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Effect of Phyto-chemical extracts on dimensional stability of *Pinus roxburghii* Sargent Wood

RK Meena, Bhupender Dutt, Rajneesh Kumar and KR Sharma

Abstract
The present studies were conducted on effect of phyto-chemicals extracts on *Pinus roxburghii* wood dimensional stability. The data on swelling, shrinkage in different planes, and per cent variation for weight were show significant variation. Among the concentrations, Maximum value for swelling in all planes was found for radial plane (5.16%) for concentration (0.25%) and minimum was found in longitudinal plane for 1.50% concentration (0.28) but non significant. Among the extraction maximum swelling in all planes was recorded in redial planes (5.08) for *Parthenium hysterophorus* treated wood sample and minimum was found in longitudinal plane (0.28) for *P. hysterophorus* treated wood sample. Among the solvent used for extraction maximum swelling value (5.05) was recorded for radial plane, the wood samples treated with petroleum ether extract and minimum was observed in the longitudinal planes (0.28) wood samples treated with methanol. Among the concentrations, Maximum value shrinkage in all planes was found for radial plane 4.76 for concentration (0.25%) and minimum was found in longitudinal plane for concentration (0.18). Among the extraction maximum shrinkage in all planes was recorded for tangential planes (4.76) for *P. hysterophorus* treated wood sample and minimum was found in longitudinal plane (0.20) for *Acorus calamus* treated wood sample but non-significant. For the solvent used for extraction maximum shrinkage value (4.72) was recorded for radial plane, the wood samples treated with petroleum ether extract and minimum was observed in the longitudinal planes (0.20) wood samples treated with methanol extract but non-significant. Per cent weight variation in swelling (dry basis) and shrinkage (Wet basis) Among the concentrations, maximum weight value find in swelling (114.47) in 2.00%} concentration but non-significant and minimum was noticed in {Shrinkage 1.00% concentration (48.89)}. Among the extraction maximum value observed {Swelling (113.27)} for *A. calamus* treated wood sample and minimum (Shrinkage) was found in (49.94) for *P. hysterophorus* treated wood sample. For the solvent used for extraction maximum value {Swelling (115.15)} was noticed for swelling, the wood samples treated with methanol extract used and minimum value noticed for {Shrinkage(49.06)} was found wood samples treated with petroleum ether. The study would help to improve the dimensional satiability structure of wood through natural plant extractive without effect the human being health and environmental.

Keywords: Plant extracts, dimensional structure, swelling, shrinkage, solvent

Introduction
Wood is one of the most vital natural resource on earth, and plays an important role in the world economy. Presently, the demand for quality timber and wood based products is very high and is increasing with time. There is heavy pressure on primary timber species like; teak, sheesham, sal, deodar etc. In this context utilization of secondary species play a very important role. The main drawback with these secondary lesser known timber species are their durability during use for different applications. These species are more biodegradable and their dimensional stability is also less. (Uzunovic *et al*., 2008) [13] Wood is porous and hydroscopic material with some weaknesses, such as decay resistance, and swelling by water. The weaknesses can be reduced by modifying the properties of wood by utilizing some substances or methods. Wood is a hygroscopic material and changes dimensions with varying moisture content because cell wall polymers contain hydroxyl and other oxygen containing groups that attracts moisture through hydrogen bonding. Moisture swells, cell wall and wood expands until the cell wall is saturated. It is a reversible process and the wood shrinks with loss of moisture (Stamm, 1964) [10]. Controlled moisture content will reduce the dimensional changes of wood, swelling or shrinkage. Wood shrinks or swells tangentially about half as much as radially, and longitudinally the changes of dimensions are slight (Glass and Zelinka 2010) [2]. Convention methods are used for the improvement of the dimensional structure of wood for these different chemical are used. These chemical are hazards for the human being and environmental point of view, so we have need to develop natural substance for improve the dimensional structure of wood. Therefore, the present investigation finding this study was aimed to investigate through using natural extracts dimensional structure and stable the

dimensional structure of wood through using natural extracts.

