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Studies on chemical compositions of *Salix* hybrids' wood

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Abstract
The chemical compositions of *Salix* hybrids' wood or clones largely determine their suitability for various end-uses. The main objective of this study was to determine the clonal variation of chemical composition in 3 year old 37 *Salix* hybrids' clones grown in Naganji experimental area, Dr. Y.S Parmar University of Horticulture and Forestry, Nauni, Solan (HP). Wood samples from three clones per *Salix* hybrid were randomly taken for this study. Chemical compositions of *Salix* hybrids wood showed significant interclonal variation, indicating the possibility of identifying clones with superior wood properties. The mean values of cold water soluble extractive, hot water soluble extractive, Alcohol-benzene soluble extractive, holocellulose content, lignin content and ash content were varied from 2.83 (UHFS299 clone) to 8.23% (UHFS221 clone), 3.98 (UHFS112) clone to 10.52% (UHFS165 clone), 2.58 (UHFS335 clone) to 6.69% (UHFS267 clone), 62.63 (UHFS299 clone) to 81.47% (UHFS221 clone), 14.30 (UHFS267 clone) to 34.18% (UHFS299 clone) and 0.45 (UHFS112 clone) to 1.47% (UHFS111 clone), respectively. In general, the results exhibited that all the *Salix* hybrids' clones have good potentials for pulp and paper production.

Keywords: chemical composition, *Salix* hybrids' wood, clones

Introduction

Salix species are eco-friendly, multipurpose, fast growing and are widely used for plantation throughout the world. The genus *Salix* is a member of the family Salicaceae, commonly known as willow and consists of 450-520 species worldwide (Wu *et al*., 2015) [29]. The *Salix* species show all forms of development from tall trees (hot-temperate climates), to shrubs (cold-temperate climates) and to creeping and dwarf shrubs (cold and arctic zones). The genus *Salix* is distributed over wide ecological and climatic zones, largely in the Northern Hemisphere with a centre of abundance in China and the former Soviet Union (Argus, 1997) [6]. Due to its wide geographic adaptation and fast growth, the genus *Salix* species has a significant economic value and some of the *Salix* species have been cultivated for a variety of end-uses such as baskets, cricket bats, hurdles, furniture, plywood, paper and pulp, rope making, firewood, poles, wicker products, wood for utensils etc. (Sharma *et al*., 2014) [25].

The world demand for the wood products and global solid wood material source is being insufficient (Huda, 2014) [10]. As a result, shortage in supply of raw material became serious issue and far behind the demand for the pulp and paper, plywood, furniture industries, etc. (Saravanan *et al*, 2014) [24]. It is, therefore, necessary to find alternative fast-growing species which are suitable to fill the gap between wood production and its consumption by using short rotation tree plantations. Therefore, *Salix* hybrids clones have received considerable attention for their high productivity due to their fast growth rate and easily hybridization of two or more species within the genus *Salix*.

Wood property information is essential to wood processors and end-users. The processing and utilization of woods for different products can be strongly influenced by their anatomical properties. That is why utilization cannot be discussed without consideration of specific wood properties. However, even though there are a few studies, information on anatomical characteristics of *Salix* hybrids' wood is still very limited. Hence, the aim of this study was to examine the anatomical properties of *Salix* hybrids' wood in Dr. YS University of Horticulture and Forestry, Nauni, Solan (HP), India.

Materials and Methods

Wood samples were obtained from clones of 3-year old 37 *Salix* hybrids.

Three clones per *Salix* hybrid and one clone per block, totally 111clones were randomly selected from Naganji experimental area, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan (HP). The elevation of the experimental area is 1200 m above mean sea level and located at 30°51'N latitude and 76°11'E longitude. Woods obtained from *Salix* hybrids' clones were chipped, and ground using grinder. The fraction of wood meals which passed a 40 mesh sieve (420 µm) and retained on a 60 mesh sieve (250 µm), was used for analysis. Cold and hot water extractives were removed by TAPPI Standard Method T1m-59 (Anonymous, 1959a) [2] and Alcohol benzene extractives by TAPPI Standard Method T6m-59 (Anonymous, 1959b) [4]. Estimation of holocellulose and lignin contents was carried out from Alcohol-benzene pre-extracted wood.

