STUDIES ON EFFECT OF *Acorus calamus* L. EXTRACT ON WOOD CHARACTERSTICS OF *Morus alba* L.

Thesis

by

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This is to certify that the thesis entitled, **"Studies on effect of *Acorus calamus* L. extract on wood characterstics of *Morus alba* L."** submitted in partial fulfillment of the requirements for the award of degree of **Master of Science** in the discipline of **(Forestry) Forest Products and Utilization** of Dr Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP)-173 230 is a bonafide research work carried out by **Ms. Shweta Rajpoot (F-2021-69-M)** daughter of Shri Sanjeev kumar under my supervision and no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigation have been fully acknowledged.

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CERTIFICATE - II

This is to certify that the thesis titled, **"Studies on effect of *Acorus calamus* L. extract on wood characteristics of *Morus alba* L."** submitted by **Ms. Shweta Rajpoot (F-2021-69-M)** daughter of Shri Sanjeev Kumar to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP)-173230 India in partial fulfillment of the requirements for the degree of **Master of Science (Forestry) Forest Products & Utilization** has been approved by the Student's Advisory Committee after Thesis Viva Voce examination of the student in collaboration with an External Examiner.

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LIST OF ABBREVIATIONS

%	:	Per cent
&	:	And
etc	:	Et cetera
°C	:	Degree centigrade
ANOVA	:	Analysis of Variance
CCA	:	Creosote chromium acetate
CD	:	Critical difference
cm	:	Centimeter
CRD	:	Completely Randomized Design
CV	:	Co-efficient of variation
df	:	Degree of freedom
et al.	:	And others
FAO	:	Food agriculture and organisation
FPL	:	Forest Product Laboratory
g	:	Gram
GS	:	Average density of wood substance
H.P	:	Himachal Pradesh
i.e.	:	That is
kg/cm^2	:	Kilogram per centimeter square
kN/mm^2	:	Kilo newton per millimeter square
mg	:	Milligram
ml	:	Milliliter
mm	:	Millimeter
MMC	:	Maximum moisture content
MOE	:	Modulus of elasticity
MOR	:	Modulus of rupture
MPa	:	Milli pascal
Nmm^{-2}	:	Newton per millimeter square
SG	:	Specific gravity
sp.	:	Species
TAPPI	:	Technical Association of Pulp and Paper Industry
v/v	:	Volume per volume
w/v	:	Weight per volume

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Chapter-1

INTRODUCTION

Wood is regarded as the most significant, versatile and natural resource on earth which has been an essential resource for human civilizations throughout history, serving various purposes due to its unique properties. According to state of world's forest report 2022, the area of other woody land was predicted to be 977 million hectares, accounting for 7 per cent of total land area (and around one-quarter of total forest area) whereas forest provide subsistence, livelihoods, employment, and income to an estimated 1.6 billion people, or 25 per cent of the global population (FAO, 2022). It has evolved over time from a simple, readily available substance to a complex industrial and engineering substance with a high capacity to enrich human lives as a material for use. To ensure the availability of this vital resource for future generations, responsible wood sourcing and sustainable forest management are required (FPL, 2021).

Wood is a prominent building material which is renewable, biodegradable and sustainable nature. It is an anisotropic, porous, hygroscopic, non-homogeneous, fibrous biopolymer with a cellular structure which composed of spindle-shaped hollow cells that are positioned roughly parallel to one another along the longitudinal axis (Meena, 2017). Anatomically, wood is secondary xylem whereas it is chemically composed of cellulose (45%), hemicelluloses (25%), lignin (25%) and extractives in a three-dimensional matrix. These components give wood its strength, flexibility, and durability. It is made up of cell wall polymers which having free hydroxyl and other oxygen-containing groups that attract moisture via hydrogen bonding. Wood changes size with moisture content as it causes the cell wall to swell and wood to expand until the cell wall is saturated. The process is reversible, and wood shrinks when moisture is below the fibre saturation point. Due to its hygroscopicity the wood gets prone to decay and dimensional instability which is liable readily to be degraded by bacteria, fungi and termites (Schultz and Nicholas, 2002).

There is high demand for high-quality timber and wood-based goods. Due to increased demand for timber, forests are under enormous strain, resulting in a shortage of wood and other woody goods. To address this rising demand, efficient usage of timber species is important. Primary timber species such as teak, sal, oak, douglas fir, pine and

deodar etc are under severe pressure, and are costly. Since the scarcity of durable species and non-durable species which are more sensitive to degradation and dimensional instability. As a result, for better and more efficient utilisation, wood and wood products must be protected during manufacturing, storage, transit, and servicing (Uzunovic *et al*., 2008).

Morus alba L. commonly known as white mulberry belongs to the family Moraceae, is found upto an altitude of 1200 m. It is a deciduous, medium sized tree which grows upto a height of 10 to 20 m. It is native to Central and Eastern China. In India, it is naturally thrives in the states of Jammu & Kashmir, Himachal Pradesh and Punjab. It is cultivated in Uttar Pradesh, Assam, Manipur, West Bengal, Madhya Pradesh, Andhra Pradesh, Kerala, Tamil Nadu, Karnataka etc. In Himachal Pradesh, it is distributed in Una, Kangra, Hamirpur, Mandi, Bilaspur, Solan.