Material and Methods

The present investigation was carried out during the years 2014-2017 in the Laboratory of Department of Forest Products, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan (Himachal Pradesh). To study the effect of plant extracts on dimensional stability selected the two plant species viz. *Acorus calamus* L. and *Parthenium hysterophorus* L. The rhizomes of *A. calamus* and aerial parts of *P. hysterophorus* L. were collected from the university campus. For extraction. Two different solvents methanol and petroleum ether were used. The wood samples size, 5cm x 2.5cm x 2.5cm +0.25cm x 0.15cm x 0.15cm (longitudinal x radial x tangential) were used for the investigation. The Six different concentrations ($T_1$0.25%), $T_2$0.50%, T31.00%, $T_4$1.5%, T_5 2.00% T_6 Control) of petroleum ether and methanol extract solutions (w/v) of both species were used for the dip treatment (72 hours), the samples meant for control were dipped in 5 per cent methanol solution prepared with distilled water. After dip treatment, the specimens were first dried in air and then dried at 105$\pm$2ºC to constant weights and measure the different dimensional by employing method. Swelling, shrinkage and per cent weight gain of treated and untreated wood on wet weight basis (Shrinkage) and dry basis (Swelling) were calculated as per the procedure given by Rowell and Ellis (1978) [8]. There were three replicates for every treatment in each species and data were analyzed by using the three factorial complete randomized block design (CRD).

Results and discussion

Swelling of wood: The data obtained for swelling in longitudinal plane is presented in table 1. The significant differences in swelling of wood in longitudinal plane for different solvents for extraction and extract, whereas, different concentration showed non-significant differences at 5 per cent level of significance. Among the plant extract, the maximum swelling (0.36%) was recorded for the *A. calamus* L extract treated wood samples and minimum of (0.28%) was found in *P. hysterophorus* L extracts treated wood samples. Among the solvents for extraction, the maximum swelling of (0.35%) was recorded for the wood samples treated with petroleum ether extract. and the minimum value of (0.29%) samples treated with methanol extract.

The interaction between extracts and concentrations, concentrations and solvents for extraction and extracts and solvents for extraction were found to be statistically significant. Interaction between extracts and concentrations, the maximum value of 0.49 was found in *P. hysterophorus* L. (E_2) extract treated wood samples at concentration (1.00%) and the minimum value of 0.20 was recorded in *P. hysterophorus* L. (E_2) extract treated wood samples at concentration (0.25%). For the interaction between concentrations and solvents for extraction, the highest value of (0.49%) was found at concentration (1.00%) in wood samples treated with petroleum ether (S_2) extract and lowest value of (0.25%) was found at concentration (0.25%) samples treated with petroleum ether (S_2) extract. In case of interaction between plant extracts and solvents for extraction, the highest value of (0.41%) was recorded with *A. calamus* L. in methanol extract (E_1S_1) and minimum value of (0.16%) was observed with *P. hysterophorus* L. in methanol extract (E_2S_1). The second order interactions between concentrations, extracts and solvents for extraction were also found to be significant at 5 per cent level significance. The maximum value of (0.83%) was recorded for $T_3xE_2xS_2$ and minimum value of (0.13%) was found in $T_4xE_2xS_1$.

The data obtained for swelling radial plane presented in table 2 the significant differences in swelling of wood in radial plane for different concentration, solvents for extraction and extract at 5 per cent level of significance. Among the concentrations, the maximum swelling (5.17%) recorded for the concentration (0.25%) and minimum value was (4.45%) noticed for the concentration (1.00%). Among the plant extract, the maximum swelling (5.09%) was recorded for the *P. hysterophorus* L extract treated wood samples and minimum of (4.71%) was found in *A. calamus* L extracts treated wood samples. Among the solvents, the maximum swelling of (5.05%) was recorded for the wood samples treated with petroleum ether (S_2) extract and minimum value of (4.74%) samples treated with methanol (S_1) extract.

