VOL. 10, NO. 8, AUGUST 2015 ISSN 1990-6145
ARPN Journal of Agricultural and Biological Science

www.arpnjournals.com

SUITABILITY OF SOME IRAQI WOODS OF FAST GROWING SPECIES FOR PULP AND PAPER PRODUCTION

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ABSTRACT

Three species of branches wood belonging to trees grown under Baghdad conditions were investigated. Axial and radial variations in fiber length, fiber diameter, cell wall thickness, vessel diameter, and wood specific gravity were examined. Results showed certain deviation in fiber geometry from that of main stem. With exception of wall thickness, all fiber and vessel examined traits were less than that of normal main stem. Specific Gravity was exceptional; it was over than conventional records. According to change in longitudinal or radial position, significant variation in most of wood element dimensions has occurred; it was species dependence. Runkel ratio values which were over than one, and also short length of fibers gave an indication that branches wood of these species grown under Baghdad conditions are not preferable for pulp and paper if there is a more convenient alternative.

Keywords: wood, willow, poplar, eucalypt, pulp.

INTRODUCTION

Woods differ in their suitability for pulp production according to inherent genetic properties of the species and also depending on growth conditions under which trees have been grown. Among the tree, there is a certain amount of variation in wood properties in axial and radial direction in addition to variation between trunk and branches wood. Short rotation of fast growing species is a famous application in maintaining proper biomass volume for the production of pulp and related industries. In such rotations, small diameter and branches comprises the raw material. *Populus, Salix,* and *Eucalyptus* are three important genera of fast growing woods. The genus *Populus* is widely distributed over the northern hemisphere. Their rapid growth lends to their use as a source of fuel, fiber, lumber, windbreak, sand protective stands to prevent soil erosion. The usefulness of black poplar timber is limited not only because it is bent, knobby and knotty, but mainly because it is not very durable (Häne, 2007). Now a day, *Populus*is one of the most important species as a source of biomass for energy and for pulp furnishes. The genus *Salix* having potential to grow as short rotation coppice tree crop and the plantation of fast growing clones, and together with poplar it can be considered as a very interesting alternative for the establishment of Short rotation plantations (Vande Walle *et al*., 2007). Third species (*Eucalypts) has* heavier wood than those two; it is durable, resistant to termites, used for some construction, flooring, fenceposts, cross-ties, and sometimes pulpwood (Duke, 1983). Anoop, *et al.* 2012 investigations on some clones of the species assured that there fibers fall within the range of dimensions required for pulping.

More than one species from each of the three genera are cultivated in Iraqi lands, some of them are native in the country. Their intensity varies from region to region following the availability of growth requirements. Willow (*Salix acmophylla* Boiss.), poplar (*Populusnigra* L,) and eucalypt (*Eucalyptus camaldulensis* Dehnh.) are the most important species in Iraq belonging to those three genera.

Cellulosic industry is very limited in the country where the only paper factory has been erected at 60th last century. It was depending on reed and imported pulp as raw material. Now a day; Iraqi market needs are satisfying by importing paper and all related products from several pulp-producing countries. Although, government has no obvious plan in establishing such industry because of unstable political conditions, the fact is an urgent necessity for establishing pulp and paper industry has arisen.

There was a wide opportunities in adopting plantation projects, especially around cities, subjecting to scientific harvest plan for maintaining environmental purposes in addition to sustaining enough volumes of biomass. Fast-growing species, certainly, would be the choice. Management of such plantations results in a large volume of branches wood which is in most cases remains in area or used as a fuel. Branches wood has some different properties from the wood of trunk; many factors participate in creating a small or a large amount of differences between them. Some authors indicated that relation of branch to trunk wood is species-specific and often individual-specific (van Gelder *et al*., 2006; Patiño *et al*., 2009). Accordingly, the aim of study was to explore branches wood properties of *P. nigra, S. acmophylla, and E. camaldulensis*growing under Baghdad region environmentin relation to their suitability for pulp and paper production.

MATERIALS AND METHODS

Five branches from each of the three species were selected from wood market at northern Baghdad city. Trees were newly harvested and having leaves used for identification. Base diameter range was 7-11, 6-13, and 12-23 cm for *Populusnigra*. *Salix acmophylla* Boiss, *and Eucalyptuscamaldulensis* Dehnh., respectively. Four discs- 5 cm thicknesses- were prepared by cross cutting at 1m intervals starting from base of branch. Five centimeters width radial band was cut from each disc. Bands were

subdivided into 4 segments, 2 represented outer wood and the other two denoted as inner wood. Each segments was subdivided into 2 parts; one for specific gravity determination, other was employed for wood elements geometry.

