Biomass and Some Wood Properties of *Taxodium distichum* (L.) Rich. Grown in Two Provenances in Egypt.

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ABSTRACT

The present study was conducted at Horticultural Research Institute, Agricultural Research Center during 2021 and 2022 years on *Taxodium distichum* (L.) grown at two research stations, namely El-Nobaria and El-Gemmeiza. The aim of this study was to estimate which of the two provenances under study is better in terms of growth, biomass and wood properties of *T. distichum* (L.) at 22 years age. Determining the height along the tree is the most appropriate for manufacturing purposes. Mean values of merchantable height of *T. distichum* tree were 11.93 ± 0.23 and 13.05 ± 1.00 m at El-Nobaria and El-Gemmeiza Research Stations, respectively. Diameter at breast height (DBH) and merchantable volume were (35.11 ± 0.72 cm and 0.5687 ± 0.05 m^3/tree) and (55.89 ± 6.12 cm and 1.0912 ± 0.11 m^3/tree) at El-Nobaria and El-Gemmeiza Research Stations, respectively. The green and dry weight of *T. distichum* stem were (620.00 ± 80.00 and 313.75 ± 38.75 Kg/tree) and (1795.66 ± 185.44 and 823.58 ± 87.56 Kg/tree) at El-Nobaria and El- Gemmeiza Research Stations, respectively. Density, Modulus of rupture (MOR), Compressive strength (Cmax) and Hardness (R and T) of wood of *T. distichum* at DBH were (0.433g.cm^{-3}, 68.180 MPa, 38.440 MPa, 3.403 N and 3.760 N) and (0.430 g.cm^{-3}, 84.890 MPa, 34.070 MPa, 3.517 N and 3.790 N) at El-Nobaria and El-Gemmeiza Research Station, respectively. The results of this study indicated that, diameter at breast height and merchantable volume of *T. distichum*in clay soil (El- Gemmeiza Research Station) were more than once and a half time as compared to calcareous loamy soil (Al Nubaria Research Station). Basal area, the green and dry weight of stem and total above-ground biomass of *T. distichum* were more than twice as much in El-Gemmeiza than in El-Nobaria. The properties of wood up to 5 m above DBH were close, good and could be used for manufacturing purposes.

Key word: Taxodium distichum, Biomass, Wood Properties.

INTRODUCTION

Adaptation studies of different environmental conditions in the field of woody trees in Egypt are limited. At the same time, there is not enough information and data on the evaluation of the biomass and the physical and mechanical properties of wood for economic high tree species grow well in Egypt. Forestry and Timber Trees Department, Horticulture Research Institute, conduct provenance studies for redistribution the local and new exotic tree species for application in new afforestation projects. Now we complete the evaluation of the woody yield in different provenances and at different ages of trees. Therefore, this study provides some information about Taxodium trees planted in two different provenances that can be used in selecting the appropriate site for this tree species, in addition to maximizing the environmental and industrial uses.

Taxodium distichum (L.) Rich. (Baldcypress) belongs to family Cupressaceae, that deciduous species. It is unique in that it is classified as a conifer but is deciduous, unlike most of its botanical cousins, however, in Egypt, it is a semi deciduous. The native range of baldcypress extends along the lower Atlantic Coastal Plain from southern Delaware to southern Florida and thence along the lower Gulf Coast Plain to southeastern Texas. Inland, baldcypress grows along the many streams of the middle and upper coastal plains and northward through the Mississippi Valley to southeastern Oklahoma, southeastern Missouri, southern Illinois, and southwestern Indiana, (Little, 1971).The wood is moderately heavy, strong, and hard. Old-growth baldcypress heartwood is one of the most decay-resistant woods, while second-growth wood is only moderately resistant. Baldcypress was mostly used for building construction when old-growth wood was available, especially where decay resistance was demanded. Caskets, sashes, doors, blinds, tanks, vats, ship and boat construction, and cooling towers were all made of it. Siding and millwork, including interior woodwork and paneling, are made from second-growth wood, (Forest Products Laboratory, 1999). The properties of wood are variance among trees and within tree for the same species. Environment and location have an important role in influencing this variation. Generally, the effects of environment on the wood properties of exotics outside their indigenous range are greater. Although wood density is thought to be the most critical element, other characteristics such as microfibril angle, spiral grain, compression wood, juvenile wood proportion, and ring width could have an equal or higher impact. Wood density is critical in the manufacturing of forest products because it influences yield, quality, and value of wood-based composites and solid timber products, and it may be altered by silvicultural techniques and genetic improvement. (Zobel and Van Buijtenen 1989). It is well known that, for softwood species, the MOE and MOR correlate with the basic wood properties, such as wood density (WD), annual ring width, and the proportion of latewood, Hautamäki et al. (2014). Bending characteristics, stiffness/ strength (MOE/MOR) are important for the engineering design and manufacture of structural lumber and for high value uses of wooden furniture components to ensure time-based performance in service **(**Ozarska, 2009**).** Information on variation in mechanical properties of wood across a tree stem is essential to investigate the influence of sawing pattern on mechanical properties of lumber products, Zhou et al. (2012)**.** This research aimed to study the variability of growth, wood biomass, wood density and some mechanical properties of wood within tree and provenances for *Taxodium distichum* trees grown in Egypt.