The interaction between extracts and concentrations, extracts and solvents for extraction were also found to be statistically significant. Among the interaction between extracts and concentrations, the maximum value of (5.69%) was found in *P. hysterophorus* L. (E_2) extract treated wood samples at concentration (0.50%) and the minimum value of (4.20%) was recorded in *A. calamus* L. (E_1) extract treated wood samples at concentration (0.50%). In case of interaction between plant extracts and solvents for extraction, the highest value of (5.35%) was recorded with *P. hysterophorus* L. in methanol extract (E_2S_1) and minimum value of (4.14%) was observed with *A. calamus* L. in methanol extract (E_2S_1).

The data obtained for swelling tangential plane presented in table 3 the significant differences in swelling of wood in tangential plane for different concentrations, solvents for extraction and extract at 5 per cent level of significance. Among the concentration, the maximum swelling (5.07%) recorded for the concentration (0.25%) and minimum swelling was (4.41%) noticed for the concentration (2.00%) Among the plant extract, the maximum swelling (4.88%) was recorded for the *P. hysterophorus* L. extract treated wood samples and minimum of (4.50%) was found in *A. calamus* L. extracts treated wood samples. Among the solvents, the maximum swelling of (4.95%) was recorded for the wood samples treated with petroleum ether (S_2) extracts and minimum value of (4.43%) wood samples treated with methanol (S_1).

The interaction between extracts and concentrations and extracts and solvents for extraction were found to be statistically significant. For the interaction between extracts and concentrations, the maximum value of (5.23%) was found in *P. hysterophorus* L. (E_2) extract treated wood samples at concentration (0.25%) and the minimum value of (3.86%) was recorded in *A. calamus* L. (E_1) extract treated wood samples at concentration (0.50%).

In case of interaction between plant extracts and solvents for extraction, the highest value of (5.06%) was recorded with *A. calamus* L. in petroleum ether extract (E_1S_2) and minimum value of (3.93%) was observed with *A. calamus* L. in methanol extract (E_1S_1).

The highest swelling has been observed in radial plane followed by tangential plane and longitudinal plane. Usta and Guray (2000) [12] have also reported similar results that swelling in tangential plane and Hiziroglu (2001) [3] also found that tangential dimensional change had highest rate of change due to parallel orientation of microfibrils along the axis of the cell wall. Temiz *et al.*, 2013 [11] in case of tangential swelling which was found to be less in case of

treated samples as compared to the control.

Shrinkage of wood: The data obtained for shrinkage longitudinal plane presented in table 4. The data showed non-significant differences in shrinkage of wood in longitudinal plane for different concentration, solvents for extraction and extract.

The interaction between extracts and concentrations, concentrations and solvents for extraction and extracts and solvents for extraction were found to be statistically significant. For the interaction between extracts and concentrations, the maximum value of (0.29%) *A. calamus* L (E_1) extract treated wood sample at concentration (0.50%). and the minimum value of (0.16) was recorded in *P. hysterophorus* L. (E_2) extract treated wood samples at concentration (0.50%). For the interaction between concentrations and solvents for extraction, the highest value of (0.26%) was found at concentration (0.50%) in wood samples treated with methanol (S_1) extract and minimum value of (0.15%) was found at concentration (1.50%) in wood samples treated with methanol (S_1) extract. In case of interaction between plant extracts and solvents for extraction, the highest value of (0.24%) was recorded with *P. hysterophorus* L. in petroleum ether extract (E_2S_2) and minimum value of (0.18%) was observed with *P. hysterophorus* L. in methanol extract (E_2S_1) The second order interactions between concentrations, extracts and solvents for extraction were also found to be significant at 5 per cent level significance. The maximum value of (0.40%) was recorded for $T_2xE_1xS_{1.}$ and minimum value of (0.12%) was found in $T5xE_1xS_{1.}$

The data obtained for shrinkage radial plane presented in table 5. All the data were find significant differences in shrinkage of wood in radial plane for different concentration, solvents for extraction and extract. Among the maximum value for concentration is recorded for the concentration 0.25% (4.80%) and minimum shrinkage was found in concentration 2.00 % (4.02%). Among the plant extracts, maximum shrinkage (4.63%) was found in *P. hysterophorus* L. treated wood samples and minimum value (4.35%) was recorded in *A. calamus* L treated wood samples. Among the solvent use for extraction, maximum value of (4.72%) was found for wood samples treated with petroleum ether (S2) extract and minimum value (4.26%) was observed for wood samples treated with methanol (S1) extract.

