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VARIABILITY IN BIOMASS PRODUCTION AND SOME WOOD PROPERTIES OF *Dalbergia sissoo* TREES GROWN IN ASWAN (SOUTHERN EGYPT)

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ABSTRACT

Aboveground- tree biomass, some of the wood properties and chemical compositions of stem wood ash were measured in five ages (2, 5, 7, 15 and 25- year-old) of *Dalbergia sissoo* trees, growing on infertile soil in the Tropical Farm, Kom-Ombo, Aswan Botanical Garden (southern Egypt). There were twenty- four trees for each age planted as a single row and the distance between trees was 5 m. As expected, biomass and its compartment of *Dalbergia sissoo* at the 25- year- old had the highest values in compared to the other ages. The mean aboveground biomass in this study was about 60.53 kg, 203.7 kg, 591.6 kg, 1210.5 kg and 3060.3 kg/ tree for the 2, 5, 7, 15 and 25- year- old of *Dalbergia sissoo* trees, respectively. Casual observation of the curve for trees shows consistent increase in the total biomass, height and diameter growth with tree age. Wood specific gravity was increased with the progress in tree age, while moisture content decreased with the increase in age. However, the percent of heartwood to sapwood was gradually increased from the young tree to the age tree. On the other hand, in most cases, nutrient accumulation in the stem wood ashes was gradually increased by the increasing in the tree age.
Keywords: Ash, biomass, *Dalbergia sissoo,* heartwood, moisture content, sapwood, specific gravity.

INTRODUCTION

Dalbergia sissoo Roxb. is one of the tropical timber tree species with it multiple uses such as fuelwood, fodder, shade, shelter and N- fixing ability (Karki *et al*., 1994 ; Sharma *et al.,* 2007). The wood is hard, heavy, strong and durable and is used for marine and aircraft plywood (Bangarwa and Singh, 1994). It can also be used in different systems like Agroforestry, Social Forestry and Industrial Plantations.

Biomass is the term used to describe all biologically matter (Babu, 2008). However, estimating tree biomass (weight) based on parameters that are measured in the field is becoming a fundamental task in forestry. The intensity of forest utilization has increased in recent years because of whole-tree harvesting and the use of wood for energy. Branches, leaves, bark, small trees, and trees of poor form or vigor are now commonly included in the harvested product. Thus, biomass of either the whole tree or individual components is a useful stand parameter (Tritton and Hornbeck, 1982).

The biomass of the various compartments in the forest, e.g. foliage, branches, and stem wood, is general interest to researchers of different scientific backgrounds, working on different scales: 1) On regional scales, estimations of carbon storage in forests require information of total tree biomass (Kursten and Burschel, 1993). 2) Foresters, who concentrate on the stand level, are mainly interested in stem wood biomass to determine thinning intensity and harvest gain. However, in large trees, particularly if grown without major competition, the amount of branch biomass can be considerable and should not be neglected (Brown, 1976). 3) On a smaller scale, ecological studies are executed to maintain sustainable management not only for stem wood but also for nutrients. Balance and flow estimations, however, have to consider different tree fractions because the nutrient concentration varies with tissue type and each compartment has different turnover rates (Martin *et al.*, 1999).

Like humans, trees are delicate when young and typically grow vigorously when given proper nutrition and a suitable environment. As age progresses, vigor is maintained for a lengthy period but then begins to wane and this called growth curve (Haygreen and Bowyer, 1996).

The moisture content of green wood varies considerably among species. However, the moisture content of green wood is important because of its direct relation to the weight of logs and green lumber. Therefore, it is of concern to those who design harvesting and transport equipment, purchase wood on a weight basis, or must ship or transport green wood. On the other hand, within any species there is considerable variation depending upon the location, age, and volume of the tree (Koch, 1972). The specific gravity of wood is its single most important physical property. Most mechanical properties of wood are closely correlated to specific gravity and density. The strength of wood, as well as its stiffness, increases with specific gravity. The yield of pulp per unit volume is directly related to specific gravity. Moreover, the heat transmission of wood increases with specific gravity as well as the heat per unit volume produced in combustion (Haygreen and Bowyer, 1996). Wood ash is the inorganic and organic residue remaining after the combustion of wood or unbleached wood fiber. The physical and chemical properties of wood ash vary significantly depending on many factors. Hardwoods usually produce more ash than softwoods and the bark and leaves generally produce more ash than the inner woody parts of the tree (Misra *et al.,* 1993). Therefore, wood ash composition can be highly variable depending on geographical location and tree species. This makes testing the ash extremely important.