MATERIALS AND METHODS

This study aimed to estimate biomass yield and some physical, mechanical, and chemical properties of *Taxodium distichum* (L.) Rich wood. The trees planted during 1999 at two provenances {El-Nobaria (Beheira Governorate) and El-Gemmeiza (Gharbia Governorate) Research Stations, Horticulture Research Institute, Agriculture Research Center. The distance between trees was 3 × 3 m. Irrigation twice a month.

Soil analysis:

Soil samples were collected from two provenances at three depths (0 - 30, 30 - 60 and 60 – 90 cm) by digging profiles. Determination of chemical analysis, available elements (nitrogen, phosphorus and potassium) mg/Kg soil and Physical properties, according to Cottenie et al. (1982). All soil analysis carried out in Water and Environment Unit - Component of Analyzes and Studies - Soils, Water & Environment Research Institute (SWERI), Table 1 (a, b and c).

Table (1a): Chemical analysis of soil at two provenances (El-Nobaria and El-Gemmeiza Research Stations).

Provenances	Depth of soil (cm)	Chemical analysis of soil										
		pH (1:2.5)	E.C. (ds/m)	Sp	Soluble cations (meq/L)				Soluble anions (meq/L)			
					Na^{+}	K^{+}	Ca^{++}	Mg^{++}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$
El-Nobaria	0 – 30	8.19	3.74	41.00	17.60	0.78	11.50	7.50	-	1.50	19.50	16.38
	30– 60	8.24	3.64	40.00	15.70	0.68	11.50	8.50	-	1.50	18.50	16.38
	60 – 90	8.21	3.14	45.00	14.80	0.58	10.50	5.50	-	1.50	17.50	12.38
El-Gemmeiza	0 – 30	8.16	3.20	67.00	14.40	0.58	9.50	7.50	-	1.50	19.50	10.98
	30– 60	8.17	3.46	70.00	14.10	0.48	9.50	5.50	-	1.50	16.50	11.58
	60 – 90	8.13	3.45	65.00	16.80	0.65	11.50	5.50	-	1.50	19.50	13.45

Table (1 b): Determination of available elements (nitrogen, phosphorus and potassium) mg/ Kg soil at two provenances.

Provenances	Soil depth	Nitrogen	Phosphorus	Potassium
El-Nobaria	0 – 30	61.00	3.44	108.00
	30– 60	95.00	2.13	75.00
	60 – 90	87.00	8.37	34.00
El-Gemmeiza	0 – 30	90.00	5.14	166.00
	30– 60	95.00	3.87	142.00
	60 – 90	144.00	12.81	91.00

Table (1 c): Physical properties of soil at two provenances.

Provenances	Soil depth (cm)	Soil grain size distribution			Texture	$CaCO_3$ %
		Sand	Silt	Clay		
El-Nobaria	0 – 30	34.50	48.00	17.50	Loamy	18.48
	30– 60	33.50	46.00	20.50	Loamy	31.50
	60 - 90	37.50	34.50	19.00	Loamy	27.30
El-Gemmeiza	0 – 30	1.50	15.00	83.50	Clay	0.42
	30– 60	2.00	12.50	83.50	Clay	0.40
	60 - 90	2.00	12.00	86.00	Clay	0.34

Determination of growth parameters:

Selection of samples trees:

Three samples of *Taxodium distichum* trees at age of 22- years- old were selected from each of El-Nobaria and El-Gemmeiza Research Station. This selects according to the average of diameter at breast height of trees block. Samples of trees were cut down at 20 – 30 cm above-ground during (October 2021). Trees were separated to proportions of main stem, branches and foliage. The following measurements were taken.

Tree height:

Total height of tree was measured from stump height (20 -30 cm from ground level to the top of tree and merchantable height of tree (from the stump up to 10 cm diameter of stem) were measured by a measuring tape (m/tree).