The interaction between extracts and concentrations, and extracts and solvents for extraction were found to statistically significant. For the interaction between extracts and concentrations, the maximum value of (5.19%) *P. hysterophorus* L(E_2) extract treated wood sample at concentration (0.25%). and the minimum value of (3.92%) was recorded in *A. calamus* L. (E_2) extract treated wood samples at concentration (2.00%).

In case of interaction between plant extracts and solvents for extraction, the highest value of (5.18%) was recorded with *A. calamus* L. in petroleum ether extract (E_1S_2) and minimum value of (3.53%) was observed with *A. calamus* L. in methanol extract (E_1S_1).

The data obtained for shrinkage in tangential plane presented in table 6. All the data were significant differences in shrinkage of wood in tangential plane for different concentrations, solvents for extraction and extract. Among the maximum value for concentration is recorded for the concentration 0.25% (4.71) and minimum shrinkage was found in concentration 2.00% (3.85%). Among the plant extracts, maximum shrinkage (4.76%) was found in *P. hysterophorus* L. treated wood samples and minimum value (4.04%) was recorded in *A. calamus* L. treated wood samples. Among the solvent use for extraction, maximum value of (4.70%) was found for wood samples treated with petroleum ether (S2) extract and minimum value (4.09%) was observed for wood samples treated with methanol (S1) extract.

Interaction between plant extracts and solvents for extraction, the highest value of (5.09%) was recorded with *P. hysterophorus* L. in methanol extract (E_2S_1) and minimum value of (3.10%) was observed with *A. calamus* L. in methanol extract (E_1S_1). The shrinkage of wood starts when the wood is dried below fibre saturation point. (Usta and Guray, 2000) [12]. Shrinkage in longitudinal plane is negligible or is very less as compared to radial and tangential planes. 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) [5]. The microfibril angle of S_2 layer is an important factor that affects shrinkage (Okkon, 2014) [6]. The differences, in shrinkage radial and tangential planes according to Desch and Dinwoodie (1983) [1] are as a result of the restricting effect of the rays on the radial plane, the difference in the degree of lignifications 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. According to Josue (2004) [4], the difference between the longitudinal, radial and tangential shrinkage is due to the alignment of wood cells.

Per cent variation in weight of treated and untreated wood: The data obtained for per cent variation in weight of wood on dry basis (Swelling) presented in table 7. The data fined the significant differences at 5 per cent level of significance in per cent variation for different solvents for extraction and solvent used for extraction, where as data for concentration showed non-significant. Among the plant extract, the maximum value for the (113.27%) was recorded for the *A. calamus* L. extract treated wood samples and minimum value (100.51%) was found in *P. hysterophorus* L. extracts treated wood samples. Among the solvents, the maximum value (115.15%) was recorded for the wood samples treated with methanol (S_1) extract. and the minimum value of (98.63%) samples treated with petroleum ether (S_2) extract.

