvaried density. The observed changes in quality are related to the changes in the content of fundamental chemical compounds (cellulose, hemicelluloses, and lignin) and their distribution in particular layers of the cell wall, Krauss et al. (2011). The *Eucalyptus* chips present 42–45% of cellulose, 27–30% of hemicellulose, 20–28% of lignin and 3–5% of extractive and non-extractive (Rencoret et al., 2007 and Klock et al., 2005).

CONCLUSIONS

In Egypt, agricultural and urban expansion in desert lands requires reliance of fast-growing tree species that adapted to these harsh environmental conditions. At the same time, it produces a large amount of biomass in a short time to achieve environmental and economic benefits such as windbreaks, shelter belts, and the preservation of soil and water sources. in addition to confront the shortage of wood and wood products. Wood yield of second rotation of *Eucalyptus gomphocephala* that planted at 5 × 5 m (density of 168 tree / feddan) in reclaimed land at age 22-years-old. Its green, dry weight of total biomass and total volume of stem were 594.384 ±96.040 and 429.240 ±69.408 (ton/feddan) and 585.928 ±80.023 (m^3/ feddan). *Eucalyptus gomphocephala* trees have produced superior wood yields with good properties of wood. That can be used to produce solid wood which use in many industries, including furniture, poxes, poles, Wooden moldings, pallets, scaffolds, glued laminated wood, doors, windows, flooring and rotative veneers to make plywood; provided that sawing is done in a proper manner and good manufacturing technology is used, especially drying conditions and splitting to ensure dimensional stability.

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الملخص العربى

الإستخدام النهائي لخشب أشجار الكافور (*Eucalyptus gomphocephala*) طبقا لخصائصه

مها فاروق محمد إسماعيل -منى مصطفى عباس - مجدي إسماعيل بهنسى - محمد عبد الجواد العتربى

قسم بحوث الغابات والأشجار الخشبية - معهد بحوث البساتين – مركز البحوث الزراعية

أجريت هذه الدراسة خلال عام 2021 في قسم بحوث الغابات والأشجار الخشبية - معهد بحوث البساتين – مركز البحوث الزراعية – جيزة – مصر. حيث تهدف هذه الدراسة الى تقييم الكتلة الحيوية وبعض صفات الخشب لأشجار الكافور (*Eucalyptus gomphocephala*) لدورة القطع الثانية عند عمر 22 عام. واختيار امكانات استخدام خشب الكافور. كانت متوسط القيم لارتفاع الساق والارتفاع التجاري والقطر عند ارتفاع الصدر والمساحة القاعدية والحجم للشجرة (19,72 ± 1,42 م و16,51 ± 32، م و118,49 ± 15,23 سم و0,40 ± 0,08 م^2 و3,49 ± 0,48 م3) على التوالي. وكان متوسط الوزن الأخضر والجاف للساق والافرع (3,54 ± 0,57 و2,56 ± 0,41) و(0,69 ± 0,18 و0,60 ± 0,16) طن للشجرة على التوالي. اما عن كثافة الخشب فكانت تنخفض كلما اتجهنا الى قمة الساق. قد تم تسجيل اعلى قيم متوسطات لخاصية قوة الخشب متمثلة في معامل الكسر ومتانة التهشم القصوى في الضغط الموازي للألياف عند المستوى الثاني من ارتفاع الساق (الارتفاع عند مستوى الصدر + 2,5 م). كانت اعلى قيم متوسطات لصلادة الخشب في الاتجاه القطري والمماسي عند المستوى الأول من ارتفاع الساق (الارتفاع عند مستوى الصدر). وكانت اعلى قيم للسليلوز واللجنين عند المستوى الثاني من ارتفاع الساق، والتي انخفضت كلما اتجهنا الى قمة الساق.