Among the large number of direct tree uses, the use of wood for fuel has probably been the most significant. Of the uses of industrial wood, lumber is the most important especially in construction of housing; furniture industry is also a major market for both softwoods and hardwoods (Tedder *et al.,* 1975). Moreover, apart from the traditional usage of wood ash as a source of alkali for the saponification of fats in soap making and as fertilizers for plants, there is no report in the literature of a comparative chemical analysis of the ashes of *Dalbergia sissoo* grown at different ages in Egypt. In this paper we present the results on aboveground biomass, growth curves and chemical composition of mineral matter in the wood ashes for different ages of *Dalbergia sissoo* trees grown in south Egypt.

MATERIALS AND METHODS

Estimation of biomass:

In 2010, different ages (2, 5, 7, 15 and 25- year- old) of *Dalbergia sissoo* Roxb. trees from plantations located in the Tropical Farm, Kom-Ombo, Aswan, were evaluated in the study. The soils of the study area were loamy sand. These were characterized as having soil pH 8.4, low organic matter (0.45%), and electrical conductivity 0.31 mmhos. There were twenty- four trees for each age planted as a single row and the distance between trees was 5 m. For each age, 10 trees were selected and used to characterize mean height (m) and diameter at breast height (cm) and from these trees, five trees were randomly selected. They were harvested, measured, and sampled by the method of direct and destructive of estimation (Goeble, 1955). The total height for each tree was measured from the stump to the tree top. All branches up to 1.0 cm diameter, stem and leaves were weighted.

Moisture content determination of wood (MC %):

The wet sample wood each per *Dalbergia sissoo* age were weighed in green condition, dry it in an oven at 103±2°C until constant weights and then reweigh it. The moisture content is computed as follows:

% MC= weight with water- oven dry weight/ oven dry weight x 100 (ASTM, 1987).

Specific gravity of wood:

Specific gravity was determined based on the fresh volume and oven-dry weight. The volume was determined by water displacement according to ASTM (1987).

Heartwood and sapwood (%):

The ratio of heartwood to sapwood was determined by the examination of a stem cross section for *Dalbergia sissoo* trees at the different ages (Rudman, 1966).

Ash preparation:

The various wood specimens (200 g of wood chips) from the different *Dalbergia sissoo* tree ages were obtained. Ashes of the woods were prepared by ashing them in Gallenkamp muffle furnace at 1000 C^0 for about 2 hours in platinum crucibles. The percentage ash of each sample was calculated based on the weight of wood.

Test for soluble base (as K_2CO_3):

2 g each of the ash sample was weighted into a 150 ml beaker and boiled with about 50 ml distilled water for 1 minute with stirring. The solution was filtered with a Whatman 42 filter paper and washed with 20 ml of distilled water into a 250 conical flask. It was titrated with 0.2 M HCl (previously standardized with a standard solution of K_2CO_3) using bromocresol green as the indicator (Guenther, 1982).

Sample preparation for elemental compositions:

Elemental and chemical compositions of the wood ash were obtained using Inductively Coupled Plasma Emission Spectroscopy (ICPES) and X-Ray Diffraction (XRD). Samples for ICPES were prepared by dissolving approximately 100 mg of the ash for each sample in 4 ml of reagent grade, concentrated hydrochloric acid. The mixture was left standing for a couple of hours for complete dissolution. This solution was later diluted to approximately 100 g using distilled, ionized water so that the concentration of various elements was within linear range of detection for the ICPE Spectrometer. The solution was analyzed for concentrations of P, K, Ca, Mg, S, Zn, Mn, Fe and Na.

Obtained data were tabulated and statistically analyzed according to the method of Snedecor (1956) and LSD mentioned by Little and Hills (1978).