The interaction between extracts and concentrations, concentrations and solvents for extraction and extracts and solvents for extraction were also found to be statistically significant. For the interaction between extracts and concentrations, the maximum value of (117.87%) was found in *A. calamus* L. (E_1) extract treated wood samples at concentration (2.00%) and the minimum value of (82.27%) was recorded in *P. hysterophorus* L. (E_2) extract treated wood samples at concentration (1.00%). For the interaction between concentrations and solvents for extraction, the highest value of (125.18%) was found at concentration (2.00%) in wood samples treated with methanol (S_1) extract. and lowest value of (78.97%) was found at concentration (1.00%) where petroleum ether (S_2) extract. Among the interaction between plant extracts and solvents for extraction, the highest value of (117.28%) was recorded with *A. calamus* L. in methanol extract (E_1S_1) and minimum value of (87.99%) was observed with *P. hysterophorus* L. in petroleum ether extract (E_2S_2). The second order interactions between concentrations,

extracts and solvents for extraction were also found to be significant at 5 per cent level significance. The maximum value of (128.83) was recorded for $T_5xE_1xS_1$ and minimum value of (47.57) was found in $T_3xE_2xS_2$.

The data obtained for per cent variation in weight of wood on wet basis (Shrinkage) presented in table 8. The data showed significant differences at 5 per cent level of significance in per cent variation for different solvents for concentration, extraction and solvent used for extraction. Among the concentration, the maximum value (52.90%) concentration (0.25%) and minimum was recorded for the concentration 1.00% (48.89%). Among the plant extract, the maximum value for the (53.20%) was recorded for the *A. calamus* L extract treated wood samples and minimum value (49.94%) was found in *P. hysterophorus* L extracts treated wood samples. Among the solvents, the maximum value (54.08%) was recorded for the wood samples treated with, methanol (S_1) extracts, and the minimum value of (49.06%) wood samples treated with petroleum ether (S_2) extract.

The interaction between extracts and concentrations, concentrations and solvents for extraction and extracts and solvents for extraction were also found to be statistically significant. For the interaction between extracts and concentrations, the maximum value of (53.90%) was found in *A. calamus* L. (E_1) extract treated wood samples at concentration (0.25%) and the minimum value of (44.20%) was recorded in *P. hysterophorus* L. (E_2) extract treated wood samples at concentration (1.00%). For the interaction between concentrations and solvents for extraction, the highest value of (55.29%) was found at concentration (2.00%) in wood samples treated with methanol (S_1) extracts. and lowest value of (43.08%) was found at concentration (1.00%) where petroleum ether (S_2) extract used for treatment. For the interaction between plant extracts and solvents for extraction, the highest value of (54.40%) was recorded with *A. calamus* L. in methanol extract (E_1S_1) and minimum value of (46.12%) was observed with *P. hysterophorus* L. in petroleum ether extract (E_2S_2). The second order interactions between concentrations, extracts and solvents for extraction were also found to be significant at 5 per cent level significance. The maximum value of (56.02%) was recorded for $T_1xE_1xS_1$ and minimum value of (33.67%) was found in $T_3xE_2xS_2$. One of the most important factors affecting the changes in wood properties is weight gain. The treated samples have shown higher weight gain as compared to untreated samples. Petr and Ales (2014) [7] have proved a close relationship between the concentration of the impregnation solution and the reached values of weight percentage gain (WPG) where the samples treated with sucrose have shown higher WPG as compared to untreated samples. Shi *et al*., 2013 [9] have shown similar results where the wood samples modified with 2 per cent alkyl ketene dimer (AKD) have lower weight gain than that of 5 per cent AKD modified samples. The treated samples have shown less shrinkage in weight as compared to the untreated samples and exhibit a decreasing trend with the increase in concentrations of plant extracts.

Table 1: Effect of treatments on swelling of *Pinus roxburghii* Sargent wood in longitudinal plane (%)