The wood of *Morus alba* L. is light to moderately heavy, straight or interlocked grained having white to yellowish-white colored sapwood and golden brown heartwood which is mainly used in manufacturing of sports goods, woodcrafts, furniture, agricultural implements and musical instruments because of its properties like elasticity, flexibility etc. The wood's aesthetic appeal and workability make it suitable for both indoor and outdoor applications. Its bark is also used for tannery purposes, while the leaves are used for rearing silkworm and cattle fodder (Chen, 2021). Under extreme weather conditions such as heat, cold, wet, and dry temperatures, the wood deteriorates more rapidly due to biological, chemical, and physical processes which reducing dimensional stability, decay resistance, and durability. In order to improve its longevity, dimensional stability and utilization the wood can be treated using a variety of processes such as impregnation, thermal modification and chemical treatments. Wood preservation is regarded as the most preferred and effective method for enhancing the service-life, dimensional stability, durability for wood which are susceptible to decay resistance. Since 1950, people all around the world have used synthetic/inorganic preservative creosote, copper chromium arsenate (CCA) which acts best against fungi, insects, borers etc. However, these treatments can induce biological assault, mechanical wear and tear, chemical and weathering deterioration of wood, and also causing environmental hazards with negatively affecting human health. To overcome this problem biopreservation is one of the best substitute i.e. non-toxic and environmental friendly plant based extracts.

Biopreservation is a technique used to protect wood from biological deterioration caused by microorganisms like fungi and insects without harming the environment and the human health. The primary goal of biopreservation is to extend the lifespan and durability of wood besides providing dimensional stability. Dimensional stability in wood refers to the wood's ability to maintain its original size and shape despite changes in moisture content, temperature, and environmental conditions. Wood preservation modifies the physical, chemical, and mechanical properties of wood while enhancing the service-life as well as dimensional stability. This method should be carefully chosen based on the specific wood species, desired level of protection, and environmental considerations.

Acorus calamus L. commonly known as sweet flag, is a tall perennial wetland monocot plant belongs to the family Acoraceae. It is native to India while widespread in Europe, Southern Russia, Northern Asia Minor, China, Japan, Burma, Sri Lanka, and the Northern United States (Balakumbahan *et al*., 2010). In India, this species is found predominantly in himalayan and sub-himalayan regions. This resilient plant thrives in tropical and subtropical regions. The ideal climate has yearly precipitation between 70 and 250 cm and temperatures between 10 and 38°C. This species thrives on light alluvial soils along riverbanks, including clayey loams, sandy loams, and loams. It contains several bioactive compounds, including volatile oils, flavonoids, tannin, sesquiterpenes, phenolic compounds, and alkaloids (Saxena and Saxena, 2012). The plant's rhizomes have long been employed in Ayurveda, Unani, Siddha, and Chinese medicine to cure a range of illnesses, including epilepsy, neurological disorders, bronchitis, kidney, liver, skin, and rheumatic problems (Joshi, 2016). This plant contains a variety of chemical compound, including α-pinene and ß-pinene, camphene, linalool, camphor, methyleugenol, (E)-methylisoeugenol, cuparene, α-terpineol, copaene, estragole, 1,8-cineol, α-funebrene, α-cedrene, α-bulnesene, α-gurjunene, α-caryophyllene, ß-caryophyllene, α-cadinol, α-bisabolol, acorenone, germacerene D, germacerene B, ß-calacorene etc (Liu *et al*. 2013). According to Li and Wah, (2017); Joshi and Bhashyal, (2018) the primary constituents found in *Acorus calamus* L. are α and ß-asarone which contribute to antioxidant, antibacterial, fungicidal, and insecticidal activities.

In order to enhance the shelf-life and dimensional stability and taking into consideration the scope and applicability of *Morus alba* L. for better utilization, the present work entitled **"Studies on effect of *Acorus calamus* L. extract on wood characteristics of *Morus alba* L."** has been carried out with following objective:

Objective

- To study the physico-chemical and mechanical properties of *Morus alba* L. wood treated with *Acorus calamus* L. extract

Chapter-2

REVIEW OF LITERATURE

In recent years, the wood preservation has prioritised plant-based extracts. These plant-based extracts could serve as eco-friendly bio-preservatives because they have anti-decaying properties that boost the durability of wood and also helps to achieve dimensional stability. The accessible and related research work done earlier related to "Studies on effect of *Acorus calamus* L. extract on wood characteristics of *Morus alba* L." is reviewed under the following headings.

2.1 Physical properties

2.2 Chemical properties

2.3 Mechanical properties

2.4 Wood preservation

2.1 PHYSICAL PROPERTIES

Color, odour, density, shrinkage, swelling, specific gravity, moisture content, and weight are all physical properties of wood that can be easily observed and measured without affecting the chemical nature of the wood. Physical properties of wood are the quantitative characteristics of wood and it has a considerable impact on the performance and strength of wood.

Chauhan *et al*. (2001) evaluated the variation in specific gravity in 18 clones of 10-year old *Populus deltoides* trees from experimental plantations in Uttrakhand, India and recorded that the specific gravity was greatest at 50 per cent of tree height, showing decreasing trend upward.

Sharma *et al*. (2006) examined the relationship of specific gravity and shrinkage (radial, tangential, volumetric, and longitudinal) with moisture content of a seven-year-old *Simarouba glauca* plantation and found that shrinkage decreased as moisture content increased while specific gravity showed inverse relation with moisture content.

Raj *et al*. (2010) evaluated the physical properties of *Pinus roxburghii* Sargent and found maximum specific gravity 0.433 before than 0.425 after the removal of extractives

from wood whereas extractive content averaged 86.25 per cent of oven-dry weight and 2.00 per cent of extractive-free oven-dry weight.