RESULTS AND DISCUSSION

Biomass estimation:

The mean values of the average, range and standard deviation of the diameter at breast height and total height for *Dalbergia sissoo* trees grown at different ages are presented in Table (1). Generally, it is noticed that there was a gradual increase in diameter at breast height and total height by increasing the tree age. It could be concluded that the annual increment of diameter at breast height for the different tree ages (2-5, 5-7, 7-15 and 15-25-year- old) was 20.9, 24.2, 3.7 and 3.6%, respectively. On the other hand, the annual increment of total height for these periods of tree ages was 5.4, 7.4, 1.8 and 4.3%, respectively (Table 2). The highest values of annual increment % in the ages period were resulted from the 2-year- old up to 7- year- old for both diameter at breast height and total height of *D. sissoo* trees.

Table (1): Average, range and standard deviation of diameter at breast height (cm) and total height (m) of *Dalbergia sissoo* trees grown for different ages.

Properties	Age (year)	Average	Range	Standard deviation
Diameter at breast height	2	11.3	8.3-13.4	±1.4
	5	18.4	15.3-20.7	±1.9
	7	27.3	25.5-31.2	±1.8
	15	35.5	32.8-37.9	±1.7
	25	48.1	40.8-63.1	±6.9
Total height	2	9.76	8.47-11.12	±0.85
	5	11.35	10.96-11.91	±0.39
	7	13.03	12.66-13.82	±0.35
	15	14.86	14.30-15.41	±0.37
	25	21.23	20.55-22.05	±0.45

Table (2): Annual increment of diameter at breast height (%) and total height (%) for the different age periods of *Dalbergia sissoo* trees.

Character	Age period (year)	Annual increment %
Diameter at breast height	2- 5	20.9
	5- 7	24.2
	7- 15	3.7
	15- 25	3.6
Total height	2- 5	5.4
	5- 7	7.4
	7- 15	1.8
	15- 25	4.3

Table (3) shows that all biomass components i e. leaves weight, branches up to 1.0 cm, branches up to 5.0 cm, total biomass, diameter and height of *Dalbergia sissoo* trees were gradually increased with increasing tree age. Significant differences were recorded with the highest values of these characters being obtained with the 25- year- old of these trees. The relationship between the tree age and total biomass, height and diameter is illustrated in Figures 1,2 and 3, respectively. These results were in accordance with Haygreen and Bowyer (1996) who reported that tree growth and production of woody plants are delicate when young and typically grow vigorously when given proper nutrition and suitable environment. As age progresses, vigor are maintained for a lengthy period but then begins to wane. Wang Shiji *et al.* (1996) on their studies on the growth characteristics of *populus euphratica* found that in the first years its growth is slow. Thus, the growth of a 5- year- old reaches a height of only about 1 to 1.5m, while the dry biomass ratio between stem and root is 1:2. After 10 year, its growth becomes faster and the peak of its height growth occurs at the age of 10- 12 years. Then, its height growth slows down at the age of 25- 30, while the growth of breast diameter continues to increase.

Table (3): Biomass (kg/ tree) components (leaves, branches up to 1.0 and 5.0 cm, main stem, total biomass and diameter) of *Dalbergia sissoo* trees grown for different ages.

Component	**Age (year)**					**LSD 5%**
	2	5	7	15	25	
Leaves weight	12.55	43.92	129.07	204.19	352.57	10.67
Branches up to 1.0 cm weight	10.24	33.20	90.53	165.31	286.79	6.47
Branches up to 5.0 cm weight	0.0	32.71	149.22	254.10	945.35	27.72
Main stem	37.74	93.92	222.74	586.90	1475.59	15.97
Total weight of biomass	60.53	203.7	591.57	1210.50	3060.30	37.15
Diameter (cm)	12.3	16.3	24.2	35.9	51.7	2.2
Height (m)	9.91	11.09	12.92	14.61	21.38	0.26

