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Impact of Initial Tree Spacing and Stem Height Levels on Chemical Composition of *Leucaena leucocephala* Trees Grown in Riyadh Region

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Abstract: Established the optimum plant density in forest trees is one of the difficult practices. It is of particular importance in chemical composition of wood because it is a very important approach for identifying wood uses. Thus the present study was carried out to investigate the influence of different planting spacing viz., 0.7m, 1.4m and 2.1m of *Leucaena leucocephala* and log height levels at breast height (BH), 25, 50 and 75% of total stem height. The study was carried out at Derab, College of Food and Agriculture Science, King Saud University Saudi Arabia. Results exhibited significant effect of spacing on chemical composition. Wide spacing had the highest average values of extractives, cellulose and ash contents, while narrow spacing gave higher average values of hemicellulose than either 1.4m or 2.1m highly significant variations in chemical composition among height levels were recorded. In general, the height level at 75% of total stem height recorded the highest average values of extractives, hemicellulose and lignin contents, whereas breast height had the highest average values of cellulose and ash contents. The increase in hemicellulose content at narrow spacing highlights another usage of wood in cattle fodder and it can be concluded that the utilization of wood from breast height is recommended than wood from the top for furniture and pulp. In addition, the wood from the top is recommended to turn the wood to furfural and ethanol.

Key words: Chemical composition · Initial tree spacing · *Leucaena* trees · Variation within tree

INTRODUCTION

Leucaena leucocephala is a species of small Mimosoid tree that is native to southern Mexico and northern Central America. The wood used for various purposes, such as firewood, fiber and livestock fodder. It has been considered for biomass production, as its reported yield of foliage corresponds to a dried mass of 2000-20000 kg/ha/year and that of wood 30-40 m^3/ha/year, with up to twice those amounts in favourable climates. Furthermore, it is also efficient in nitrogen fixation, at more than 500 kg/ha/year. It has a very fast growth rate; young trees reach a height of more than 20 ft in 2-3 years. During the 1970s and 1980s it was promoted as a "miracle tree" for its multiple uses. It has also been described as a "conflict tree" in that it is both promoted for forage production and spreads like a weed in some places. The seeds contain mimosine, an amino acid known to be toxic to non-ruminant vertebrates. It provides an excellent source of high protein cattle fodder [1, 2]. World solid wood material source is being insufficient as the world demand is getting over the wood products. Recently, scientific researches focused toward a short rotation plantation forests attempting in order to close the gap between wood production and its consumption. In the meantime, the silvicultural treatments may play a vital role in the characteristics of the produced timber. It is well known that wood quality is affected by silvicultural treatments, which includes factors such as stand density control and genetics [3-5]. Roth *et al.* [6] concluded that planting density or tree spacing is a critical management practices, because of its large effect on the overall yield per unit area, stem size and tree form. Larson [7] stated that stand density has a tremendous influence on the quality of the wood formed. In the meantime, to meet the increase of wood demand for different uses forest service has been trying to adapt fast growing tree species. Some efforts were carried out at Plant Production Department, King Saud University, Saudi Arabia aimed at increasing wood production by introducing fast growing tree species. These studies have been directed towards the evaluation of biomass production from newly introduced

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species (*Leucanea leucocephala* and *Acacia salicina*) when planted at different spacing [8, 9], *Zizyphus spina-christis* [10] and on *Conocarpus erectus* [11]. However, little studies were carried out in Saudi Arabia to evaluate the effect of spacing between trees on the wood quality of these species.

Chemical components of wood profoundly affect the utilization of wood varying widely with wood species and the portion of the tree because wood is not a uniform substance. Thus the species with high cellulose content and low lignin content are usually preferred for pulp and paper making. The species rich in extractive contents could have a higher potential for production of certain chemicals such as tannin, resin and rubber. Chemically, wood cell walls are composed of three groups of structural substances cellulose, hemicellulose and lignin. Cellulose as supported substance, contributes its high tensile strength to the complex of wood structure. The presence of hemicelluloses in the cell wall has a tremendous influence on certain physical properties of wood. The function of lignin is to provide rigidity and stiffness to cell walls [12].