Fiber maceration was conducted according to (Franklin, 1945). Fiber length, diameter, wall thickness, and vessel diameter were the measured traits. Specific gravity was determined by immersion method using distilled water after coverage the specimens by paraffin. Experiment was designed as CRD factorial with tow variables; height (4 levels), and radial position (2 levels). Wood species was not included in analysis, i.e. each species was analyzed separately. Replications were 10 for specific gravity, and 30 for each of wood element traits. Results have been analyzed statistically using Statistica (Statsoft Incorporated, 1997) and differences between treatments were tested by Duncan Multiple Range Test.

RESULTS AND DISCUSSIONS

General view to fiber dimension of the three speciesshows that branches of trees grown under Baghdad conditions possessed finer fiber than common range of main stem fiber dimensions. Overall mean of *Salix* fiber length was 542 µm (Table-1); it is less than what was found by

Table-1. Mean values of fiber length as affected by species, radial, and axial position.

Radial		Axial	Salix		Populus		Eucalyptus	
			Mean	Range	Mean	Range	Mean	Range
Fiber length (µm)	Inner	Base	530 (bc)	263-842	445 (c)	289-737	586 (b)	342-789
		1 m	603 (ab)	368-799	557 (b)	368-737	535 (b)	368-711
		2 m	487 (c)	289-771	506 (bc)	342-684	545 (b)	316-842
		3 m	518 (bc)	289-684	488 (bc)	368-711	494 (bc)	368-789
		Mean	535	302-774	499	342-717	540	349-783
	Outer	Base	583 (ab)	447-763	548 (b)	447-710	666 (a)	447-868
		1 m	511 (bc)	316-737	615 (a)	368-868	692 (a)	500-895
		2 m	453 (c)	342-579	443 (c)	236-632	671 (a)	421-921
		3 m	645 (a)	315-868	510 (bc)	410-658	668 (a)	447-816
		Mean	548	355-736	529	365-717	674	454-875
Fiber diameter (µm)	Inner	Base	15.0 (bc)	8.4-25.3	12.9 (ab)	7.9-18.4	10.5 (a)	3.9-17.1
		1 m	17.7 (a)	10.5-26.3	12.6 (ab)	5.3-17.1	10.6 (a)	5.3-18.4
		2 m	13.1 (cd)	7.9-18.4	12.1 (abc)	7.9-18.4	10.8 (a)	4.2-17.9
		3 m	11.0 (d)	5.3-15.8	12.5 (ab)	7.9-18.4	10.8 (a)	4.7-19.2
		Mean	14.2	8.0-21.5	12.5	7.3-18.1	10.7	4.5-18.2
	Outer	Base	16.9 (a)	10.5-26.3	10.3 (c)	6.6-15.8	10.5 (a)	5.3-14.5
		1 m	12.8 (cd)	8.4-18.9	12.1 (abc)	6.6-15.8	8.9 (a)	5.3-13.2
		2 m	10.9 (d)	7.9-15.8	10.7 (bc)	5.3-18.4	10.7 (a)	5.8-15.8
		3 m	11.6 (d)	5.3-19.7	13.4 (a)	7.9-19.7	9.1 (a)	6.6-17.1
		Mean	13.1	8.0-20.2	11.6	6.6-17.4	9.8	5.8-15.2

Note: Mean values having same letter inside column have no significant differences at ($p \geq 0.05$).

(Monteoliva *et al*., 2005, Sharma, *et al*., 2014) in their investigations on main stem fibers. It was demonstrated that brancheshave different wood element properties thanthat of trunk (Mahdavi and Habibi, 2004, Samariha, *et al*., 2011). *P. nigra and E. camaldulensis* fiber length were 514 and 607 µm respectively. They were below normal stem fiber length, too. With few exceptions, length of fiber followed the most usual pattern; it decreased along the branch from base upwards, similar findings on main stem were demonstrated by (Abady, 1988, Feng, *et al.* 2014). Age of cambium might be the reason where basal wood is older than wood at upper end. Radially, it was found that fibers nearer to cambium were longer than inner wood fibers by 2%, 6%, and 22% for *S. acmophylla, P. nigra, and E. camaldulensis,* respectively. Similar tendency was found for many wood species (Kord and Kord, 2010, Pande, 2011).