Diameter at breast height:

Diameter at a height of 130 cm of the tree from the ground level, and determined by a measuring tape (cm).

Above-ground biomass:

Green weights (Kg/ tree) of main stem including bark (up to diameter of 10 cm), branches (till 0.5 cm diameter) and foliage (leaves, branches less than 0.5 cm and fruits) were measured using digital scale (± 0.1 kg) at the field. Samples from each component were oven dried until constant weight at 70˚C for foliage and 103 ± 2˚C for stem and branches. Dry mass was determined and recorded to calculate total oven-dry mass of tree. The percentages of green and dry mass for each component to the total above-ground mass were calculated. Total above-ground biomass (green and dry) per feddan, distance of planting 3×3 m (density 466 trees / feddan) was calculated.

Stem volume calculation:

Stem volume (outside bark) of each tree was measured using a measuring tape and recording stem diameter at the certain points intervals along tree stem, and length between these points. The volume of each section was determined and they were summed to give the total volume of stem. Total volume yield per feddan was calculated by multiple numbers of trees per feddan by the mean volume of stem.

Basal area:

Basal area is the cross- sectional area of tree at 130 cm above-ground level (DBH) was calculated (cm^2/tree).

Properties of wood:

Wooden samples:

Three disks of 40 cm length were sectioned to determined physical and mechanical properties and chemical analysis of wood. First disk was taken at DBH (diameter at breast height), and the other two disks were taken at 2.5 and 5.0 m of total height tree above DBH, and they were dried at 102 ± 3˚C to constant weight.

Physical properties of wood:

Density were determined using specimen of Static Bending Test near the failure point.. Density 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:

Wood samples were cut into rectangular sections with dimensions of 2 × 2 × 30 cm according to British Standard Specifications (1957). Mechanical testes were carried out using Amsler Universal Testing Machine (Model, DBZF 120). Dimensions of specimens were 2 × 2 × 30 cm over a span length of 28 cm for Static Bending Test, 2 × 2 × 3 cm for Compressive Strength Parallel to grain and 2 × 2 × 6 cm for Janka Hardness Test. Moisture content was calculated based on the air-dry and oven-dry weight of samples of wood. Moisture Contents (MC) of test specimens ranged from 10.86 to 11.35 % and 10.90 to 11.56 %at El-Nobaria and. El-Gemmeiza Research Station, respectively.

Statistical Analysis:

The average and standard deviation for the different parameters of biomass were determined by using the SPSS software package. Distribution of the biomass components (stem, branches and foliage) of the tree was calculated as a percentage from the total of green and dry above-ground biomass. Wood properties were statistically analyzed using to Duncan's multiple range test 1% (1955), according to Snedecor and Cochran (1980). Correlation analysis was conducted to estimate the relationship between density and mechanical properties of *Taxodium distichum* wood. Correlation coefficient studies were carried out according to Steel and Torrie (1987).

RESULTS AND DISCUSSION

Growth parameters of *Taxodium distichum*

Data presented in Table (2) showed that, total and merchantable height of *Taxodium distichum* tree were closed in El-Nobaria and El-Gemmeiza Research Station (14.00 ± 0.50 and 11.93 ± 0.23 m) and (15.00 ± 0.90 and 13.05± 1.00 m), respectively. However, diameter at breast height and merchantable volume in El-Gemmeiza were more than once and a half time (55.89 ± 6.12cm and 1.0912± 0.11m^3/tree) compared to El-Nobaria (35.11 ± 0.72 cm and 0.5687 ± 0.05 m^3/tree). Basal area was more than twice as much in El-Gemmeiza (0.2472 ± 0.05m^2) than in El-Nobaria (0.0980 ± 0.01 m^2).

Table (2): Growth parameters of *Taxodium distichum* tree at age of 22- year- old at two provenances (El-Nobaria and El-Gemmeiza Research Station).

Parameters \ Provenance	El-Nobaria Research Station	El-Gemmeiza Research Station
Total height of tree (m)	14.00 ± 0.50	15.00± 0.90
Merchantable height of tree (m)	11.93 ± 0.23	13.05± 1.00
Diameter at breast height (cm)	35.11 ± 0.72	55.89± 6.12
Basal area (m^2)	0.0980 ± 0.01	0.2472± 0.05
Merchantable volume (m^3/tree)	0.5687 ± 0.05	1.0912± 0.11

Merchantable height and volume (from the stump up to 10 cm diameter of stem).
Mean values ± standard deviation.