Gupta, (2012) investigated the effect of *Lantana camara* L. extract using methanol as a solvent on the physical properties of *Celtis australis* L., *Pinus roxburghii* Sargent and *Bombax ceiba* L. wood and found the highest specific gravity (0.573) recorded in *Celtis australis* L. wood at 2 per cent extract concentration and the lowest (0.415) in *Bombax ceiba* L. untreated wood samples. The maximum volumetric swelling co-efficient (12.46%) at 1.5 per cent extract concentration and volumetric shrinkage co-efficient (10.40%) at 2 per cent extract concentration was observed in *Pinus roxburghii* Sargent wood whereas minimum volumetric swelling co-efficient (9.08%) at 0.25 per cent extract concentration and volumetric shrinkage co-efficient (7.72%) at 1.5 per cent extract concentration had in *Bombax ceiba* L. wood.

Chauhan, (2013) observed the effect of *Melia azedarach* L. fruit extract using methanol as a solvent on *Celtis australis* L., *Bombax ceiba* L. and *Pinus roxburghii* Sargent wood and reported that the maximum specific gravity (0.570) had in *Celtis australis* L. wood at 2 per cent extract concentration while minimum (0.420) in *Bombax ceiba* L. untreated wood sample, whereas the highest value (12.37%) for volumetric swelling co-efficient and volumetric shrinkage co-efficient (12.24%) was observed in untreated wood samples of *Pinus roxburghii Sargent* while the lowest value for volumetric swelling co-efficient (8.60%) and volumetric shrinkage co-efficient (7.89%) was recorded in *Bombax ceiba* L. wood at 2 per cent extract concentration.

Devi, (2013) studied effect of *Azeratum conyzoides* L. extract using methanol as a solvent on the physical properties of *Pinus roxburghii* L., *Celtis australis* L., and *Bombax ceiba* L. and recorded the highest specific gravity in *Pinus roxburghii* L. wood (0.516) at 2 per cent extract concentration and minimum in *Bombax ceiba* L. (0.500) untreated wood samples, whereas the maximum value for volumetric swelling co-efficient (9.07%) and volumetric shrinkage co-efficient (8.43%) was recorded in *Pinus roxburghii* L. for untreated wood sample while minimum value for volumetric shrinkage co-efficient (7.62%) and volumetric swelling co-efficient (8.42%) was observed in *Celtis australis* L. wood at 2 per cent extract concentration.

Kumar, (2013) studied the effect of *Parthenium hysterophorus* L. extract using methanol as a solvent on the physical properties of *Bombax ceiba* L., *Pinus roxburghii* Sargent and *Celtis australis* L. wood and found that *Celtis australis* L. wood had the highest specific gravity (0.576) at 2 per cent extract concentration and the lowest in *Bombax ceiba* L. (0.432) for untreated wood samples. The maximum volumetric shrinkage co-efficient (10.37%) at untreated wood samples and volumetric swelling co-efficient (12.34%) at 1.5 per cent concentration was recorded in *Pinus roxburghii* Sargent wood and minimum volumetric shrinkage co-efficient (7.73%) found in *Bombax ceiba* L. wood samples at 2 per cent concentration and volumetric swelling co-efficient (8.86%) in *Celtis australis* L. wood at 0.25 per cent extract concentration.

Dhiman, (2014) evaluated the effect of *Acorus calamus* L. extract using methanol as a solvent on physical attributes of *Celtis australis* L., *Pinus roxburghii* Sargent and *Bombax ceiba* L. and reported that the maximum specific gravity (0.586) found in *Celtis australis* L. wood samples treated with 2 per cent extract concentration and minimum (0.465) in untreated wood samples of *Bombax ceiba* L. whereas the maximum volumetric shrinkage co-efficient (8.16%) and volumetric swelling co-efficient (10.85%) found in untreated wood samples of *Pinus roxburghii* Sargent and minimum volumetric shrinkage co-efficient (6.63%) and volumetric swelling co-efficient (8.32%) at 1.50 per cent extract concentration were found in *Bombax ceiba* L. wood.

Chandel, (2016) studied the effect of *Nerium oleander* L. extract using methanol as a solvent on specific gravity of *Celtis australis* L., *Pinus roxburghii* Sargent and *Bombax ceiba* L. wood and observed that the maximum specific gravity (0.569) was found in *Celtis australis* L. wood at 2 per cent extract concentration and the minimum (0.428) in untreated wood samples of *Bombax ceiba* L. The highest value for volumetric shrinkage co-efficient (8.45%) and volumetric swelling co-efficient (12.21%) found in untreated wood samples of *Pinus roxburghii* Sargent and the lowest value for volumetric shrinkage co-efficient (6.98%) in *Celtis australis* L. wood sample at 0.5 per cent concentration and volumetric swelling co-efficient (8.87%) in *Bombax ceiba* L. wood at 0.25 per cent extract concentration.

Meena, (2017) observed the physical properties of *Pinus roxburghii* Sargent wood using *Acorus calamus* L. and *Parthenium hysterophorus* L. plant extract and observed the maximum value for specific gravity (0.559) in *Acorus calamus* L. extract treated wood samples at 2 per cent concentration and minimum value (0.544) in *Parthenium hysterphorus*

L. extract for untreated wood samples by using petroleum ether as a solvent. The maximum value for volumetric swelling co-efficient (12.06%) and volumetric shrinkage co-efficient (10.13%) was observed in *Parthenium hysterphorus* L. extract for untreated wood samples and minimum value for volumetric swelling co-efficient (10.01%) and volumetric shrinkage co-efficient (9.05%) was observed in *Acorus calamus* L. extract treated wood samples at 2 per cent concentration by using methanol as a solvent, respectively.