Table 1: Details of clonal material

S. no	Clone name	Hybrid details	Sn	Clone name	Hybrid details
1	UHFS061	*Salix matsudana* x *S. babylonica x S. alba*	20	UHFS296	*S.matsudana x S.alba*
2	UHFS075	*Salix matsudana* x *S. babylonica x S. alba*	21	UHFS297	*S.matsudana x S.alba*
3	UHFS087	*Salix matsudana* x *S.alba x* S. *matsudana*	22	UHFS298	*S.matsudana x S.alba*
4	UHFS111	*Salix matsudana* x *S.alba x* S. *matsudana*	23	UHFS299	*S.matsudana x S.alba*
5	UHFS112	*Salix matsudana* x *S.alba x* S. *matsudana*	24	UHFS309	*S.matsudana x S.alba*
6	UHFS113	*Salix matsudana* x *S.alba x* S. *matsudana*	25	UHFS333	*S.matsudana*
7	UHFS121	*Salix matsudana* x *S. babylonica* x *S.alba S.matsudana*	26	UHFS340	*S.matsudana*
8	UHFS144	*Salix matsudana* x *S.matsudana* x *S.arbutifolia* x *S.matsudana*	27	UHFS335	*S.matsudana*
9	UHFS165	*Salix matsudana* x *S.matsudana x S.alba*	28	UHFS412	S.tetrasperma X S.tetrasperma
10	UHFS187	*Salix matsudana* x *S.matsudana x S.alba*	29	UHFS242	*Salix matsudana* x *S.alba*
11	UHFS202	*Salix matsudana* x *S.matsudana x S.alba*	30	UHFS336	*S.matsudana*
12	UHFS208	*Salix matsudana* x *S.matsudana x S.alba*	31	UHFS370/12	*S.matsudana*
13	UHFS221	*Salix matsudana* x *S.tetrasperma*	32	NZ1002	*S.matsudana x S.alba*
14	UHFS340/11	*Salix matsudana* x *S.tetrasperma*	33	J795	*S.matsudana x S.alba*
15	UHFS248	*Salix matsudana* x *S.alba*	34	SI-64-017	*S.alba*
16	UHFS60/11	*Salix matsudana* x *S.alba*	35	Kashmiri Willow	*S.alba*
17	UHFS267	*S. matsudana* X *S.tetrasperma*	36	Austree	*S.alba x S.matsudana*
18	UHFS289	*S.matsudana x S.alba*	37	J194	*S.matsudana* x *S.arbutifolia* x *S.matsudana*
19	UHFS282	*S.matsudana x S.alba*			

The holocellulose content was determined by TAPPI Standard Method T9m-59 (Anonymous, 1959) [3] and lignin content by TAPPI Standard Method T12m-59 (Anonymous, 1959c) [5].

The ash content was determined according to AOAC (Association of Analytical Chemists, 2005) [7]. Two grams of each sample of oven dried tree sample was added into a pre-weighed crucible and put in the muffle furnace and incinerated in muffle furnace at 575±25°C for 3 hours and then placed in a desiccators for 30 minutes. After cooling, the crucible along with the ash was weighed and the ash content was estimated using the formula:

$$\text{Ash (\%)} = \frac{(W3-W1)}{W2-W1} \text{X}100$$

Where, W1 is the weight of cleaned and dried crucible, W2 the weight of the crucible and sample, and W3 the weight of the crucible and sample after incinerating at 575±25°C and cooling in an airtight homogenized vessel.

ANOVA was used to analyse the obtained data, by testing the level of significance of the chemical compositions, among the different *Salix* hybrids' wood. All the mean data obtained were statistically analysed using SPSS16.

