Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2017; 6(4): 263-266
Received: 06-05-2017
Accepted: 07-06-2017

Heena Gupta
Department of Forest Products, College of Forestry, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni- Solan, H.P., India

KR Sharma
Department of Forest Products, College of Forestry, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni- Solan, H.P., India

Chander Lekha
Department of Forest Products, College of Forestry, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni- Solan, H.P., India

Bhupender Dutt
Department of Forest Products, College of Forestry, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni- Solan, H.P., India

Correspondence
Heena Gupta
Department of Forest Products, College of Forestry, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni- Solan, H.P., India

Potentials of *Lantana Camara* L. leaf extract treatment for the dimensional stability of some lesser known wood species

Heena Gupta, KR Sharma, Chander Lekha and Bhupender Dutt

Abstract
Wood is a hygroscopic material that shrinks and swells to different extents in three anatomical directions. The dimensional changes that accompany the shrinking and swelling of wood are major sources problems in the structural utilization of wood. Therefore, the present investigation was carried out to test the potentials of *Lantana camara* L. methanol leaf extract for the dimensional stability of wood samples of some lesser known wood species viz. *Pinus roxburghii* Sargent, *Celtis austral* L., and *Bombax ceiba* L. of size 5cm x 2.5cm x 2.5cm (longitudinal x radial x tangential) treated at different concentrations viz. 0.25%, 0.5%, 1%, 1.5% and 2.0%. These samples were analysed for swelling and shrinkage in three different planes viz. longitudinal, radial and tangential and the results revealed highest swelling and shrinkage in tangential plane followed by radial plane and longitudinal plane. *Pinus roxburghii* Sargent wood samples were recorded with the highest swelling and shrinkage in all the three planes. Among the treatments, 1.5% was observed with maximum swelling and 2% concentration with minimum shrinkage. The treated samples exhibited good dimensional stability as compared to untreated samples. Thus, the plant extract offers a great potential in improving the dimensional stability of wood without adversely affecting the environment.

Keywords: wood, dimensional stability, shrinkage, swelling, longitudinal, radial, tangential

Introduction

Wood is hygroscopic material and it changes dimensions with changing moisture content because the cell wall polymers contain hydroxyl and other oxygen containing groups that attracts moisture through hydrogen bonding. The hemicelluloses are the most hygroscopic components in the wood cell wall, but cellulose and lignin also contribute to hygroscopicity. Moisture swells the cell wall and the wood expands until the cell wall is saturated. Water beyond this point is free water in the cell lumen and does not contribute to further expansion. It is reversible process and the wood shrinks with loss of moisture (Stamm, 1964) [15].

Wood is an anisotropic material, which means that it shrinks and swells to different extents in three anatomical directions, shrinking most in the direction of the annual growth rings (tangentially), about one-half as much across the rings (radially) and only slightly along the grain (longitudinally) (Anonymous, 1999) [1]. As the S_2 layer of the wood cell wall is generally thicker than the other layers combined, the molecular orientation of this layer largely determines how shrinkage occurs. Most of the chain molecules in the S_2 layer are oriented almost parallel to the long axis of the cell (with micro fibril angles of 10-30°). When water enters between the cellulose chains in the S_2 layer it forces the chains apart, causing transverse (radial and tangential) swelling, while any change in the longitudinal direction will be minor (Bowyer *et al*. 2003, Siau 1984) [2, 14]. Stresses will arise in the wood due to moisture gradients between the surface and the interior and unbalanced stresses can result in surface warping, twisting and checking.

Wood constituent polymers, during exterior use are readily degraded by weathering. The main problem associated with wood under outdoor use are its dimensional instability due to moisture absorption or desorption, breakdown of wood polymers by UV light and its decay by micro-organisms (Feist and Hon, 1984) [5]. Chemical modification of cell wall polymers is one of the effective methods to induce dimensional stability, UV resistance and biological resistance in wood (Rowell, 2005) [15]. The dimensional stability can be improved by bonding cell wall polymers with hydrophobic groups or bulking cell wall polymers with bonded chemicals. Resistance to ultraviolet radiations can be achieved by bonding UV absorbers or blockers to lignin (Kiguchi and Evans, 1998) [7]. Although chemical modification of cell wall polymers through conventional wood preservatives is one of the effective methods to induce dimensional stability in wood (Rowell, 2005) [12] but these are said to cause environmental pollution and a few of them are hazardous to animals and human beings (Onuorah, 2000) [10]. Therefore, the development of eco-friendly formulations from natural resources such as *Lantana camara* has been emphasized for wood treatments.