Concentrations (T)	Plant extracts (E)						Solvents for extraction (S)		Mean
	Acorus calamus L.(E_1)			*Parthenium hysterophorus* L. (E_2)					
	Methanol (S_1)	Petroleum ether (S_2)	Mean	Methanol (S_1)	Petroleum ether (S_2)	Mean	Methanol (S_1)	Petroleum ether (S_2)	
T_1 (0.25%)	0.55	0.27	0.41	0.17	0.23	0.20	0.36	0.25	0.30
T_2 (0.50%)	0.32	0.54	0.43	0.18	0.23	0.20	0.25	0.38	0.32
T_3 (1.00%)	0.36	0.14	0.25	0.15	0.83	0.49	0.26	0.49	0.37
T_4 (1.50%)	0.40	0.18	0.29	0.13	0.42	0.27	0.27	0.30	0.28
T_5 (2.00%)	0.32	0.37	0.34	0.17	0.42	0.30	0.25	0.39	0.32
T_6(Control)	0.51	0.33	0.42	0.17	0.31	0.24	0.34	0.32	0.33
Mean	0.41	0.30	0.36	0.16	0.40	0.28	0.29	0.35	

CD $_{0.05}$

Concentration (T)	NS
Extract (E)	0.06
Solvent (S)	0.06
T*E	0.16
T*S	0.16
E*S	0.09
T*E*S	0.22

Table 2: Effect of treatments on swelling of *Pinus roxburghii* Sargent wood in radial plane (%)

Concentrations (T)	Plant extracts (E)						Solvents for extraction (S)		Mean
	Acorus calamus L.(E_1)			*Parthenium hysterophorus* L. (E_2)					
	Methanol (S_1)	Petroleum ether (S_2)	Mean	Methanol (S_1)	Petroleum ether (S_2)	Mean	Methanol (S_1)	Petroleum ether (S_2)	
T_1 (0.25%)	4.79	5.48	5.14	5.02	5.37	5.19	4.91	5.43	5.17
T_2 (0.50%)	3.65	4.75	4.20	5.78	5.60	5.69	4.72	5.17	4.94
T_3 (1.00%)	4.04	5.00	4.52	4.98	3.76	4.37	4.51	4.38	4.45
T_4 (1.50%)	4.44	5.60	5.02	5.97	4.55	5.26	5.20	5.07	5.14
T_5 (2.00%)	3.79	4.76	4.27	5.40	4.77	5.09	4.59	4.77	4.68
T_6(Control)	4.12	6.06	5.09	4.95	4.89	4.92	4.54	5.47	5.01
Mean	4.14	5.28	4.71	5.35	4.82	5.09	4.74	5.05	

CD $_{0.05}$

Concentration	(T) 0.50
Extract (E)	0.29
Solvent (S)	0.29

T*E	0.71
T*S	NS
E*S	0.41
T*E*S	NS

Table 3: Effect of treatments on swelling of *Pinus roxburghii* Sargent wood in tangential plane (%)

Concentrations (T)	Plant extracts (E)						Solvents for extraction (S)		Mean
	Acorus calamus L.(E_1)			*Parthenium hysterophorus* L. (E_2)					
	Methanol (S_1)	Petroleum ether (S_2)	Mean	Methanol (S_1)	Petroleum ether (S_2)	Mean	Methanol (S_1)	Petroleum ether (S_2)	
T_1 (0.25%)	4.38	5.43	4.90	4.88	5.58	5.23	4.63	5.50	5.07
T_2 (0.50%)	3.05	4.68	3.86	5.21	4.81	5.01	4.13	4.74	4.44
T_3 (1.00%)	4.09	5.98	5.03	4.16	3.81	3.98	4.12	4.89	4.51
T_4 (1.50%)	3.94	5.02	4.48	5.08	5.08	5.08	4.51	5.05	4.78
T_5 (2.00%)	3.87	3.89	3.88	5.17	4.71	4.94	4.52	4.30	4.41
T_6(Control)	4.27	5.39	4.83	5.08	5.01	5.04	4.68	5.20	4.94
Mean	3.93	5.06	4.50	4.93	4.83	4.88	4.43	4.95	

CD $_{0.05}$

Concentration (T)	0.49
Extract (E)	0.28
Solvent (S)	0.28
T*E	0.69
T*S	NS
E*S	0.40
T*E*S	NS

Table 4: Effect of treatments on shrinkage of *Pinus roxburghii* Sargent wood in longitudinal plane (%)