Results and Discussion

The most important parameters which determine suitability of wood as raw material for pulp and paper industry are its chemical constitutes. The amounts of holocellulose and lignin contents are mainly related to pulping characteristics. A Table 2 shows the values of chemical composition for all the *Salix* hybrids' wood. The results showed that except Alcohol-benzene extractive, all the studied chemical traits were significantly different among the different *Salix* hybrids' wood ($p < 0.05$).

The maximum value of cold water soluble extractive was found in clone UHFS221 clone (8.23%) and minimum was noticed in UHFS299 clone (2.83%). The cold water soluble compounds in wood are generally sugars, salts, tannins and gums. The species containing large amount of extractives have better durability, dimensional stability and plasticization. Narayanamurti and Verma (1964) [18] have also stated that the content, type and position of extractives could affect the strength properties of wood. The results of this study are in conformity with findings for 4 willow clones (5.58%) by Sharma *et al.* (2014) [25], *Neolamarckia cadamba* wood (5.65%) by Latib *et al*. (2014) [16], *Morus nigra* wood (3.90%) by Walia (2013) [28] and *Maclura Pomifera* (Raf.) C.K. Schneid wood (4.12%) by Salem and Mohame (2013) [22]. Moreover, the variation in cold water soluble extractives of wood have been reported by Kumar *et al.* (2005) [15] in *Dalbergia sissoo,* and Shirsat (2011) [26] in *Acacia nilotica.*

The maximum value of hot water soluble was recorded in UHFS165 clone (10.52%) and minimum value was observed in UHFS112 clone (3.98%). Hot water soluble compounds are important in the evaluations of hot water solubility of wood. These extractives are generally compound of fats, waxes, alkaloids, phenols, sugar, salts, starch, tannin, gums and phenolic compounds within any lignocellulosic material. The values of hot water soluble extractives in this study were higher than cold water soluble extractives in majority of the clones. The difference in solubility might be due to the hydrolysis and corresponding increase in solubility of wood substance during the boiling with water. The hot water soluble extractives have been estimated by various researchers such as Sharma *et al*. (2014) [25] in 4 willow clones (7.72%), Latib *et al*. (2014) [16] in *Neolamarckia cadamba* wood (6.56%), Walia (2013) [28] in *Morus nigra* wood (4.98%), Salem and Mohame (2013) [22] for *Maclura Pomifera* (Raf.) C.K. Schneid wood (6.62%) and Guler *et al*. (2007) [8] in *Pinus* *nigra* Arnold, 4.71% in mature wood and 2.25% in juvenile wood. The present studies are almost in line with all these studies.

The value of Alcohol -benzene soluble extractive was varied from 2.58 -6.69%. Even though their inter-clonal variations were non-significant, these values fell within the range of 2.73-7.10% reported by Sharma *et al.* (2014) [25] for the 4-year old willow clones. Moreover, significant variations of Alcohol-Benzene extractives have been observed by Latib *et al*. (2014) [16] in *Neolamarckia cadamba* wood (2.45%), Walia (2013) [28] in *Morus nigra* wood (2.60%), Samariha and Kiaei (2011) [23] on *Ailanthus altissima* wood (3.5%), Guler *et al*. (2007) [8] in *Pinus nigra* Arnold, 6.07% for mature wood and 2.51% in juvenile wood and Mistui *et al*. (2010) [17] in willow clones (2.1-4.0%).

Alcohol-Benzene extractives are commonly composed of oleoresins, fats, waxes and oils. Wood extractives in general give the colour and odour to the trees and protect the tree from microbic and insect attacks and used as tree metabolism and energy reserves. However, extractives of a raw material are undesirable parts and decrease the quality of the pulp and paper yields (Jahan *et al*., 2008 and Jahan *et al*., 2010) [13, 12]. Therefore, the lower values of extractive solubility of *Salix* hybrids' clones are more favorable for good quality of pulp and paper.