Similar change pattern upwards was a fact alsofor fiber diameter in case of *S. acmophylla* and *P. nigra*especially in outer part of branch. Unlikely, fiber

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diameter of *E. camaldulensis* did not show an obvious response to axial position neither for inner nor for outer wood (Table-1).

Diminishing in fiber geometry as compared with main stem did not involve cell wall thickness. Obtained mean values (4.3 µm and 3.4 µm) are normal wall thicknesses for *S. acmophylla, P. nigra*woods, but for *E. camaldulensis*, 2.9 µm wall thickness seemed to be lower than normal (Table-2). Short, thin walled fibers may produce dense paper which is weak in tearing strength (Samariha, *et al*. 2011). Vertically, S. acmophyllashowed more significant decrease in wall thickness than the two other species, while radially no significant differences were obtained in any of the three species.

Wood suitability for pulp and paper is mainly determined by fiber geometry. Runkel ration (RR) which is 2x wall thickness/ cell lumen diameter gives confident decision in this subject. The number (1) has been fixed by specialists to be the (RR) limit over which wood would be less favorable. Fibers with high (RR) will be stiff, less flexible and have a weak bonding during sheet making. Applyingthe above formula on obtained findings resulted in 1.70, 1.29, and 1.36 (RR) values for *S. acmophylla, P. nigra*

Table-2. Mean values of cell wall thickness and vessel element diameter as affected by species, radial, and axial position.

Radial		Axial	Salix		Populus		Eucalyptus	
			Mean	Range	Mean	Range	Mean	Range
Cell wall thickness (µm)	Inner	Base	6.1 (a)	2.6-7.9	3.0 (a)	1.3-5.3	2.9 (ab)	1.3-4.7
		1 m	4.1 (bc)	2.4-5.8	3.3 (a)	1.8-5.3	2.4 (b)	1.6-4.5
		2 m	2.9 (d)	1.8-6.1	3.1 (a)	1.8-5.0	3.3 (a)	1.4-5.5
		3 m	3.5 (cd)	1.6-5.8	3.8 (a)	1.6-5.8	2.9 (ab)	1.6-5.2
		Mean	4.2	2.1-6.4	3.3	1.6-5.4	2.9	1.5-5.0
	Outer	Base	4.7 (b)	2.6-7.4	3.5 (a)	2.4-5.8	3.2 (a)	1.5-5.6
		1 m	5.7 (a)	2.6-9.4	3.6 (a)	1.3-5.8	3.1 (ab)	1.3-5.3
		2 m	4.2 (bc)	2.9-6.1	3.5 (a)	1.8-4.7	2.9 (ab)	1.7-4.8
		3 m	3.0 (d)	1.6-4.2	3.5 (a)	1.6-5.8	2.7 (ab)	1.3-6.1
		Mean	4.4	2.4-6.8	3.5	1.8-5.5	3.0	1.5-5.4
Vessel element diameter (µm)	Inner	Base	67.4 (a)	26.3-121.1	50.8 (ab)	26.3-83.2	65.7 (b)	31.6-115.8
		1 m	54.6 (ab)	29.5-103.2	46.0 (ab)	20.0-76.8	65.0 (b)	36.8-150.5
		2 m	55.5 (ab)	31.6-78.9	47.9 (ab)	26.3-78.9	88.3 (a)	28.4-121.1
		3 m	50.6 (b)	26.3-121.2	42.3 (b)	25.3-63.2	87.5 (a)	32.6-1337
		Mean	57.0	28.4-106.1	46.8	24.5-75.5	76.6	32.4-130.3
	Outer	Base	52.5 (ab)	31.6-73.7	43.1 (b)	21.1-63.2	98.7 (a)	57.9-168.4
		1 m	60.5 (ab)	30.5-108.0	57.4 (a)	21.1-75.8	60.7 (b)	21.1-113.7
		2 m	54.8 (ab)	26.3-84.2	57.0 (a)	40.0-84.2	101.0 (a)	43.2-145,3
		3 m	55.8 (ab)	23.2-103.2	48.9 (ab)	26.3-89.5	59.3 (b)	37.9-148.4
		Mean	55.9	27.9-92.3	51.6	27.1-78.2	79.9	40.0-143.9

woods, and *E. camaldulensis*, respectively. They simply refer that all three woods are not optimum material for quality paper product. Despite short length, RR of branches wood was better than main stem in Mahdavi and Habibi, 2004 investigations on *Carpinusbetulus.*