Concentrations (T)	Plant extracts (E)						Solvents for extraction (S)		Mean
	Acorus calamus L.(E_1)			*Parthenium hysterophorus* L. (E_2)					
	Methanol (S_1)	Petroleum ether (S_2)	Mean	Methanol (S_1)	Petroleum ether (S_2)	Mean	Methanol (S_1)	Petroleum ether (S_2)	
T_1 (0.25%)	0.16	0.16	0.16	0.20	0.17	0.19	0.18	0.17	0.18
T_2 (0.50%)	0.40	0.19	0.29	0.13	0.18	0.16	0.26	0.19	0.23
T_3 (1.00%)	0.24	0.16	0.20	0.12	0.34	0.23	0.18	0.25	0.21
T_4 (1.50%)	0.12	0.24	0.18	0.17	0.26	0.22	0.15	0.25	0.20
T_5 (2.00%)	0.12	0.20	0.16	0.20	0.30	0.25	0.16	0.25	0.20
T_6(Control)	0.25	0.17	0.21	0.26	0.20	0.23	0.26	0.18	0.22
Mean	0.22	0.19	0.20	0.18	0.24	0.21	0.20	0.21	

CD $_{0.05}$

Concentration (T)	NS
Extract (E)	NS
Solvent (S)	NS
T*E	0.08
T*S	0.08
E*S	0.05
T*E*S	0.12

Table 5: Effect of treatments on shrinkage of *Pinus roxburghii* Sargent wood in radial plane (%)

Concentrations (T)	Plant extracts (E)						Solvents for extraction (S)		Mean
	Acorus calamus L.(E_1)			*Parthenium hysterophorus* L. (E_2)					
	Methanol (S_1)	Petroleum ether (S_2)	Mean	Methanol (S_1)	Petroleum ether (S_2)	Mean	Methanol (S_1)	Petroleum ether (S_2)	
T_1 (0.25%)	3.56	5.14	4.35	5.04	5.34	5.19	4.30	5.24	4.77
T_2 (0.50%)	3.42	4.98	4.20	5.27	5.07	5.17	4.34	5.02	4.68
T_3 (1.00%)	3.34	4.86	4.10	5.16	3.30	4.23	4.25	4.08	4.17
T_4 (1.50%)	3.90	5.88	4.89	5.51	3.91	4.71	4.70	4.90	4.80
T_5 (2.00%)	3.35	4.48	3.92	4.29	3.95	4.12	3.82	4.21	4.02
T_6(Control)	3.64	5.72	4.68	4.77	4.05	4.41	4.20	4.88	4.54
Mean	3.53	5.18	4.36	5.00	4.27	4.64	4.27	4.72	

CD $_{0.05}$

Concentration (T)	0.47
Extract (E)	0.27
Solvent (S)	0.27
T*E	0.67
T*S	NS
E*S	0.38
T*E*S	NS

Table 6: Effect of treatments on shrinkage of *Pinus roxburghii* Sargent wood in tangential plane (%)

Concentrations (T)	Plant extracts (E)						Solvents for extraction (S)		Mean
	Acorus calamus L.(E_1)			*Parthenium hysterophorus* L. (E_2)			Methanol (S_1)	Petroleum ether (S_2)	
	Methanol (S_1)	Petroleum ether (S_2)	Mean	Methanol (S_1)	Petroleum ether (S_2)	Mean			
T_1 (0.25%)	4.07	5.28	4.68	4.59	4.88	4.74	4.33	5.08	4.71
T_2 (0.50%)	2.99	4.51	3.75	5.12	4.51	4.81	4.05	4.51	4.28
T_3 (1.00%)	3.23	5.44	4.34	5.35	4.09	4.72	4.29	4.77	4.53
T_4 (1.50%)	3.04	4.99	4.01	5.12	4.50	4.81	4.08	4.74	4.41
T_5 (2.00%)	2.37	3.87	3.12	5.06	4.11	4.58	3.72	3.99	3.85
T_6(Control)	2.88	5.76	4.32	5.31	4.47	4.89	4.09	5.11	4.60
Mean	3.10	4.98	4.04	5.09	4.42	4.76	4.09	4.70	