The green and dry weight of stem and total above-ground biomass of *Taxodium distichum* (Table, 3) were more than twice as much in El-Gemmeiza (1795.66 ± 185.44 and 823.58 ± 87.56Kg/tree) and (2299.56 ± 230.33 and 1031.87 ± 106.40 Kg/tree) than in El-Nobaria (620.00 ± 80.00 and 313.75 ± 38.75 Kg/tree) and (976.75 ± 134.75 and 424.06 ± 56.16 Kg/tree). At the same time, the green and dry weight of branches and foliage of *T. distichum* were one and a half times at El-Gemmeiza Research Station more than at El-Nobaria Research Station. These results may be due to properties of soil at each provenance. Data in Table 1 (b) showed that, the available elements (nitrogen, phosphorus and potassium) mg/ Kg soil at El-Gemmeiza Research Station more than at El-Nobaria Research Station. In addition to, the high level of calcium carbonate in the soil of El-Nobaria Research Station (Table, 1(c) cause of reduced availability of some macro and micro nutrients elements, such as N, P, Fe, Mn and Zn.

Table (3): Green and dry weight of stem, branches, foliage and total above- ground biomass (kg/tree) of *Taxodium distichum* at age of 22- year- old at two provenances (El- Nobaria and El-Gemmeiza Research Station).

Parameters \ Provenance	El-Nobaria Research Station		El-Gemmeiza Research Station	
	Green weight (Kg/tree)	Dry weight (Kg/tree)	Green weight (Kg/tree)	Dry weight (Kg/tree)
Stem	620.00 ± 80.00	313.75 ± 38.75	1795.66± 185.44	823.58 ± 87.56
Branches	239.75± 39.75	84.00± 14.00	362.50 ± 37.50	155.88 ± 16.13
Foliage	117.00± 15.00	26.31 ± 3.41	141.67± 7.64	52.42 ± 2.83
TAGB	976.75± 134.75	424.06 ± 56.16	2299.56 ± 230.33	1031.87 ± 106.40

TAGB = total above- ground biomass, Mean values ± standard deviation

Data in Table (4) indicated that, distribution of biomass components as a percentage from the total green and dry above-ground biomass (TAGB) of *Taxodium distichum*at two provenances (El-Nobaria and El-Gemmeiza Research Station). This distribution was a descending order from stem to branches then foliage. The percentages of green and dry weight of stem at El-Gemmeiza were higher (78.09 and 79.81 %) than in El-Nobaria (63.48 and 73.99 %). However, the percentages of green and dry weight of branches and foliage in El-Gemmeiza were lower (15.76 and 15.11 %) and (6.16 and 5.08 %) than at El-Nobaria (24.55 and 19.81 %) and (11.98 and 6.20 %), respectively. The results indicated that, at El-Nobaria Research Station *T. distichum* gave lower biomass than at El-Gemmeiza Research Station may be due to the reduction of soil fertility (available of NPK) and nutritional imbalance between elements such as potassium (K), magnesium (Mg) and calcium (Ca) in calcareous soil,(El-Hady and

Abo - Sedera, 2006). Nutrients are the building blocks of new tree growth, because phosphorous, nitrogen, calcium and magnesium, along with 14 other elements, are important components of new cells. In addition to poor aeration in calcareous soil at El-Nobaria Research Station, this negatively affects the growth of roots and their inability to play their role in absorbing water and nutrients.

Table (4): Distribution of biomass components as a percentage from the total green and dry above-ground biomass (TAGB) of *Taxodium distichum* at two provenances (El-Nobaria and El-Gemmeiza Research Station).

Proportion \ Provenance	El-Nobaria Research Station		El-Gemmeiza Research Station	
	Green	**Dry**	**Green**	**Dry**
Stem (%)	63.48	73.99	78.09	79.81
Branches (%)	24.55	19.81	15.76	15.11
Foliage (%)	11.98	6.20	6.16	5.08

Green and dry biomasses of stems (Table 5) at El-Gemmeiza were more two and half time (836.78 ± 86.42 and 383.79 ± 40.80 ton/ feddan) compared to that at El-Nobaria (288.92 ± 37.28and 146.21 ± 18.06 ton/feddan). Total volume of stems at El-Gemmeiza was nearly two folds (508.50 ± 53.31 m^3/ feddan) compared to that at El-Nobaria (265.01 ± 21.62 m^3/feddan). This indicates that the environmental conditions have a critical impact on the biomass productivity of *Taxodium distichum* trees.