Chemical composition is important technology properties for wood uses. Therefore, before suggesting proper utilization of trees, it is essential to evaluate the basic technological properties. Thus the objective of the study was to determine the effect of initial spacing on the chemical composition of *Leucaena leucocephala* woods including extractives, cellulose, hemicellulose, lignin and ash content.

MATERIALS AND METHODS

Raw Materials: *Leucanea leucocephala* were planted at Agriculture Research and Experiment Station, Dirab, College of Food and Agriculture Science, King Saud University Saudi Arabia; 24° 6 N, latitude; 46° 5 E, longitude, 650 m altitude; temperature ranged between 10°C in winter and 37°C in summer as an average of each season and 50 mm annual rainfall. Soil site texture was sandy loam (61, 23 and 15% for sand, silt and clay). *Leucanea leucocephala* were planted using a randomized complete block design with three blocks in 1995, each block had 108 seedlings distributed into three experimental plots; where seedlings were planted in 6 rows with spacing either 0.70 or 1.40 or 2.10 meter. This experiment was designed to evaluate the effects of three levels of spacing (20408 seedlings/ha), moderate spacing (5102 seedling/ha) and wide spacing (2267 seedling/ha) on chemical composition of *Leucaena* wood. In March 2010, three trees from the three planting spaces (0.7, 1.4 and 2.1 m) with a total of 27 trees were randomly chosen and felt down. Cross-sectional disks (about 20 cm long) from each tree were cut at four position of the tree stem. Four positions were one at breast height (BH) and the other three positions were taken as a percentage of the total tree height (25, 50 and 75% of total height). After removing bark, wood samples were converted into shavings and air dried to the equilibrium moisture content (about 6-8%). Then, the air dried shavings were ground into wood meal to pass through 40-mesh screen and retain on a 60-mesh screen and stored to the further chemical analysis.

Extractives Content Determination: Air dried wood meal samples were extracted in a Soxhlet apparatus with benzene-alcohol (2:1 v/v) for four hour, followed by extraction with 95% ethanol for four hours and finally extracted with hot-water for four hour with changing water every one hour. Extractives content was calculated as a percentage based on the oven-dry weight of wood samples according to ASTM standard method D1105-56 [13].

Wood Chemical Analysis: Extractive-free wood meal samples were used to determine the contents of cellulose, hemicellulose and lignin according to the method described by ASTM, D1106-84[13] Nikitin [14] and Rozmarin and Simionescu [15], respectively. In addition, ash content of wood was determined according to the NREL, Chemical Analysis and Testing Task Laboratory Analytical Procedure #005 [16].

Statistical Analysis: The analysis of variance was carried out according to randomized complete block design (RCBD) and the Duncan multiple test method at 95% level of probability was used to test the differences among the means of planting spacing and stem position and as well as to detect the interaction between them of extractives, cellulose, hemicellulose and ash content [17].

RESULTS

Initial Spacing Between Trees and Chemical Analysis of Wood: The statistical analysis of the results indicated that the differences among tree spacing were highly significant, while the interaction between tree spacing and height levels was not significant for all chemical component of wood including extractives, cellulose, hemicellulose, lignin and ash. Generally, as shown in Table 1, it can be seen that wide spacing gave the highest average values of extractives, cellulose and ash contents; the averages were 8.92%, 46.90% and 2.53% respectively.