Table 2: Vriation in chemical compositions of *Salix* hybrids` wood

Clone name	Parameters					
	Cold water (%)	**Hot water (%)**	**Alcohol-Benzene (%)**	**Holocellulose (%)**	**Lignin (%)**	**Ash (%)**
UHFS061	7.22	7.93	4.30	76.78	18.35	0.72
UHFS075	7.75	9.38	3.53	78.68	17.67	0.65
UHFS087	7.53	4.20	3.02	79.23	18.12	1.03
UHFS111	7.48	8.12	3.53	78.27	17.92	1.47
UHFS112	5.27	3.98	4.54	79.35	15.78	0.45
UHFS113	6.92	7.75	3.64	78.30	17.78	0.87
UHFS121	7.82	9.13	4.28	78.93	16.42	1.17
UHFS144	5.72	5.87	4.45	74.43	20.67	0.58
UHFS165	6.90	10.52	5.13	75.12	19.33	0.75
UHFS187	7.82	9.25	2.72	79.69	17.15	0.60
UHFS202	6.52	9.85	3.93	78.96	17.25	0.83
UHFS208	7.37	7.37	3.16	78.71	17.33	0.77
UHFS221	8.23	6.62	2.63	81.47	15.43	0.97
UHFS240/11	6.07	8.32	3.88	73.78	20.98	0.90
UHFS248	7.40	6.15	5.34	78.81	16.25	0.70
UHFS260/11	5.98	7.95	4.21	73.93	21.52	0.55
UHFS267	7.65	8.47	6.69	79.79	14.30	0.60
UHFS289	6.03	9.50	2.94	76.07	20.53	1.25
UHFS282	6.53	9.85	3.80	75.89	20.15	1.32
UHFS296	7.17	9.27	3.71	78.04	17.98	1.03
UHFS297	3.75	7.03	3.69	66.44	29.32	0.98
UHFS298	3.78	6.18	2.92	75.24	21.20	1.12
UHFS299	2.83	8.27	3.13	62.63	34.18	0.850
UHFS309	7.77	6.25	4.14	78.56	16.88	0.85
UHFS333	7.85	7.47	3.95	77.06	18.88	0.78
UHFS340	3.40	6.98	4.70	66.75	27.83	0.97
UHFS335	7.37	8.28	2.58	77.29	19.73	1.05
UHFS412	7.08	7.00	4.87	78.17	16.95	0.72
UHFS242	7.38	5.25	3.60	76.68	19.05	0.68
UHFS336	5.53	4.65	5.30	77.24	17.22	0.67
UHFS370/12	7.37	7.702	3.89	78.087	18.42	0.98
NZ1002	7.30	6.00	3.62	81.04	15.28	0.767
J795	3.68	9.12	4.38	77.75	25.28	1.28
SI-64-017	3.90	6.42	3.13	73.63	22.70	0.62
KASHMIRI WILLOW	3.75	5.67	2.67	67.50	30.45	1.30
AUSTREE	3.82	6.50	5.92	72.89	23.72	1.43
J194	7.65	5.10	3.16	75.88	21.07	0.72
SE	0.24	0.37	1.10	2.77	3.20	0.25

The maximum value of holocellulose content was recorded in clone UHFS221 (81.47%) and minimum value was observed in clone UHFS299 (62.63%). These values are approximately similar as compared with mean and/or range of some wood species or clones as reported by Zhou *et al*. (2017) [30] in 3-year old *Salix psammophila* (78.86-80.38%), Riyaphan *et al*. (2015) [21] in 13 year old *Hevea brasiliensis* tree clones (68.0-71.2%), Sharma *et al*. (2014) [25] in 4-year old willow clones (64.27-79.30%), Walia (2013) [28] in *Morus nigra* wood (69.15%), Mitsui *et al.* (2010) in willow clones (78.9 - 81.2%), Guler *et al*. (2007) [8] in *Pinus nigra* Arnold, 72.2% in mature wood and 64.70% in juvenile wood.