Table (5): Above-ground biomass in green and dry state (tons/ feddan) and total volume of stem (m^3/feddan) of *Taxodium distichum*at two provenances (El-Nobaria and El-Gemmeiza Research Station) at age of 22-year-old.

Parameters \ Provenance	El-Nobaria Research Station	El-Gemmeiza Research Station
Green biomass of stem (t/f)	288.92 ± 37.28	836.78±86.42
Green biomass of branches (t/f)	111.72 ± 18.52	168.93 ± 17.48
Green biomass of foliage (t/f)	54.52 ± 6.99	66.02 ± 3.56
Total green biomass (t/f)	455.17 ± 62.79	1071.59 ± 107.33
Dry biomass of stem (t/f)	146.21 ± 18.06	383.79 ± 40.80
Dry biomass of branches (t/f)	39.14 ± 6.52	72.64 ± 7.52
Dry biomass of foliage ((t/f))	12.26 ± 1.59	24.43 ± 1.32
Total dry biomass (t/f)	197.61 ± 26.17	480.85 ± 49.58
Total volume of stem (m^3/f)	265.01 ± 21.62	508.50 ± 53.31

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

Wood properties of *Taxodium distichum*

Some physical and mechanical properties of *Taxodium distichum* wood were determined at three levels of main stem of the tree. Level (1) at DBH, level (2) at 2.5 m after DBH and level (3) at 5.0 m above DBH at two provenances (El-Nobaria and El-Gemmeiza Research Station).

Wood density of *Taxodium distichum* wood (Table, 6) significantly decreased from tree base to the top, in the two provenances. This in trend with the increase of the percentage of juvenile wood more than mature wood. As the percentage of juvenile wood increases over mature wood, the density decreases, Darmawan et al. (2015). Mean of wood density of *T. distichum* at El-Nobaria (0.411 $g.cm^{-3}$)significantly increased as compared to mean of wood density at El-Gemmeiza Research Station (0.406 $g.cm^{-3}$). There are significantly differences in wood density between three levels of the tree and two provenances. The highest value of wood density in level (1) At El-Nobaria Research Station (0.433 $g.cm^{-3}$) while, The lowest value of wood density in level (3) at the two provenances (0.383 $g.cm^{-3}$). These results are close to results of (El-Morshedy, 1995) who reported that, wood density ranged between 0.410 to 0.540 $g.cm^{-3}$ with an average of 0.420 $g.cm^{-3}$. Wood density of most trees' species can be used to predict the mechanical properties of wood.

Table (6): Wood density (g. cm^{-3}) of *Taxodium distichum* wood at three levels of height of stem in two provenances (El-Nobaria and El-Gemmeiza Research Station) at age of 22-year-old.

Property	Level No.	El-Nobaria Research Station	El-Gemmeiza Research Station	Mean
Wood density ($g.cm^{-3}$)	**1**	0.433 a	0.430 b	0.432 a
	2	0.417 c	0.403 d	0.410 b
	3	0.383 e	0.383 e	0.383 c
	Mean	0.411 a	0.406 b	

Level No.1= height of stem at DBH (1.30 m), Level No.2= after DBH 2.50 m, Level No.3= after DBH 5.00 m Mean

Data presented in Table (7) showed that, strength properties of *Taxodium distichum* wood, e.g., Modulus of rupture (MOR) and Compressive strength (Cmax) significantly decreased from tree base to the top, in the two provenances. Low strength of wood is directly correlation with high moisture content, Allwi et al. (2008). Mean of MOR at El-Gemmeiza Research Station (75.750 MPa) significantly increased as compared to it at El-Nobaria Research Station (63.070 MPa).The high value of MOR in level (1) at El-Gemmeiza Research Station (84.890MPa) while, The low value of MOR in level (3) at El-Nobaria Research Station (59.120 MPa). Mean of C maxat El-Nobaria Research Station (34.240 MPa) significantly increased as compared to it at El-Gemmeiza Research Station (31.420MPa). The highest value of C max in level (1) at El-Nobaria Research Station (38.440MPa) while, the lowest value of C max in level (3) at El-Nobaria Research Station (28.190 MPa).

Table (7): Modulus of rupture (MOR), Compressive strength (C max) at three levels of height of stem for *Taxodium distichum* wood.