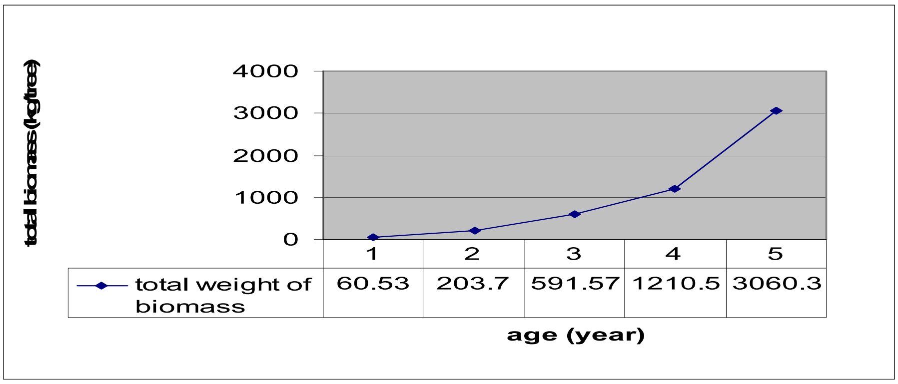

Figure (1): Relationship between tree age (1;2;3;4;5 in the Figure = 2;5;7;15;25-year-old, respectively) of *Dalbergia sissoo* and total biomass.

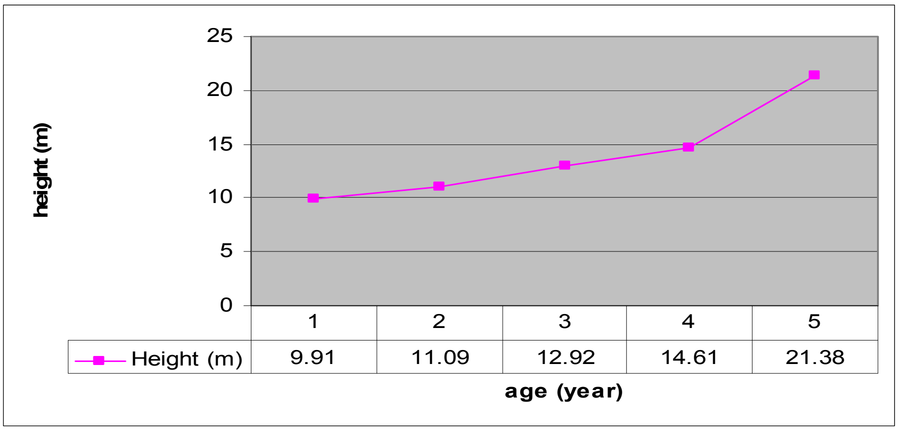

Figure (2): Relationship between tree age (1;2;3;4;5 in the Figure = 2;5;7;15;25-year-old, respectively) of *Dalbergia sissoo* and height growth.

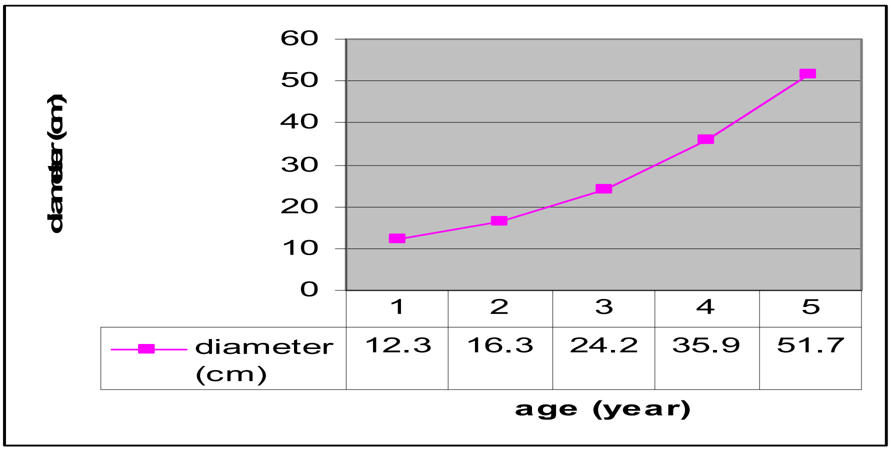

Figure (3): Relationship between tree age (1;2;3;4;5 in the Figure = 2;5;7;15;25-year-old, respectively) of *Dalbergia sissoo* and diameter growth.