Lantana camara L., belonging to the family Verbenaceae, is a native of tropical America but now naturalises in India. The essential oils and leaves of *Lantana camara* L. reveals wide spectrum of anti-bacterial and anti-fungal activity (Deena and Thoppil, 2000) [13]. Several tri-terpenoids, naphthoquinones, flavanoides, alkaloids and glycosides isolated from Lantana are known to exert activities which have a great potential for improving the dimensional stability of the wood.

Materials and methods

Sample preparation

The wood samples of size 5cm x 2.5cm x 2.5cm ±0.25cm x 0.15cm x 0.15cm (longitudinal x radial x tangential) were got prepared from air-dried woods of *Pinus roxburghii* Sargent, *Celtis austral is* L., and *Bombax ceiba* L. These samples were properly planed and sanded for smoothness on surface and straight lines were drawn with lead pencil on all the planes for taking dimensions on the same point every time.

Preparation of extract and treatment

The tender twigs of *Lantana camara* L. along with leaves were collected, shade dried and grounded into fine powder. The powdered material was extracted with methanol in soxhlet apparatus on a boiling water bath. After complete extraction, methanol was completely distilled off from the extract and the residue was vacuum dried. Stock solution of 10 per cent concentration was prepared by dissolving the vacuum dried extract in 5 per cent methanol. From the prepared 10 per cent stock solution, different concentrations of 0.25%, 0.5%, 1.00%, 1.50% and 2.00% for dip treatment were prepared. The control was taken as 5% methanol solution (in distilled water). The wood specimens of *Pinus roxburghii* Sargent, *Celtis austral* L., and *Bombax ceiba* L. were dried at 105±2 ^{o}C to constant weights and dipped in the different concentrations (w/v) of *Lantana camara* L. extract solution for 72 hours. The samples meant for control were dipped in 5% methanol solution. The treated samples were then dried at 105±2 ^{o}C to constant weights. These wood samples were analysed for Swelling and shrinkage of wood in three different planes viz., longitudinal, radial and tangential as given by Rowell and Ellis (1978) [13].

Results and Discussion

Swelling: The swelling of wood in longitudinal, radial and tangential plane revealed significant differences among different species. In longitudinal plane (Table 1), the maximum swelling [0.71% (0.84)] was recorded in S_2 (*Pinus roxburghii* Sargent) and minimum [0.42% (0.65)] in S_3 (*Bombax ceiba* L.). Among the treatments, T_4 (1.5% concentration) was observed to be highest [0.66% (0.81)] and T_2 (0.5% concentration) the lowest value [0.53 (0.72) %]. For radial plane (Table 2), the highest swelling was recorded in S_2 (*Pinus roxburghii* Sargent) [5.38% (2.32)] and the lowest in S_1 (*Celtis austral* L.) [3.86% (1.96)]. T_4 (1.5% concentration) with maximum swelling [4.61% (2.14)] and T_1 (0.25% concentration) with minimum [4.15% (2.02)] have been noticed among different treatments. In tangential plane (Table 3), the maximum swelling of 5.96 (2.44) per cent was noticed in *Pinus roxburghii* Sargent and minimum value of 4.46 (2.11) per cent was recorded in *Bombax ceiba* L.

Shrinkage: The shrinkage of wood in longitudinal, radial and tangential plane revealed significant differences for different species and treatments. In longitudinal plane (Table 4), the maximum shrinkage [0.59% (0.76)] was recorded in *Pinus roxburghii* and minimum [0.27% (0.50)] in *Bombax ceiba* L. Among the treatments, highest shrinkage [0.68% (0.82)] was noticed in control and the lowest in T_5 (2% concentration) [0.31% (0.54)]. In radial plane (Table 5), *Pinus roxburghii* Sargent was recorded with maximum shrinkage [4.48% (2.20)] whereas, *Celtis austral is* with the minimum [3.34% (1.82)]. Among the treatments, the highest value [4.48% (2.12)] was observed in control and the lowest [3.75% (1.94)] at 2 per cent concentration. In tangential plane (Table 6), *Pinus roxburghii* showed maximum shrinkage of 5.30 (2.23) per cent while *Bombax ceiba* showed minimum shrinkage of 4.00 (2.00) per cent. Among the treatments, the highest shrinkage [5.82% (2.39)] was recorded in control and the lowest [4.24% (2.04)] in T_4 and T_5 (1.5% and 2% concentrations).