Property	Level No.	El-Nobaria Research Station	El-Gemmeiza Research Station	Mean
MOR (MPa)	**1**	68.180 c	84.890 a	**76.540 a**
	2	61.910 e	76.070 b	**68.990 b**
	3	59.120 f	66.290 d	**62.700 c**
	Mean	**63.070 b**	**75.750 a**	
C max (MPa)	**1**	38.440 a	34.070 c	**36.250 a**
	2	36.100 b	31.620 d	**33.860 b**
	3	28.190 f	28.570 e	**28.380 c**
	Mean	**34.240 a**	**31.420 b**	

Level No.1= height of stem at DBH (1.30 m), Level No.2= after DBH 2.50 m,
Level No.3= after DBH 5.00 m

Janka Hardness Number (JHN) in radial and tangential of wood of *Taxodium distichum* (Table, 8) significantly decreased from tree base to the top, in the two provenances. The highest value of (JHN) in radial and tangential of wood of *T. distichum*in level (1) at El-Gemmeiza Research Station (3.517 and 3.790 N), respectively. While, the lowest value of (JHN) in radial and tangential was in level

(3) at El-Gemmeiza Research Station (2.717 and 2.930 N), respectively. On the other hand, mean values of JHN in radial and tangential of wood of *T. distichum* at El-Nobaria Research Station significantly increased (3.254 and 3.681 N) as compared to those at El-Gemmeiza Research Station (3.100 and 3.366N), respectively.

Table (8): Janka Hardness Number (JHN) in radial and tangential at three levels of height of stem for *Taxodium distichum* wood.

Property	Level No.	El-Nobaria Research Station	El-Gemmeiza Research Station	Mean
JHN in radial (N)	**1**	3.403 c	3.517 a	3.460 a
	2	3.407 b	3.067 d	3.237 b
	3	2.953 e	2.717 f	2.835 c
	Mean	3.254 a	3.100 b	
JHN intangential (N)	**1**	3.760 c	3.790 a	3.775 a
	2	3.760 b	3.377 e	3.568 b
	3	3.523 d	2.930 f	3.227 c
	Mean	3.681 a	3.366 b	

Level No.1= height of stem at DBH (1.30 m), Level No.2= after DBH 2.50 m,
Level No.3= after DBH 5.00 m

These results are in line with published results by El-Morshedy, (1995) stated that, static bending MOR of *Taxodium distichum* ranged between 333 to 723 kg/cm^2 with an average of 507 kg/cm^2. Compressive strength, Cmax ranged between 186 to 387 kg/cm^2 with an average of 252 Kg/cm^2. Hardness ranged between 230 to 390 kg/cm^2 with an average of 295 kg/cm^2. Also**,** Izekor et al. (2010) reported that, density and mechanical properties decrease from the tree base to the top. The wood is somewhat dense, with medium strength and hardness. The old-growth bald cypress is one of the American species with the highest level of degradation resistance. Bald cypress was predominantly employed in building construction, particularly where decay resistance was essential. It was also used in the building of cooling towers, ships and boats, containers, vats, doors, blinds, and sashes, **(Regis 1999).**

Wood density is an important wood property for both solid wood and fiber products in both conifers and hardwoods (De Guth, 1980). At El-Nobaria Research Station (Table 9), correlation coefficients were significant between density and (C max) compressive strength (0.757*), and highly significant between density and (JHN-R**)** Janka Hardness Number in radial direction (0.851**). There was a significant correlation between C max and JHN-R (0.771*). At El-Gemmeiza Research Station (Table 10), correlation coefficients were significant between density and (MOR) Modulus of rupture (0.761*), JHN-R (0.731*) and in tangential direction (0.782*). Correlation coefficients was significant between MOR and C max (0.754*). There were highly significant correlation coefficients between Janka Hardness Number in tangential direction and MOR and C max (0.929**) and (0.836**), respectively. The overall behaviors showed noticeable correlations between the mechanical properties and density, Knapic et al. (2022). The correlations between density and MOR, density and MOE, density and CS were significant ($p < 0.001$), Izekor et al. (2010).

Table (9): A matrix of simple correlation coefficients between density and mechanical properties of *Taxodium distichum* wood at El-Nobaria Research Station.

	Density	MOR	C max	JHN-R	JHN-T
Density	1.000				
MOR	0.073	1.000			
C max	0.757*	0.561	1.000		
JHN-R	0.851**	0.012	0.771*	1.000	
JHN-T	0.466	0.453	0.213	0.500	1.000

*, ** indicates significant at the 0.05 and 0.01 levels of probability, respectively.

MOR= Modulus of rupture, C max= Compressive strength, JHN-R=. Janka Hardness Number (JHN) in radial direction, JHN-T= =. Janka Hardness Number in tangential.

Table (10): A matrix of simple correlation coefficients between density and mechanical properties of *Taxodium distichum* wood at El-Gemmeiza Research Station.