The highest value of lignin content was found in clone UHFS299 (34.18%) and lowest value of 14.30% in UHFS267. Lignin is present in cell walls to give the plant structural rigidity, impermeability and resistance against microbial attack and oxidative stress. It is an amorphous polymer and the chemical structure of lignin is irregular *i.e.* different structural elements are not linked to each other in any systematical order and it is often called the cementing agent which binds the cell wall material cells together.

However, lignin is an undesirable polymer for pulp and paper, and its removal during pulping requires high amounts of energy and chemicals. Variation in lignin of wood depends upon specific environmental and genetic factors (Samariha and Kiaei, 2011; Jirawat *et al*., 2015) [23, 14]. Tree to tree variation is believed to contribute to lignin heterogeneity and variations in lignin composition are also found between different parts of the tree (Samariha and Kiaei, 2011) [23].

Similar to the current study, Sharma *et al*. (2014) [25] have reported the significant variation of lignin content in 4 year old different willow clones varied from 19.10 to 26.33%. Moreover, significant variations of lignin contents have been observed by Zhou *et al*. (2017) [30] for 3-year-old *Salix psammophila (*17.33-18.97%), Riyaphan *et al*. (2015) [21] in 13 years old *Hevea brasiliensis* tree clones (18.7-21.2%), Latib *et al*. (2014) [16] in *Neolamarckia cadamba* sp. wood (24.58-30.92%), Walia (2013) [28] for *Morus nigra* wood (21.42%), Salem and Mohame (2013) [22] in *Maclura Pomifera* wood (40%), Irbe *et al*. (2012) [11] in 31 year - old *Picea abies* (27.0-28.9%), Mitsui *et al*. (2010) in willow clones (27.0-32.3%), Akgul and Tozluoglu (2009) [1] in *Fagus orientalis* (29.2%) and *Pinus nigra* (33%), Guler *et al*. (2007) [8] for 20-23 years old *Pinus nigra* Arnold, (28.50%) in mature wood and (33.00%) in juvenile wood, Szczukowski *et al*. (2002) [27] in willow wood (13.79%) and Hosseinzade *et al*., (2001) [9] in *Eucalyptus streiaticalyx* (23.01%).

The maximum value of ash content was recorded in clone 231 (1.47%) and minimum value was noticed in clone UHFS112 (0.45%). The ash content normally related to the amount of mineral such as silica. These mineral salt and silica could be found in the cell wall, lumen cell and other cells. The present results are in conformity with findings of different wood species and clones as reported by Riyaphan *et al*. (2015) [21] on 13 year old *Hevea brasiliensis* tree clones (0.9% or 0.7-1.1%), Walia (2013 [28]) for *Morus nigra* wood (0.85%), Salem and Mohame (2013) [22] in *Maclura Pomifera* (Raf.) C.K. Schneid wood (0.45%), Samariha and Kiaei (2011) [23] in *Ailanthus altissima* Wood (1.25%), Neimsuwan and Laemsak (2010) [19] and Pinto *et al*. (2005) [20] in *Eucalyptus camaldulensis* (0.6%) and *Acacia mangium* (0.22%), Akgul and Tozluoglu (2009) [1] for *Fagus orientalis* (0.4%) and *Pinus nigra* (0.90%) and Hosseinzade (2001) [9] in *Eucalyptus streiaticalyx* (0.55%).

Conclusions

This paper presents the experimental results of chemical compositions of 3 years old 37 *Salix* hybrids clones. The aim of the study was to determine the variation in chemical composition among the different *Salix* hybrids' clones. The analysis of chemical composition in *Salix* hybrids showed significant difference among clones, indicating the possibility of selecting clones with desirable attributes. The results exhibited that all the *Salix* hybrids' clones have good potentials for pulp and paper productions. Therefore, the results of this information can be used for comparative studies with other *Salix* species as well as other tree species being evaluated for wood quality improvement and other applications. However, a continuous research is needed to evaluate any change of chemical characteristics associated with age increment and environmental factors.

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