Table 1: Wood chemical composition* of Leucaena leucocephala wood as affected by tree spacing

	Content of (%)				
Tree spacing	Extractive	Cellulose	Hemicellulose	Lignin	Ash
Narrow	7.91[c]	44.52[c]	23.40[a]	32.07[b]	2.20[b]
Moderate	8.26[b]	45.80[b]	21.05[b]	33.14[a]	2.46[a]
Wide	8.92[a]	46.90[a]	20.60[b]	32.48[b]	2.53[a]

* Each value is an average of 36 specimens

**Means having the same letters in a column are not significantly different at 0.05 level of probability according to Duncan multiple tests

Table 2: Wood chemical composition* of *Leucaena leucocephala* wood as affected by sample height levels

	Content of (%)				
Sample height levels+	Extractive	Cellulose	Hemicellulose	Lignin	Ash
Breast height	8.03[c]	47.67[a]	20.79[c]	31.52[c]	2.60[a]
25%	8.17[c]	46.34[b]	21.31[c]	32.33[b]	2.57[a]
50%	8.47[b]	45.34[c]	21.99[b]	32.65[b]	2.21[b]
75%	8.78[a]	43.60[d]	22.65[a]	33.74[a]	2.21[b]

* Each value is an average of 27 specimens

** Means having the same letters in a column are not significantly different at 0.05 level of probability according to Duncan multiple tests

+ As a percentage of the total stem height

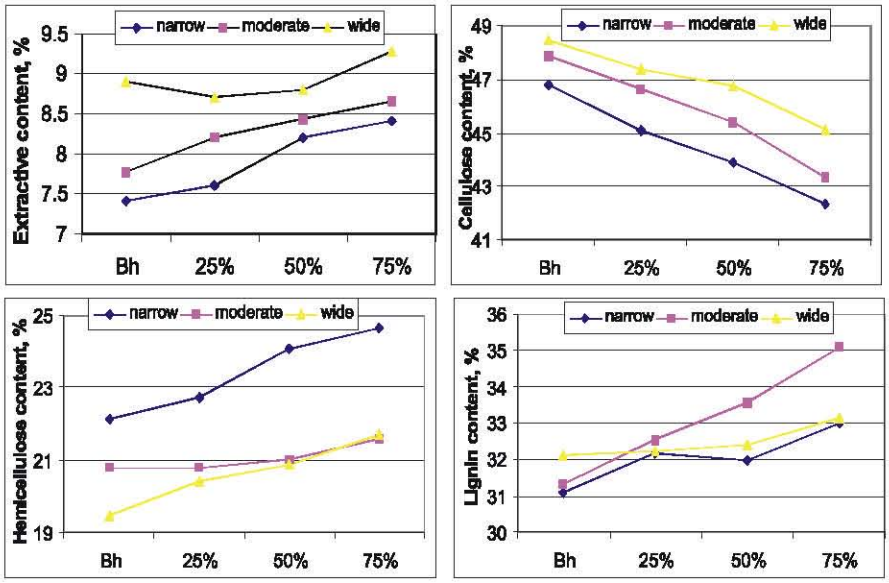

Fig. 1: Effect of initial spacing and height levels (breast height, 25%, 50% and 75% of total stem height) on chemical composition of *Leucaena leucocephala* wood.

Narrow spacing gave higher average values of hemicellulose (23.40 %) than moderate and wide spacing (21.05% and 20.60% respectively). Our results indicated that, the initial spacing (wide spacing) increased the extractives and cellulose contents of wood, while narrow spacing increased hemicellulose content in *Leucaena* wood, whereas lignin content of wood did not have a trend from wide to narrow spaces (Table 1 and Fig. 1).

Height Levels of Total Stem Height and Wood Chemical Analysis: The results indicated that, the differences among sample heights were highly significant in extractives, cellulose, hemicellulose, lignin and ash contents. It clear from Table 2 that, taken wood from breast height had the highest average values of cellulose content (47.67%), whereas the taken wood samples from the stem at 75% of total stem height had the highest of extractives, hemicellulose and lignin as shown in Table 2.