	Density	MOR	C max	JHN-R	JHN-T
Density	1.000				
MOR	0.761*	1.000			
C max	0.485	0.754*	1.000		
JHN-R	0.731*	0.605	0.571	1.000	
JHN-T	0.782*	0.929**	0.836**	0.573	1.000

*, ** indicates significant at the 0.05 and 0.01 levels of probability, respectively.

MOR= Modulus of rupture, C max= Compressive strength, JHN-R=. Janka Hardness Number (JHN) in radial direction, JHN-T= =. Janka Hardness Number in tangential.

CONCLUSIONS

Based on the results of our investigation, it is possible to conclude that, *Taxodium distichum* trees needs fertile soil and sufficient water. The calcareous soil not suitable for good growth of *T. distichum*. Productivity of *T. distichum* trees biomass grown in clay soil reach more than two and half time as compared to that grown in calcareous loamy soil. Whenever, planting distances of 3×3 m, Green and dry biomass of stems at El-Gemmeiza were (836.78 ± 86.42 and 383.79 ± 40.80 ton/ feddan), while at El-Nobaria were (288.92 ± 37.28 and 146.21 ± 18.06 ton/feddan). Total volume of stems at El-Gemmeiza was (508.50 ± 53.31 m^3/feddan), while at El-Nobaria was (265.01 ± 21.62 m^3/feddan). The values of wood properties of *T. distichum* at age of 22 years were close from DBH to five meter after DBH. This tree species can be planted in afforestation programs, especially in the Nile Valley and the Delta.

REFERENCES

Allwi, N.I.M., Sahri, M.H. and Chun, S.K. (2008). Wood and Cellular Properties of 4 New Hevea Species. KFS Journal.19 (4): 273- 282.

Barnett, J.R. and Jeronimidis, G. (2003). Wood Quality and its Biological Basis. Biological Sciences Series, CRC Press, Florida.

British Standard Specifications (1957). Testing Small Clear Specimens of Timber. British Standards Institution. London, United Kingdom.

Cottenie, A., Verloo, M., Kickens, L., Velghe, G. and Camerlynck, R. (1982). Chemical analysis of plants and soils. Laboratory of Analytical and Agrochemistry. State University, Ghent Belgium, pp: 63.

Darmawan, W., Nandika, D., Sari, R.K., Sitompul, A., Rahayu, I. and

Gardner, D. (2015). Juvenile and mature wood characteristics of short and long rotation teak in Java. IAWA Journal 36 (4): 428–442.

De Guth, E.B. (1980). Relationship between Wood Density and Tree Diameter in Pinuselliottii of Missiones Argentina. IUFRO Conf. Div. 5 Oxford, England. 1p.

Duncan, D.B. (1955). Multiple range and Multiple F test, Biometrics,11:1-42.

El-Hady, O. A. and Abo-Sedera, S. A. (2006). Conditioning Effect of Composts (natural) or/and Acrylamide Hydrogels (synthesized) on a Sandy Calcareous Soil. I-Physico-bio-chemical Properties of the Soil. J. Agric. Biol., 8 (6), 876 – 884.

El-Morshedy, M.M. (1995). Some strength properties of Taxodium distichum grown in north Egypt. Menofiya J. Agric. Res., 20 (6): 2297-2309.

Forest Products Laboratory (1999). Wood handbook - Wood as an engineering material. Gen. Tech. Rep. FPL–GTR–113. Madison, WI: U.S. Department of Agriculture, Forest Service, 463 p.

Hautamäki, S., Kilpeläinen, H. and Verkasalo, E. (2014). Factors and Model for Bending Properties of Sawn Timber from Finland and North-Western Russia. Part II: Scots Pine. Balt For., 20, 142–156.

Izekor, D.N., Fuwape, J.A and Oluyege, A.O. (2010). Effects of density on variations in the mechanical properties of plantation grown Tectona grandis wood. Arch. Appl. Sci. Res., 2 (6):113-120.

Knapic, S., Linhares, C.S.F. and Machado, J.S. (2022). Compressive and Bending Strength Variations in the Properties of Portuguese Clear Oak Wood. Forests, 13, 1056.

Little, Jr., E.L. (1971). Atlas of United States trees. Volume 1. Conifers and important hard woods. Misc. Pub. 1146. Washington, DC: U.S. Department of Agriculture, Forest Service. 9 p., 200 maps.

Ozarska, B. (2009). Engineering properties of selected young plantation-grown Australian hardwoods for furniture. Forest Products Journal 59(7/8): 27-30.