Some of wood properties:

As expected, the differences in specific gravity, green moisture content and heartwood/ sapwood ratio were significant among tree ages of *Dalbergia sissoo* (Table 4). Specific gravity in the different tree ages followed the sequence:25-year-old>15-year-old>7-year-old>5-year-old>2-year-old.

Meanwhile, green moisture content decreased in the order: 2-year-old>5-year-old>7-year-old>15-year-old>25-year-old. On the other hand, results of heartwood and sapwood percentage pointed out that, when a tree or tree part is young, it often contains no heartwood and this was observed in the age of 2- year- old as shown in Table (5). Once initiated, the transformation of sapwood into heartwood occurs continuously up to 25-year-old of *Dalbergia sissoo* trees.

Density decreases as moisture content decreases, but below the fiber saturation point the specific gravity of the sample increases as the moisture content decreases. This occurs because the dry weight remains constant while the volume decreases during drying (Haygreen and Bowyer, 1996). On the other hand, increase in heartwood/ sapwood ratio from young trees to the aged trees was assured by Hillis (1987); Hazenburg and Yang (1991); Yang and Hazenburg(1991). This means that the number of sapwood rings tend to increase early in the life of a tree; once attainment of maturity, crown closure, or other stimulus reduces the size of the crown, the formation of heartwood may exceed one ring per year, thus reducing the number of sapwood rings (Yang and Hazenburg, 1991).

Table (4): Specific gravity and moisture content % of wood as influenced by the age of *Dalbergia sissoo trees.*

Character	Age(year)					LSD 5%
	2	5	7	15	25	
Specific gravity	0.63	0.66	0.67	0.68	0.75	0.06
Moisture content	63.57	57.47	55.67	50.39	49.77	5.38

Table (5): Heartwood and sapwood percentage as affected by the age of Dalbergia sissoo trees.

Character	Age(year)				
	2	5	7	15	25
Heartwood	00	33.3	39.6	60.1	75.7
Sapwood	100	66.7	60.4	39.9	24.3

Chemical characterization of the ashes:

Depicted in Table (6) are the various parameters (ash content; soluble base as K_2CO_3; elements: P, K, Ca, Mg, Mn, Fe, Na) determined from each sample of the different tree ages. Data reported that the ash content of the woods, ranges from 0.56 in the 2-year- old to 0.85% in the 25-year- old, while the percentage soluble base (as K_2CO_3) of the wood ashes varies from 6.42 in first age to 8.06 in the last age. On the other hand, the element concentrations pointed out that calcium followed by potassium were found to be the highest in all the samples and the 25-year-old produced the best results of them.

Table (6): Comparison of ash content (%), soluble base and elements in ash (%) from stem wood of *Dalbergia sissoo* trees grown for different ages.

Age (year)	Ash content %	Soluble base % as K_2CO_3	Element %						
			P	K	Ca	Mg	Mn	Fe	Na
2	0.56	6.42	3.15	18.30	19.03	3.02	0.50	0.45	0.07
5	0.66	7.15	4.15	18.03	20.16	3.15	0.59	0.49	0.06
7	0.74	7.45	3.73	19.12	21.45	3.30	0.67	0.51	0.07
15	0.83	8.01	4.01	19.76	20.58	3.54	0.70	0.55	0.08
25	0.85	8.06	4.11	20.16	21.90	4.02	0.81	0.61	0.06

Meanwhile, Na followed by Fe and then Mn concentrations were least in all the studied samples. The earlier reports of Ahonkhai and Nwokoro (1987); Ahonkhai (1988) made on some African hardwoods and Taipale (1996) on solid fuels were in a good agreement with our observations.

Conclusion

Substantial differences found in woody biomass of the different studied ages of *Dalbergia sissoo* trees grown on infertile soils in Aswan. However, woody biomass was gradually increased with increasing tree age up to 25-year- old. Total woody biomass of the artificially afforested agricultural lands in Aswan is about 514 ton/ fed for *Dalbergia sissoo* trees. Meanwhile, it produced about 247.9 ton/ fed or 185.9 m^3/ fed of wood and that for the most productive age (25-year-old). Trees like *Dalbergia sissoo* that form the highest- density wood will be the most valuable to different purposes as to the producer of structural lumber products. There was a variability of ash content and its chemical composition between the five different ages. The analysis of wood ash of these trees showed that tree at 25-year- old has more ash content, soluble base and a higher element content. The study further reinforces the fact that valuable woody trees in general and this species in particular could be potential sources of timber, especially in a regions like Aswan. Results of the present study may be useful in the choice of species for establishing artificial forests and/ or for afforestation programs in Egypt.