DISCUSSION

Effect of Initial Spacing and Height Levels on Extractives Content of Wood: The initial spacing and height levels had marked effects on the chemical composition of *L. leucocephala* wood. Extractives content of wood increased due to initial spacing and height levels. This result is very important because extractives are natural products that can be extracted using solvents and their have been used for centuries to waterproof wooden boats, in torches and as a binder such as resins. They have also applications in medicine, cosmetics and as preservatives [12], so it is possible to control extractives content by initial spacing between trees. This result was in agreement with conclusion obtained by Abdel-Aal and Kayad [18] who found that, the thinning treatments increased extractives content of *Citharexylum quadrangular* and *Cordia myxa,* compared with control (no thinning). On the other hand, this result was disagreement with Adam [19] who found that, thinning treatments had no significant effect on the average extractives content of trees. The increment in extractives content caused as increasing in height level was disagreement with those obtained by Abdel-Aal and Shetta [20] who found that, there was decrease in extractives content with increasing the tree height level in River red gum wood *(Eucalyptus camaldulensis)*.

Effect of Initial Spacing and Height Levels on Cellulose Content: The initial spacing and height levels had marked effects on the cellulose content of *L. leucocephala* wood. Wide spacing increased cellulose content, while narrow spacing decreased cellulose content in *L. leucocephala* wood Table 1, so it can be increase the yield of some industries like pulp of paper and cellulose derivatives because cellulose is used for two general purposes: for many centuries it has served mankind as a polymer construction material, but also in the form of natural textile fibers like cotton or flax, or in the form of paper and board. On the other hand, cellulose is a versatile starting material for subsequent chemical conversion, aiming at the production of artificial cellulose-based threads and films as well as of a variety of stable soluble cellulose derivatives to be used in many areas of industry and domestic life. Cellulose content increased with increasing the initial spacing between trees and this increase in cellulose may be due to increase of available nutrients of trees which increase the photosynthesis and the tree create the long polymer of cellulose whereas the narrow spacing decrease available nutrients and the tree can not create a lot of long polymer of cellulose. The increase in cellulose content due to initial spacing was in agreement with those obtained by Abdel-Aal *et al.* [21] who found that the heavy thinning gave higher values of cellulose. Heavy thinning had the highest average values followed by moderate thinning and the least average values of cellulose were of control. In other words, the wide spacing was the highest in cellulose content while, the narrow spacing was the lowest. Russell *et al.* [22] found that, there is an effect of thinning on cellulose crystallite width of *Eucalyptus globulus* and the most important effect was on cellulose crystallite width, which increased with thinning intensity. Shupe *et al.* [23] found that, lower stand densities yielded greater cellulose mean values on Loblolly pine wood *(Pinus taeda)*. The decrease in cellulose content with height increase was in agreement with those obtained by Abdel-Aal and Shetta [20] who found that cellulose content decreased with increasing tress height of *Eucalyptus camaldulensis*; and Abdel-Aal *et al.* [21] who found that the stem base had the highest average values of cellulose content then at breast height and the least average value was at 50% 0f the total stem height of *Casuarina cunninghamiana*.

Effect of Initial Spacing and Height Levels on Hemicelluloses Content: The wide spacing decreased hemicellulose, while narrow spacing increased hemicellulose content of *L. leucocephala* wood. Hemicellulose was decreased with increasing the initial spacing between trees and this decrease in hemicellulose may be due to increase of available nutrients of trees which increase the photosynthesis and the tree tend to create the long polymer (cellulose) than short polymer (hemicellulose), whereas the narrow spacing decrease available nutrients and the tree tend to create the short polymer like hemicellulose. It can be increase the yield of some industries by initial spacing between the trees like fuel products from the sugars derived from hemicelluloses after fermented into fuel products, such as ethanol, which can decrease the consumption of petroleum-based gasoline and other transportation fuels. Also, it can be increase the hemicelluloses to replace some polymers from petroleum sources for use in biodegradable plastics. Hemicellulose content decreased with increasing the initial spacing between trees, this result was in agreement with Abdel-Aal and Kayad [18] who found that the thinning treatments decreased hemicelluloses content. Control had the highest average values followed by moderate thinning and the heavy thinning had the least average value with significant differences among three