Regis, B. Miller (1999). Characteristics and availability of commercially important woods. Wood handbook: wood as an engineering material. Madison, WI: USDA Forest Service, Forest Products Laboratory. General technical report FPL; GTR-113: Pages 1.1-1.34.

Snedecor, G. W. and Cochran, W.G. (1980). Statistical Methods. 7thed., The Iowa State Univ. Press Ames., Iowa, U.S.A., pp. 593.

Steel, R.G.D. and Torrie, J.H. (1987). Principles and Procedures of Statistics. A Biometrical Approach. 2nd Ed. 6th printing. Mc. Graw. Hill Book company. USA: 272-277.

Zobel, B.J. and Van Buijtenen, J.P. (1989). Wood Variation, its Causes and Control. Springer-Verlag, Heidelberg. 362 pp.

Zhou, C., Chui, Y.H. and Gong, M. (2012). Within-stem variation in wood properties of red pine (*Pinus resinosa*.). Wood and Fiber Science, 44(4): 412-421.

الكتلة الحيوية وبعض صفات الخشب لأشجار التاكسوديوم النامية في موقعين بمصر

مها فاروق محمد إسماعيل – مجدى إسماعيل بهنسى – محمد عبد الجواد العتربى – منى مصطفى عباس
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أجريت هذه الدراسة في معهد بحوث البساتين خلال عامي ٢٠٢١ و٢٠٢٢ على أشجار التاكسوديوم النامية في محطتي بحوث تابعين لمركز البحوث الزراعية، هما محطة بحوث النوبارية ومحطة بحوث الجميزة. تهدف الدراسة الى تحديد أي من الموقعين تحت الدراسة الأفضل من حيث النمو وإنتاج الكتلة الحيوية وصفات الخشب لأشجار التاكسوديوم عند عمر ٢٢ عام. ايضا تحديد الارتفاع على طول الساق للشجرة الأفضل للتصنيع. كان متوسط الارتفاع الصالح للتصنيع ١١.٩٣±٠.٢٣ و١٣.٠٥±١.٠٠ في محطة بحوث النوبارية والجميزة، على التوالي. القطر عند ارتفاع الصدر والحجم الصالح للتصنيع كانتا (٣٥.١١±٠.٧٢ سم و٠.٥٦٨٧±٠.٠٥ م^{٣}/شجرة) و(٥٥.٨٩±٦.١٢سم و١.٠٩١٢±٠.١١ م^{٣}/شجرة) في محطة بحوث النوبارية والجميزة على التوالي. الوزن الأخضر والجاف لساق أشجار التاكسوديوم كانتا (٦٢٠.٠٠±٨٠.٠٠ و٣١٣.٧٥±٣٨.٧٥ كجم/شجرة) و(١٧٩٥.٦٦±١٨٥.٤٤و٨٢٣.٥٨±٨٧.٥٦ كجم/شجرة) في محطة بحوث النوبارية والجميزة على التوالي. خصائص خشب أشجار التاكسوديوم، متوسطات الكثافة ومعامل الكسر ومتانة التهشم القصوى في الضغط الموازي للألياف واختبار جانكا للصلابة (في الاتجاه القطرى والمماسى) عند ارتفاع الصدر كانت (٠,٤٣٣ جم/سم^{٣} و٦٨,١٨٠ ميجابسكال و٣٨,٤٤٠ ميجابسكال و٣,٤٠٣ نيوتن و٣,٧٦٠ نيوتن) و(٠,٤٣٠جم/سم^{٣} و٨٤,٨٩٠ ميجابسكال و٣٤,٠٧٠ ميجابسكال و٣,٥١٧ نيوتن و٣,٧٩٠ نيوتن) في محطة بحوث النوبارية والجميزة على التوالي. اشارت نتائج هذه الدراسة الى القطر عند ارتفاع الصدر والحجم الصالح للتصنيع لأشجار التاكسوديوم في التربة الطينية (محطة بحوث الجميزة) كانت مرة ونصف بالمقارنة بالتربة الجيرية (محطة بحوث النوبارية). المساحة القاعدية والوزن الأخضر والجاف للساق والكتلة الحيوية الكلية فوق سطح التربة كانت أكثر من الضعف في محطة بحوث الجميزة بالمقارنة بمحطة بحوث النوبارية.خصائص الخشب حتى الارتفاع ٥ م بعد الارتفاع عند مستوى الصدر كانت متقاربة وجيدة ويمكن استخدامها في أغراض التصنيع.