Pawar, (2020) evaluated the effect of *Melia composita Willd.* (leaf and seed*)* extract using methanol as a solvent for *Toona ciliata* M. Roem wood and reported that leaf extract treated wood had maximum specific gravity (0.488) at 1.5 and 2 per cent concentration and minimum in seed extract treated samples (0.483) at 0.25 per cent concentration. Similarly, maximum volumetric swelling co-efficient (9.50%) and volumetric shrinkage co-efficient (7.43%) was observed in untreated wood samples and minimum volumetric swelling co-efficient (9.35%) and volumetric shrinkage co-efficient (7.30%) was found in seed extract treated wood samples at 2 per cent concentration.

Jayara, (2022) studied the effect of *Acorus calamus* L. extract on wood *Toona ciliata* M. Roem wood and reported the maximum volumetric shrinkage co-efficient (7.37%) and volumetric swelling co-efficient (8.91%) for untreated wood samples of aqueous extract whereas minimum volumetric shrinkage co-efficient (7.01%) and volumetric swelling co-efficient (8.49%) recorded at 2 per cent petroleum ether extract concentration.

Sharma, (2022) examined the effect of *Lantana camara* L. on *Acrocarpus Fraxinifolius* Arn. and found the highest value for volumetric swelling co-efficient (9.64%) and volumetric shrinkage co-efficient (7.97%) for untreated wood samples and the lowest value for volumetric swelling co-efficient (8.91%) and volumetric shrinkage co-efficient (7.58%) was observed in 2 per cent concentration using methanol solvent.

2.2 CHEMICAL PROPERTIES

Chemically wood is a biopolymer composite, where the main constituents are cellulose, hemicelluloses, lignin and some amounts of extractives like fats, resin, waxes etc. Sharma and Sharma, (2003) studied vertical variation for the lignin and holocellulose content in *Eucalyptus tereticornis* wood and reported that the lignin content decreased while the holocellulose content increased from bottom to top of the tree.

Guler *et al*. (2007) observed the chemical properties of juvenile and mature wood of *Pinus nigra* and found the highest lignin content (33%) was in the juvenile pine as compared to mature pine (22.2%) whereas the mature pine had the higher holocellulose content (72.2%) than the juvenile pine (65%).The alcohol-benzene soluble extractives in juvenile wood was 2.51 per cent while in mature wood was 6.07 per cent.

Lopez *et al*. (2008) stated that the *Leucaena leucocephala* contains hot water soluble,1% NaOH soluble, ethanol-benzene extracts, holocellulose, lignin and alpha-cellulose was 4 per cent, 18.4 per cent, 4.6 per cent, 75.9 per cent, 21.4 per cent and 44.4 per cent, respectively.

Yasuo *et al*. (2008) conducted a chemical analysis of *Eucalyptus globules* from two plantation sites and found that holocellulose content, cellulose content, hemicelluloses content and lignin content was ranged from 85.0 to 87.7 percent, 44.80 to 48.3 percent, 38.2 to 41.4 per cent and 15.4 to 18.7 percent, respectively.

Shreshta and Budhathoki, (2012) studied chemical compositions of *Rhododendron arboretum* wood and found that holocellulose, ash content, lignin, hemicellulose and extractives was 69.82 per cent, 0.75 per cent, 24.88 per cent,22 per cent and 4.39 per cent, respectively.

Sharma, (2016) studied the chemical properties of wood samples of *Cedrus deodara* collected from different sites of Himachal Pradesh. The results showed the samples collected from Kandyali site had maximum cold water (5.85%), hot water (7.01%) and alcohol-benzene soluble extractives (12.01%).

Dhiman, (2018) had collected the *Toona ciliata* M. Roem from nine districts of Himachal Pradesh and reported the maximum percentage of cold water, hot water and alcohol benzene in Mandi (6.38%), Sarahan (9.80%) and Nauni (8.48%) whereas the minimum percentage were found in Sujanpur, Una and Renuka (4.10%), Palampur (7.25%) and Baddi (6.59%), respectively.

Sahoo, (2018) investigated the chemical characteristics of eucalyptus hybrid wood from two agro-climatic zones of Odisha (Titlagarh and Bissamcuttack) and observed that Titlagarh zone had higher cellulose content (36%), hemicellulose content (17.40%), and

lignin content (33.20%) than Bissamcuttack zone hemicellulose content (16.60%) and lignin content (31.80%).

Heena *et al*. (2019) evaluated the Ban Oak (*Quercus leucotrichophora*) wood from twenty-two provenances of Himachal Pradesh and resulted the maximum holocellulose content was found in Barog provenance (71.30%) and minimum in Banikhet provenance (65.31%) whereas the maximum lignin content was reported in Dhami provenance (28.46%) and minimum in Jibhi provenance (20.48%).

Chambyal, (2020) evaluated the effect of vertical variation on chemical properties of *Toona ciliata* M. Roem and reported that the maximum value for cold water extractives was (6.05%) and hot water extractive (8.15%) at base respectively whereas minimum value for cold water extractives (4.73%) and hot water extractives (7.33%) at 90 per cent of total bole height, respectively.