thinning treatments. In other words the narrow space between trees gave higher values of hemicelluloses content. The decreased in hemicelluloses content was in agreement with those obtained by Poo [24] who found that, the narrowly spaced trees gave higher values for pentosan content on autumn olive, black locust, eastern cottonwood and sycamore. On the other hand this result was in disagreement with Shupe *et al.* [23] found that, lower stand densities yielded greater holocellulose and cellulose mean values.

The increase in hemicelluloses content with increasing height levels was in agreement with those results obtained by Abdel-Aal *et al.* [21] who found that, the hemicelluloses content increased with height in the tree trunk of *Casuarina cunninghamiana* and Abdel-Aal and Shetta [20] who found increase in hemicelluloses content with increasing the tree height level in *Eucalyptus camaldulensis* trees. The same trend was found by Harwood [25] who found that in *Pinus radiata* the xylose, galactose and arabinose contents increased slightly with increasing height in the tree trunk.

Effect of Initial Spacing and Height Levels on Lignin Content: Lignin is amorphous, highly complex, mainly aromatic polymers of phenylpropane units. Lignin content had not trend from wide to narrow spaces and this result was in disagreement with Abdel-Aal *et al.* [21] who found that, the thinning treatments increased lignin content. The wide spacing produced the highest lignin while, the narrow spacing was the lowest and Shupe *et al.* [23] who found that, lower stand densities resulted in higher Klason lignin mean values and Poo *et al.* [24] who found that, the widely spaced trees gave higher values for lignin. The decreased in lignin content with increasing height was in disagreement with Abdel-Aal *et al.* [21] who found that the stem base had the highest average values of lignin content followed by breast height, while the lowest average value was at 50% of the total stem height of *Casuarina* trees.

Effect of Initial Spacing and Height Levels on Ash Content: Ash is the residue that remains after complete combustion of the wood material at 575±25°C. It is composed primarily of inorganic substances such as calcium oxide (CaO) and silica (SiO_2) and small percentages of alumina (Al_2O_3), iron oxide (Fe_2O_3) and magnesium oxide (MgO). Ash is another secondary wood component and is considered an undesirable material in most industrial situations. The increase of wood utilization as a fuel may cause an ash disposal problem because it will accumulate in furnaces, this problem may be eliminated since ash is useful as a soil conditioner and fertilizer when supplemented with nitrogen to produce the compost from wood wastes as a peat moss like substance [26-30]. The wide spacing increased ash content, this result was in disagreement with Abdel-Aal and Kayad [18] who found that the wide spacing trees were the lowest in ash content, while the narrow spacing was the highest on *Citharexylum quadrangulare*, *Cordia myxa* and *Eugenia cumini* and Poo *et al.* [31] who found that, the narrow space trees exhibited significantly higher values for ash content.

The decreased in ash content with height increase was in disagreement with the findings obtained by Abdel-Aal and Shetta [20] who found that, ash content increased with increasing the tree height level of *Eucalyptus camaldulensis*; and Abdel-Aal *et al.* 2008 who found that, ash content of wood at 50% of stem height had the highest average value than those of the breast height and the stem base of *Casuarina cunninghamiana*.

CONCLUSION

Based on the previous results, it can be concluded that, chemical composition of wood was influenced by initial spacing and stem height levels. Furthermore, such results are very important to chemical technologists and wood scientists working on pulp wood quality parameters in hardwoods. In addition, it can be increased hemicelluloses content by the narrow spacing if the wood will be converted to fuel products such as ethanol whereas, wide spacing, increased spacing to increase cellulose and extractives content to applied tensile strength and durability to fungus attach.

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