Wood being anisotropic material swells and shrinks upto fibre saturation point to different extent in the three anatomical directions. The wood swells with the absorption of water up to fibre saturation point and shrinks when dried below fibre saturation point. In the present investigation, the swelling of wood in different planes have been observed with significant differences among the different species. This might occur in wood because of the hygroscopic expansion which is dependent on density and vary from species to species due to their varied cellular compositions. The highest swelling and shrinkage has been observed in tangential plane followed by radial plane and longitudinal plane. This is due to parallel orientation of fibres along the axis of cell wall in tangential plane, followed by radial plane, the existence of wood rays having restraining effect or poorer orientation of micro fibrils may be responsible for less shrinkage in radial plane than tangential plane. Usta and Guray (2000) [17] have also reported similar results that swelling in tangential plane (perpendicular to the grain and parallel to the growth rings) is always greater than radial plane(perpendicular to growth rings), and is considered negligible in longitudinal plane (along the grain). Similar findings have been reported by Hiziroglu (2001) [6] who found that the tangential dimensional change had highest rate of change due to parallel orientation of micro fibrils along the axis of the cell wall. Ritter and Mitchell (1952) [11] observed that wood shrinks most in the direction of the annual growth rings (tangentially), somewhat less across these rings (radially), and very little along the grain (longitudinally). Variation of shrinkage in different directions is due to the cellular structure and physical organization of cellulose chain molecules within the cell walls (Llic *et al.*, 2000) [8]. The microfibril angle of S_2 layer is an important factor that affects shrinkage (Okon, 2014) [9]. The mean percentage shrinkage obtained in the tangential direction is more than that in the radial direction. These differences, according to Desch and Dinwoodie (1983) [4] are as a result of the restricting effect of the rays on the radial plane, the difference in the degree of lignification's between the radial and tangential walls, the difference in micro-flibrillar angle between the two walls and the increase in thickness of the middle lamella in the tangential direction in relation to that in the radial direction.

Among the species, the highest swelling and shrinkage has been recorded in *Pinus roxburghii* Sargent in all the three planes. This may be due to the direct relationship between density of wood and shrinkage values. Species with higher density shrink more than those with lower density. All the treatments have shown less swelling and shrinkage in longitudinal and radial planes as compared to control. Dimensional stability can be due to bulking effect (Thunder *et al*, 2001) [16]. The results show that the *Lantana camara* L. extract treatment is proving effective in enhancing the dimensional stability of wood.

Table 1: Effect of treatments on swelling of wood in longitudinal plane (%)

Treatment	Species			
	(S_1) *Celtis australis* L.	**(S_2) *Pinus roxburghii* Sargent**	**(S_3) *Bombax ceiba* L.**	**Mean**
T_1 (0.25%)	0.65 (0.81)	0.63 (0.79)	0.40 (0.63)	0.56 (0.74)
T_2 (0.50%)	0.64 (0.80)	0.60 (0.77)	0.34 (0.58)	0.53 (0.72)
T_3 (1.00%)	0.73 (0.85)	0.61 (0.78)	0.42 (0.65)	0.59 (0.76)
T_4 (1.50%)	0.72 (0.85)	0.85 (0.92)	0.42 (0.65)	0.66 (0.81)
T_5 (2.00%)	0.53 (0.72)	0.75 (0.87)	0.44 (0.67)	0.57 (0.75)
Control	0.57 (0.75)	0.83 (0.91)	0.48 (0.70)	0.63 (0.79)
Mean	0.64 (0.80)	0.71 (0.84)	0.42 (0.65)	

*(Values in parenthesis are square root transformed values)

$CD_{0.05}$

Species (S) : 0.03
Treatments (T) : 0.04
S x T : 0.07

Table 2: Effect of treatments on swelling of wood in radial plane (%)

Treatment	Species			
	(S_1) *Celtis australis* L.	**(S_2) *Pinus roxburghii* Sargent**	**(S_3) *Bombax ceiba* L.**	**Mean**
T_1 (0.25%)	2.93 (1.71)	5.64 (2.37)	3.87 (1.97)	4.15 (2.02)
T_2 (0.50%)	3.54 (1.88)	5.37 (2.32)	3.71 (1.93)	4.21 (2.04)
T_3 (1.00%)	4.18 (2.04)	5.39 (2.32)	4.03 (2.01)	4.53 (2.12)
T_4 (1.50%)	4.12 (2.03)	5.63 (2.37)	4.08 (2.02)	4.61 (2.14)
T_5 (2.00%)	4.05 (2.01)	5.64 (2.37)	3.99 (1.20)	4.56 (2.13)
T_6 (Control)	4.36 (2.08)	4.62 (2.15)	4.20 (2.05)	4.39 (2.09)
Mean	3.86 (1.96)	5.38 (2.32)	3.98(1.99)	

*(Values in parenthesis are square root transformed values)

$CD_{0.05}$

Species (S) : 0.06
Treatments (T) : 0.08
S x T : 0.14

Table 3: Effect of treatments on swelling of wood in tangential plane (%)