Sunny *et al*. (2020) investigated the variation in chemical properties of *Artocarpus heterophyllus* wood obtained from three altitudinal zones in the Thrissur region of Kerala. The values obtained for cold water solubility, hot water solubility, alcohol benzene extracts, cellulose, hemicellulose, holocelluloses, klason lignin, NaOH soluble extracts, and ash content were 3.40 per cent, 7.11 per cent, 13.91 per cent, 44.33 per cent, 29.12 per cent, 71.42 per cent, 28.21 per cent, 21.48 per cent, and 0.80 per cent, respectively.

Farkhanda, (2021) evaluated the chemical properties of air and water seasoned willow clones and found the maximum value in air seasoned clones for cold-water extractives (6.95%) was in J194 clone and hot-water extractives (9.75%) in 131/25 clone while the minimum value in water seasoned clones for cold water extractives (2.83%) and hot water extractives (4.62%) was found in NZ-1130 clone, respectively.

Jayara, (2022) studied the effect of *Acorus calamus* L. extract on chemical properties of *Toona ciliata* M. Roem and observed the highest value for hot water-soluble extractives and cold water soluble extractives was 9.88 per cent in aqueous extract treated wood samples and 5.53 per cent while the lowest value was 9.42 per cent and 5.17 per cent in untreated wood samples, respectively.

Sharma, (2022) studied the effect of *Lantana camara* L. extract on chemical properties of *Salix tetrasperma* Roxb and recorded the highest value for cold water soluble

extractives (6.15 per cent), hot water soluble extractives (10.15%) was found in aqueous extract treated wood samples at 2 per cent concentration while lowest value for cold water-soluble extractives (5.83%), hot water-soluble extractives (9.83%) was found in untreated wood samples.

2.3 MECHANICAL PROPERTIES

The strength and capacity to withstand different kinds of external forces are mechanical qualities of wood. Elastic characteristics, cleavability, tension, bending, and strength properties that are characterized by resistance to deformation when load is applied on wood.

Macchioni, (2001) evaluated the mechanical properties of Atlas cedar (*Cedrus atlantica*) wood and found that the compression value was 48.8 MPa whereas the modulus of elasticity was 94 MPa and the mean of modulus of rupture was 10101 MPa.

Kumar and Sahu, (2005) evaluated the heartwoods of lesser known timber species viz., *Albizia odoratissima* (Ceylon rosewood) and *Samanea saman* (rain tree) which used as "substitutes" and "adulterants" for making furniture of *Dalbergia latifolia* (Indian rosewood) in the Kerala and reported that the mechanical properties of *Albizia odoratissima* were superior to *Dalbergia latifolia* and *Samanea saman*.

Guler *et al*. (2007) studied the mechanical properties of Juvenile Black Pine wood (*Pinus nigra*) and reported the static bending and compression strength were 79.1 Nmm^{-2} and 42.4 Nmm^{-2}, respectively.

Shukla and Kamden, (2010) studied mechanical properties of red pine wood (*Pinus resinosa*) and found that compressive strength, modulus of elasticity (MOE) and modulus of rupture (MOR) was ranged between 8.69-8.02 MPa, 5.9-5.5 MPa and 55.28-51.62 MPa, respectively.

Kiaei and Samariha, (2011) investigated mechanical properties (modulus of rupture, modulus of elasticity, compression parallel to the grain) of five hardwood plants: oak (*Quercus castaneaefolia*), beech (*Fagus orientalis*), hornbeam (*Carpinus betulus*), alder (*Alnus glutinosa*), and ash (*Fraxinus excelsior*) plants. The highest values for modulus of

rupture, modulus of elasticity, and compression parallel to the grain were recorded in hornbeam, beech, ash, and oak plants.

Awan *et al*. (2012) studied the mechanical properties of *Eucalyptus camaldulensis* Dehn., *Dalbergia sisso* Roxb., *Cedrus deodara* Roxb. and observed that the *Eucalyptus camaldulensis* had greater compressive strength and nail holding capacity as 88 kg/cm^2 and 129 kg/cm^2, respectively.

Elzaki and Khider, (2013) compared the strength characteristics of *Ailanthus excelsa* from Western Sudan with same wood species from India (static bending tests, impact bending, compression strength parallel to grain, maximum crushing strength, and shear stress) and reported that the Sudanese *Ailanthus excelsa* had lower average value for basic density (316.0 kg/m^3), MOR (468.0 kPa/cm^2) than that of Indian wood species for basic density (361.0 kg/m^3) and MOR (543.0 kPa /cm^2).

Heena, (2014) studied the mechanical properties of willow (*Salix* sp.) clones and observed the maximum tensile strength (0.073 kN/mm²) and bending strength (0.006 kN/mm²) in clone J-795 and V-99, respectively. She also reported maximum compressive strength parallel to grain (0.044 kN/mm²) and compressive strength perpendicular to grain (0.007 kN/mm²) in clone NZ-1002 and MB-368, respectively.

Saravanan *et al*. (2014) investigated the mechanical characteristics of three, four, and five years age gradations of *Melia dubia* wood samples and reported that the five year old *M. dubia* samples had maximum value for parameters such as static bending strength (616.30 kg/cm^2), Modulus of Elasticity (68384.50 kg/cm^2) compression strength parallel to grain (283.30 kg/cm^2,) compression strength perpendicular to grain (104.20 kg/cm^2).

Ataguba *et al*. (2015) studied the mechanical properties of *Gmelina arborea* and observed that the estimated values for compression parallel to grain was 7.4 N/mm^2, compression perpendicular to grain was 2.5 N/mm^2, tensile strength was 6.5 N/mm^2.