Averages of vessel element diameter were also lower than that of normal wood of main stem. Generally, they were narrower at branch end than in lower positions. The trend was more systematic in willow than in poplar or eucalypt, and more in inner than in outer wood. Transversely, no expecting increase in vessel diameter could be observed from pith to bark in any one of the studied woods. For certain species, environmental conditions and management practices have their definite influences on vessel volume, Sisi, *et al.* (2010) demonstrated that increasing initial spacing between trees affected the diameter and frequency of the vessels. In regards to pulp preparation, vessels have important role in cooking process by accelerating chemical penetration inside wood chips. From other hand, it can cause a problem with paper quality through loosening the surface, linting, and it may adhere to printing plates and deteriorate printing quality (Granlof, *et al*. 2012). For manufacturing vessel - free pulp from *Eucalyptus* and because of the

unique complicated construction of vessel cell wall, Lindström and Fardim, 2012 suggested chemical modification during pulping process.

The more exceptional result was the values of wood specific gravity (SG), they were over than normal in two species; *S. acmophylla* and *P. nigra*, but that of *E. camaldulensis* remained within normal limits (Table-3) but still away from Abbassali and Kiaei, 2011 records. Most of previous works on the first two species (Al-Abady, 1988, Monteoliva *et al.,* 2005, Wani, *et al*. 2014) did not indicate that wood specific gravity could reach or exceed 500 although few authors (Sharma, *et al*., 2014) recorded highest (SG) than we obtained. Average of densities of the examined branches exceeded normal stem wood density of those species by about 20%. Finest wood elements and narrower voids (vessels) of examined woods could result in higher wood density.The trend of axial variation was not fixed for all the species. Little increase and then decrease in willow and poplar wood SG, while no significant variation in eucalypt has obtained. Previous works on this type of variation appeared miscellaneouskinds of relation (Skolmen, 1972, Kordand Kord, 2010, Mukui *et al*., 2014). Transversally, periphery possessed few denser wood than center (Table-3), such relation was found by many authors (Pande, 2011, KORD, *et al*., 2010, Feng, *et al*. 2014) while Plourdee, 2014 in his work on many wood species found radial increase in species with inner specific gravity below 0·5, and radial decreases in species with inner specific gravity above 0·7. Age of cambium, size of branch, and growth conditions have their influence upon wood characteristics, density is one of

Table-3. Mean values of wood density as affected by species, radial, and axial position.

Radial		Axial	*Salix*		*Populus*		*Eucalyptus*	
			Mean	**Range**	**Mean**	**Range**	**Mean**	**Range**
Wood specific gravity	**Inner**	Base	541(bc)	507-564	594 (ab)	584-605	745 (a)	718-777
		1 m	581 (ab)	568-607	634 (a)	607-662	720 (a)	701-744
		2 m	537 (ab)	513-695	544 (b)	541-547	707 (a)	678-746
		3 m	512 (c)	418-520	537 (b)	537-538	716 (a)	693-733
		Mean	552	502-597	577	567-588	722	698-750
	Outer	Base	532 (bc)	501-555	598 (ab)	556-641	748 (a)	723-750
		1 m	558 (abc)	533-590	565 (ab)	543-588	737 (a)	683-751
		2 m	613 (a)	597-620	551 (b)	545-537	735 (a)	711-761
		3 m	586 (ab)	574-602	558 (b)	558-559	733 (a)	680-756
		Mean	572	551-592	568	551-581	738	699-755

Note: Mean values having same letter inside same column have no significant differences at ($p \geq 0.05$).

the most affective traits. Qumruzzaman, *et al*., 2013 suggested that the influence of age or diameter on wood density varied among species that in slower-growing trees, De Castro *et al*., 1993 found greater slop in density gradient. For branches wood, Williamson and Wiemann, 2010 referred that specific gravity can be strongly affected by juvenile wood in young branches or by tension/compression wood in older branches.

CONCLUSIONS

From above mentioned results it was concluded that:

- Fiber dimensions of branches wood for each of willow, poplar, and eucalypt growing under Baghdad -area conditions were smaller than normal dimensions of main stem fibers.
- With few exceptions, fiber length and diameter decreased from base upwards, and increased radially from pith to bark.
- Cell wall thickness did not include by dimension shortening; it remained within normal limits, the main reason of rising SG values.
- Species dependence variation could be observed in vessel diameter according to axial or radial transmission.
- Specific gravity of willow and poplar was the distinctive trait when it was beyond the normal limits by about 20%. Position variation in SG was not the same for all the three species.
- Over than one Runkel ratio for the three investigated woods indicates little favorability to pulp and paper, so; they are not preferable when other alternatives are available.

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