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الاختلاف فى انتاج الكتلة الحيوية وبعض خصائص الخشب لأشجار السرسوع النامية بأسوان (جنوب مصر)

رمضان محمد محمد سيد و أحمد فخرى على عبيد
قسم بحوث الغابات- معهد بحوث البساتين- مركز البحوث الزراعية- مصر

أجريت هذه الدراسة بالمزرعة الاستوائية بكوم أمبو- أسوان والتابعة للحديقة النباتية بأسوان خلال عام ٢٠١٠ بغرض دراسة العلاقة بين عمر أشجار السرسوع (٢، ٥ ، ٧ ، ١٥ ، ٢٥ سنة) وانتاج الكتلة الحيوية، الثقل النوعى للخشب، محتوى الخشب من الرطوبة، النسبة المئوية لخشب القلب والخشب العصارى، محتوى خشب الساق من الرماد، والمكونات الكيميائية للرماد. وقد تمت الدراسة على أشجار منزرعة فى صفوف طولية وبكل صف (لكل عمر) ٢٤ شجرة، والمسافة بين الأشجار داخل الصف ٥ م. وقد تم قياس القطر عند مستوى الصدر لعدد ١٠ أشجار من كل عمر، ثم اختيار ٥ أشجار عشوائيا لتمثل الصف تم قطعها لتقدير الطول الكلى للشجرة، وزن الأفرع فى الحالة الخضراء، وزن الساق، ووزن الأوراق. بالاضافة الى تقدير بعض خواص الخشب سالفة الذكر.

وكان أهم النتائج ما يلى:

* زادت مكونات الكتلة الحيوية طرديا مع زيادة العمر، وبلغت أقصى قيمة لها عند عمر ٢٥ سنة ٣٠٦٠ كجم/ شجرة.
* زادت صفة الثقل النوعى للخشب- والتى تعطى مؤشرا للخصائص الطبيعية للخشب- مع زيادة العمر من ٢ سنة الى أقصى قيمة عند عمر ٢٥ سنة.
* انخفض محتوى الرطوبة للخشب بزيادة العمر وكانت أعلى قيمة للرطوبة عند عمر سنتين لأشجار السرسوع.
* اختلفت النسبة المئوية لخشب القلب و الخشب العصارى مع اختلاف العمر، حيث كانت النسبة المئوية للخشب العصارى ١٠٠ % عند عمر سنتين وانخفضت تدريجيا مع التقدم فى العمر حتى بلغت ٢٤ % عند العمر الأخير.
* زاد محتوى خشب ساق السرسوع من الرماد ومكوناته من العناصر المعدنية الهامة مثل الفوسفور، البوتاسيوم، الكالسيوم والماغنسيوم بزيادة عمر الأشجار. وكان عنصرا الكالسيوم والبوتاسيوم يمثلان النسبة الأعلى فى الرماد، بينما كان أقل مكون فى الرماد هو الصوديوم يليه الحديد ثم المنجنيز.
* و عليه فانه من خلال هذه الدراسة يتضح أن أشجار السرسوع تعد من أهم صالدات الأخشاب سريعة النمو فى مصر والتى يجب أن تلقى اهتماما أكبر فى زراعتها على نطاق واسع فى انشاء الغابات الصناعية وبرامج التشجير خاصة وأنها يمكن أن تجود فى الأراضى الفقيرة، ويمكن أن يعلق عليها الأمال فى زيادة الثروة الخشبية بمصر.

قام بتحكيم البحث

أ.د / محمد نزيه شرف الدين	**كلية الزراعة – جامعة المنصورة**
أ.د / صفوت لبيب مكسيموس	**مركز البحوث الزراعية**