Kumar *et al*. (2017) evaluated the mechanical properties of *Pinus roxburghii* collected from different locations of Himachal Pradesh and found maximum value for bending strength (0.008 kN/mm²) and compression parallel to grain (0.057 kN/mm²) for wood samples collected from same site i.e Banethi site, compression perpendicular to grain (0.018 kN/mm²) from Nurpur site and tensile strength (0.043 kN/mm²) from Chabbal site whereas

minimum value for bending strength (0.003 kN/mm²) observed in wood samples collected from Nihari site, compression parallel to grain (0.034 kN/mm²) from Platu site, compression perpendicular to grain (0.006 kN/mm²) from Swarghat and tensile strength (0.022 kN/mm²) from Malan site.

Thakur, (2017) observed the mechanical properties of market samples of *Acacia nilotica* L. Willd ex Delile wood and the maximum compressive strength parallel to grain was observed in samples from Baddi market while the maximum compressive strength perpendicular to grain was recorded in Parwanoo-2. However maximum tensile strength was observed in samples collected from Chowkiwala and Parwanoo-2, respectively.

Deepa, (2019) evaluated the vertical variation in mechanical properties of *Acrocarpus fraxinifolius* Wight & Arn. and resulted the maximum bending strength (0.0103 kN/mm^2) at base while minimum (0.0087 kN/mm^2) at 80 per cent bole height. However, the maximum tensile strength was (0.069 kN/mm^2) at base and the minimum was (0.044 kN/mm^2) at 90 per cent of total bole height.

Sunny *et al*. (2019) investigated the wood properties of *Dalbergia sissoo* obtained from various market places in Himachal Pradesh and found the highest value for bending strength (0.006 kN/mm^2) and tensile strength (0.094 kN/mm^2) and compressive strength perpendicular to grain (0.038 kN/mm^2) was observed in wood samples collected from the Baroh site while the compressive strength parallel to grain (0.069 kN/mm^2) was obtained in the Kangu site. The maximum value for Modulus of Elasticity parallel to grain (0.231 kN/mm^2) was detected in wood samples of Ghumarwin, and Modulus of Elasticity perpendicular to grain (1.653 kN/mm^2) was collected from Galore location.

Sharma, (2020) examined the mechanical properties of *Toona ciliata* M. Roem and recorded that the highest values of tensile strength (0.072 kN/mm^2), bending strength (0.022 kN/mm^2), compression parallel to the grain (0.052 kN/mm^2), and compression perpendicular to the grain (0.039 kN/mm^2) whereas the lowest values of tensile strength (0.039 kN/mm^2), bending strength (0.008 kN/mm^2), compression parallel to the grain (0.041 kN/mm^2), and compression strength perpendicular to the grain (0.027 kN/mm^2).

Jayara, (2022) studied mechanical properties of *Toona ciliata* M. Roem using *Acorus calamus* L. extract and observed the maximum values for tensile strength (0.064 kN/mm^2),

bending strength (0.015 kN/mm^2), compression parallel to grain (0.055 kN/mm^2) and compression perpendicular to grain (0.029 kN/mm^2) was found in aqueous extract treated wood samples at 2 per cent extract concentration whereas the minimum values for tensile strength (0.061 kN/mm^2), bending strength (0.011 kN/mm^2), compression parallel to grain (0.052 kN/mm^2) and compression perpendicular to grain (0.024 kN/mm^2) was observed in untreated wood samples.

Sharma, (2022) evaluated mechanical properties of *Salix tetrasperma* Roxb and reported that the tensile strength (0.051 kN/mm^2), bending strength (0.013 kN/mm^2), compression parallel to grain (0.034 kN/mm^2), and compression perpendicular to grain (0.030 kN/mm^2) was the highest at 2 per cent concentration of aqueous extract treated wood samples whereas the lowest tensile strength (0.048 kN/mm^2), bending strength (0.008 kN/mm^2), compression parallel to grain (0.030 kN/mm$^{2)}$, and compression perpendicular to grain (0.025 kN/mm$^{2)}$ found in untreated wood samples.

2.4 WOOD PRESERVATION

Wood preservation is a highly effective method for extending the life of wood in a variety of environments. Many compounds, such as copper, chromium, arsenate, zinc, and others, are now used to improve the durability of wood and wood-derived products. These preservatives are useful in protecting wood from deterioration, but their use is limited due to environmental concerns. To reduce these negative impacts, biopreservation is one of the best approach i.e. ecofriendly in nature which aims to protect wood from decay, insect attack and other forms of degradations, enhancing its longevity and structural integrity.

Taylor *et al*. (2006) observed that the methanol soluble extractives of the heartwood of *Thuja plicata* and *Chamaecyparis nootkatensis* were crucial in protecting heartwood from C*optotermes formosanus* and *Postia placenta* attack and showed a favourable correlation with both termite and decay resistance.

Chandra *et al*. (2010) evaluated the effect of extract of *Lantana camara* L. (using petroleum ether, acetone, methanol and hot water as solvents) on bamboo wood against *Polyporu sarcularis* and *Schizophyllum commune* and reported that methanolic extracts of *Lantana camara* L. were found to be highly fungicidal at very low concentration.

Gupta, (2012) studied the effect of different concentration i.e 0.25, 0.5, 1.00, 1.50, and 2 per cent of *Lantana camara* L. extract using methanol as a solvent on the wood properties of *Pinus roxburghii* Sargent, *Celtis australis* L. *and Bombax ceiba* L. and found that wood treated with 2 per cent extract concentration inhibited the fungus growth and increased the dimensional stability of the wood specimens as compared to untreated wood samples.