$CD_{0.05}$

Concentration (T)	0.55
Extract (E)	0.32
Solvent (S)	0.32
T*E	NS
T*S	NS
E*S	0.45
T*E*S	NS

Table 7: Per cent variation in weight of treated and untreated *Pinus roxburghii* Sargent wood on dry weight basis (Swelling)

Concentrations (T)	Plant extracts (E)						Solvents for extraction (S)		Mean
	Acorus calamus L.(E_1)			*Parthenium hysterophorus* L. (E_2)			Methanol (S_1)	Petroleum ether (S_2)	
	Methanol (S_1)	Petroleum ether (S_2)	Mean	Methanol (S_1)	Petroleum ether (S_2)	Mean			
T_1 (0.25%)	109.98	108.57	109.28	108.06	104.08	106.07	109.02	106.33	107.67
T_2 (0.50%)	113.54	100.80	107.17	106.22	118.27	112.24	109.88	109.53	109.71
T_3 (1.00%)	121.94	110.38	116.16	116.96	47.57	82.27	119.45	78.98	99.21
T_4 (1.50%)	112.82	122.00	117.41	115.20	78.33	96.76	114.01	100.16	107.09
T_5 (2.00%)	128.83	106.90	117.87	121.54	100.60	111.07	125.18	103.75	114.47
T_6(Control)	116.60	106.91	111.76	110.15	79.08	94.62	113.38	93.00	103.19
Mean	117.28	109.26	113.27	113.02	87.99	100.51	115.15	98.63	

$CD_{0.05}$

Concentration (T)	NS
Extract (E)	7.15
Solvent (S)	7.15
T*E	17.51
T*S	17.51
E*S	10.11
T*E*S	24.76

Table 8: Per cent variation in weight of treated and untreated *Pinus roxburghii* Sargent wood on wet weight basis (Shrinkage)

Concentrations (T)	Plant extracts (E)						Solvents for extraction (S)		Mean
	Acorus calamus L.(E_1)			*Parthenium hysterophorus* L. (E_2)			Methanol (S_1)	Petroleum ether (S_2)	
	Methanol (S_1)	Petroleum ether (S_2)	Mean	Methanol (S_1)	Petroleum ether (S_2)	Mean			
T_1 (0.25%)	56.02	51.78	53.90	52.72	50.81	51.77	54.37	51.30	52.83
T_2 (0.50%)	54.67	50.05	52.36	52.53	54.06	53.29	53.60	52.06	52.83
T_3 (1.00%)	54.70	52.48	53.59	54.73	33.67	44.20	54.71	43.08	48.89
T_4 (1.50%)	52.63	54.60	53.61	53.98	43.94	48.96	53.30	49.27	51.29
T_5 (2.00%)	55.51	51.28	53.39	55.06	49.74	52.40	55.29	50.51	52.90
T_6(Control)	52.85	51.87	52.36	53.59	44.47	49.03	53.22	48.17	50.70
Mean	54.40	52.01	53.20	53.77	46.12	49.94	54.08	49.06	

$CD_{0.05}$

Concentration (T)	2.88
Extract (E)	1.66
Solvent (S)	1.66
T*E	4.08
T*S	4.08
E*S	2.35
T*E*S	5.77

Conclusion

Wood being anisotropic material swells and shrinks upto fibre saturation point to different extent in the three anatomical directions. *viz.*, longitudinal (critical direction), radial

(perpendicular to the annual growth rings) and tangential (parallel to annual growth rings). The highest swelling has been observed in. radial plane followed by tangential plane and longitudinal plane. The shrinkage of wood starts when the wood is dried below fibre saturation point. The highest shrinkage noticed in the radial pale and followed by tangential and longitudinal planes. The maximum per cent weight variation noticed in wood on dry swelling and followed by Shrinkage.

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