Treatment	Species			
	***Celtis australis* L.**	***Pinus roxburghii* Sargent**	***Bombax ceiba* L.**	**Mean**
T_1 (0.25%)	4.81 (2.19)	6.21 (2.49)	4.18 (2.05)	5.07 (2.24)
T_2 (0.50%)	4.57 (2.14)	5.87 (2.42)	4.62 (2.15)	5.02 (2.24)
T_3 (1.00%)	3.61 (1.90)	6.00 (2.44)	4.44 (2.11)	4.68 (2.15)
T_4 (1.50%)	4.31 (2.08)	6.26 (2.50)	4.42 (2.10)	5.00 (2.23)
T_5 (2.00%)	5.10 (2.25)	5.98 (2.45)	4.43 (2.10)	5.17 (2.27)
T_6 (Control)	4.67 (2.16)	5.42 (2.33)	4.70 (2.17)	4.93 (2.22)
Mean	4.51 (2.12)	5.96 (2.44)	4.46 (2.11)	

*(Values in parenthesis are square root transformed values)

$CD_{0.05}$

Species (S) : 0.06
Treatments (T) : NS
S x T : 0.15

Table 4: Effect of treatments on shrinkage of wood in longitudinal plane (%)

Treatment	Species			
	(S_1) *Celtis australis* L.	**(S_2) *Pinus roxburghii* Sargent**	**(S_3) *Bombax ceiba* L.**	**Mean**
T_1 (0.25%)	0.56 (0.75)	0.60 (0.76)	0.23 (0.45)	0.46 (0.66)
T_2 (0.50%)	0.52 (0.72)	0.52 (0.72)	0.19 (0.43)	0.41 (0.62)
T_3 (1.00%)	0.66 (0.81)	0.48 (0.69)	0.31 (0.56)	0.48 (0.68)
T_4 (1.50%)	0.56 (0.75)	0.67 (0.82)	0.15 (0.39)	0.46 (0.65)
T_5 (2.00%)	0.25 (0.50)	0.48 (0.69)	0.19 (0.43)	0.31 (0.54)
T_6 (Control)	0.68 (0.82)	0.81 (0.90)	0.54 (0.74)	0.68 (0.82)
Mean	0.54 (0.73)	0.59 (0.76)	0.27(0.50)	

*(Values in parenthesis are square root transformed values)

$CD_{0.05}$

Species (S) : 0.04
Treatments (T) : 0.06
S x T : 0.11

Table 5: Effect of treatments on shrinkage of wood in radial plane (%)

Treatment	Species			
	(S_1) *Celtis australis* L.	**(S_2) *Pinus roxburghii* Sargent**	**(S_3) *Bombax ceiba* L.**	**Mean**
T_1 (0.25%)	2.69 (1.64)	5.06 (2.25)	3.53 (1.88)	3.76 (1.92)
T_2 (0.50%)	3.13 (1.77)	4.85 (2.20)	3.55 (1.88)	3.84 (1.96)
T_3 (1.00%)	3.30 (1.82)	4.84 (2.20)	3.63 (1.90)	3.92 (1.98)
T_4 (1.50%)	3.33 (1.82)	4.84 (2.20)	3.26 (1.80)	3.81 (1.95)
T_5 (2.00%)	3.34 (1.82)	4.58 (2.14)	3.34 (1.83)	3.75 (1.94)
T_6 (Control)	4.25 (2.06)	4.84 (2.20)	4.37 (2.09)	4.48 (2.12)
Mean	3.34 (1.82)	4.84 (2.20)	3.62(1.90)	

*(Values in parenthesis are square root transformed values)

$CD_{0.05}$

Species (S) : 0.05

Treatments (T) : 0.07

S x T : 0.12

Table 6: Effect of treatments on shrinkage of wood in tangential plane (%)

Treatment	Species			
	(S_1) *Celtis australis* L.	**(S_2) *Pinus roxburghii* Sargent**	**(S_3) *Bombax ceiba* L.**	**Mean**
T_1 (0.25%)	4.36 (2.09)	5.51 (2.35)	3.78 (1.94)	4.55 (2.13)
T_2 (0.50%)	4.18 (2.04)	5.16 (2.27)	4.11 (2.03)	4.48 (2.11)
T_3 (1.00%)	3.86 (1.96)	5.44 (2.33)	4.01 (2.00)	4.44 (2.10)
T_4 (1.50%)	3.89 (1.97)	5.26 (2.29)	3.55 (1.88)	4.24 (2.05)
T_5 (2.00%)	4.31 (2.07)	4.83 (2.20)	3.60 (1.90)	4.24 (2.06)
Control	6.94 (2.63)	5.59 (2.36)	4.94 (2.22)	5.82 (2.39)
Mean	4.59 (2.12)	5.30 (2.23)	4.00 (2.00)	

*(Values in parenthesis are square root transformed values)

$CD_{0.05}$

Species (S) : 0.09

Treatments (T) : 0.13

S x T : 0.22

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