Devi, (2013) investigated the effect of *Ageratum conyzoides* L. leaf extract on *Bombax ceiba* L., *Celtis australis* L. and *Pinus roxburghii* Sargent wood using methanol solvent and found that fungus growth was inhibited at 2 per cent concentration of extract as well as dimensional stability was improved.

Chandel, (2016) studied the effect of *Nerium oleander* L. extract at different concentration (i.e 0.25, 0.50, 1.00, 1.50 and 2.00%) against fungus growth (Polyporus spp.) on different wood samples and reported that maximum fungus inhibition in *Pinus roxburghii* Sargent (83.34%), followed by *Bombax ceiba* L. (66.67%) and *Celtis australis* L. (58.34%) at 2 per extract concentration as compared to untreated wood samples.

Dhiman and Dutt, (2014) investigated the antifungal efficacy of *Acorus calamus* L. extract as a biopresevative on *Bombax ceiba* L., *Celtis australis* L. and *Pinus roxburgii* Sargent wood against Polyporus fungus and findings demonstrated that the average growth of fungus was reduced up to 69.44 per cent after applying 2 per cent extract concentration on wood samples.

Meena, (2017) studied effect of *Acorus calamus* L. and *Parthenium hysterophorus* L. extract against white rot fungi (*Trametes versicolor* L.) and brown rot fungi (*Gloeophyllum striatum* (Fr.) Murrill on *Pinus roxburghii* Sargent wood and found the maximum fungus inhibition for white rot fungi (87.19%) and brown rot fungi (85.08%) was recorded at 2 per cent concentration with *Parthenium hysterphorus* L. extract whereas the minimum fungus inhibition for white rot fungi (21.18%) and brown rot fungi (26.80%) was recorded at 0.25 per cent concentration with *Acorus calamus* L. extract.

Rawat *et al*. (2017) reported that neem oil has the ability to inhibit the growth of different fungi such as *Schizophyllum commune, Fusarium proliferatum, Fusarium oxysporum, Coniophora puteana* and *Alternaria alternate* at the concentration of 0.25, 0.50,

0.75, 1.00, 2.00, 4.00, 6.00, 8.00 and 10 per cent and found that neem oil above 2 per cent concentration was highly effective against these pathogens.

Hassan *et al*. (2018) evaluated the anti-microbial activity of chinaberry (*Melia azedarach*) fresh leaves and fruit extract against *Pseudomonas syringae* Pv. *Syringae* growth on different mediums including hot aqueous, cold aqueous and ethanol at various concentration of 50, 100, 150, 200 mg/ml and concluded that the fruit extract with ethanol at 200 mg/ml gave maximum inhibition for bacterial growth 11.7 mm in diameter, followed by 10.97 mm and 10.93 mm in hot and cold aqueous extract.

Pawar, (2020) investigated the effect of antifungal activity of *Melia composita* Willd., (seed and leaf extract) using methanol as a solvent on *Toona ciliata* M. Roem wood at different concentrations (i.e. 0.25%, 0.5%, 1%, 1.5% and 2%) and found that the maximum growth of fungus colonization was recorded for untreated wood samples and minimum was in 2 per cent extract concentration.

Sharma, (2022) studied the effect of antifungal properties of *Lantana camara* L. leaf extract on *Acrocarpus fraxinifolius* Arn. and found that the growth of fungus was maximum in untreated wood samples while minimum in extract treated wood samples at 2 per cent concentration.

Chapter-3

MATERIALS AND METHODS

The present work entitled "Studies on effect of *Acorus calamus* L. extract on wood characterstics of *Morus alba* L." was carried out in the laboratory and wood workshop of the department of Forest Products, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (H.P) during 2022-2023. Details of the experimental material, techniques and the methods of analysis employed during the course of investigations are presented in this chapter under the following headings:

3.1 EXPREIMENTAL DETAILS

3.1.1 Species selection

Wood of *Morus alba* L. was procured from the field of Department of Tree Improvement and Genetic resources of Dr. Yashwant Singh Parmar University of Horticulture and Forestry Nauni, Solan (H.P) and trees having age of 17 years with height of 4m. The experiments were laid out in Completely Randomized Block Design (CRD) Factorial.

3.1.2 Felling and conversion

The trees were felled on 26th of August 2022. It was converted into logs of the length 1m each for the investigations and was subjected to saw mill for sawing purpose (Plank formation).

3.1.3 Preparation of sample

Planks were converted in the wood workshop of the Department of Forest Products to prepare samples of the following dimensions as per the standard (IS; 1708, 1996).

a. 10 mm × 10 mm × 10 mm (Moisture content and specific gravity of wood)
b. 50 mm × 25 mm × 25 mm (Swelling and Shrinkage)
c. 300 mm × 20 mm × 20 mm (Static bending)
d. 300 mm × 10 mm × 10 mm (Tensile strength)
e. 50 mm × 20 mm × 20 mm (Compression strength parallel to grain)
f. 50 mm × 20 mm × 20 mm (Compression strength perpendicular to grain)

3.2 PREPARATION OF EXTRACT FROM RHIZOMES OF *Acorus calamus* L.

The rhizomes of *Acorus calamus* L. were collected from the field of Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (H.P). The *Acorus calamus* L. was uprooted, rinsed with water to remove mud, and dried under shade for seven days. Before they become completely dry, the rhizomes were cut into small pieces with a sharp secateur. Then a wood chipper cum grinder was used to finely powder the chipping material, once it had dried fully. The powdered material was extracted with petroleum ether, methanol, water and were distilled out after complete extraction, and the extract material was dried under vaccum. Each dried extract was collected in a total of 120 g. For each extract, a stock solution of 2 litre at 2 per cent concentration was made and used to prepare additional concentrations for wood sample treatment.

3.3 EFFECT OF *Acorus calamus* L. EXTRACT TREATMENT ON WOOD CHARACTERSTICS OF *Morus alba* L.

The experiment was laid out in Completely Randomized Block Design (CRD) factorial. In total, three replicates for each treatment were taken.

i) Preparation of rhizome extract solution for dip treatment

Different concentrations for dip treatment were made from a 2 per cent stock solution that had already been prepared. The wood specimens of *Morus alba* L. were dipped in 0.25, 0.50, 1.00, 1.5, 2.00 per cent (w/v) *Acorus calamus* L. extract solution for 72 hours. The samples meant for control were dipped in distilled water. After dipping treatment, specimens were first dried in air and then dried in oven at 105±2ºC to constant weight.

ii) Weight and dimensional measurements

The samples were air dried before oven drying. The dimensions of wood samples were measured with the help of digital Vernier-Caliper and weights were recorded on Electronic Weighing Balance. After that, the treated samples were dried at 105±2ºC to constant weights and the dimensions of the samples were measured in millimetres. The difference in weights and dimensions before and after treatment was taken as weight and dimensional change in the wood samples, respectively.

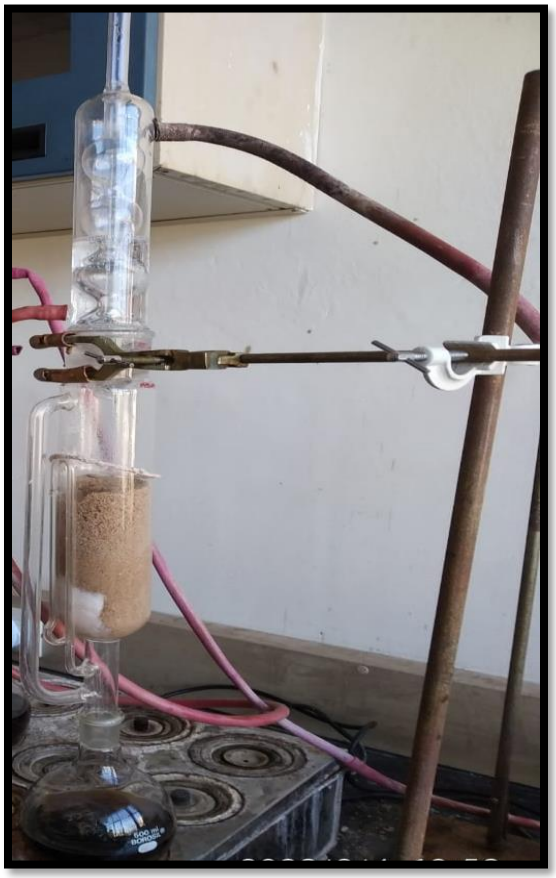
3.4 PHYSICAL PROPERTIES OF WOOD

The experiment was carried out in CRD factorial. Three replicates were taken for each treatment.

Step: 1 Collection of *Acorus calamus* L. rhizome

Step: 2 Shade drying of *Acorus calamus* L. rhizome after chipping

Step: 3 Powder of *Acorus calamus* L. rhizome

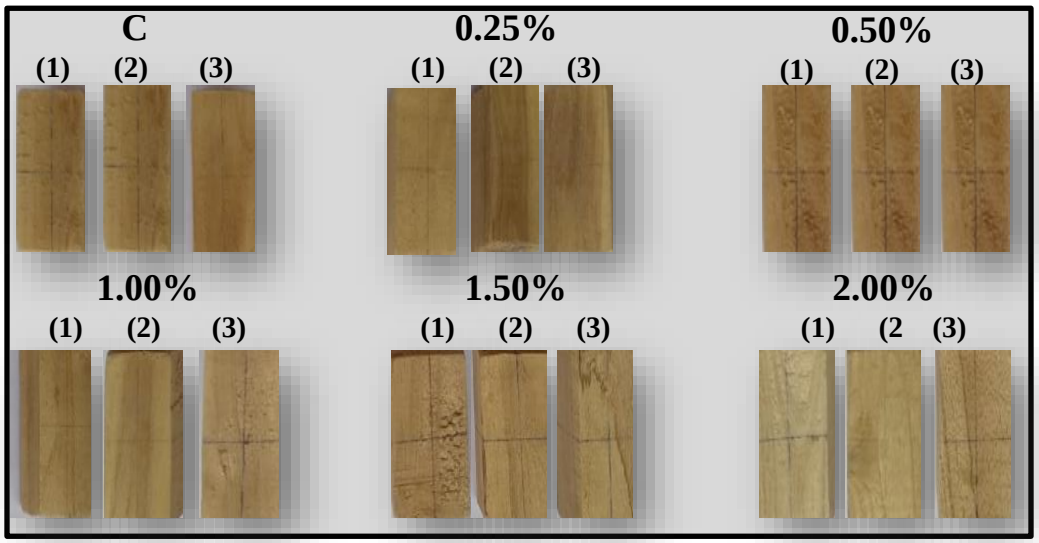


Soxhlet extraction of *Acorus calamus* L (rhizome).

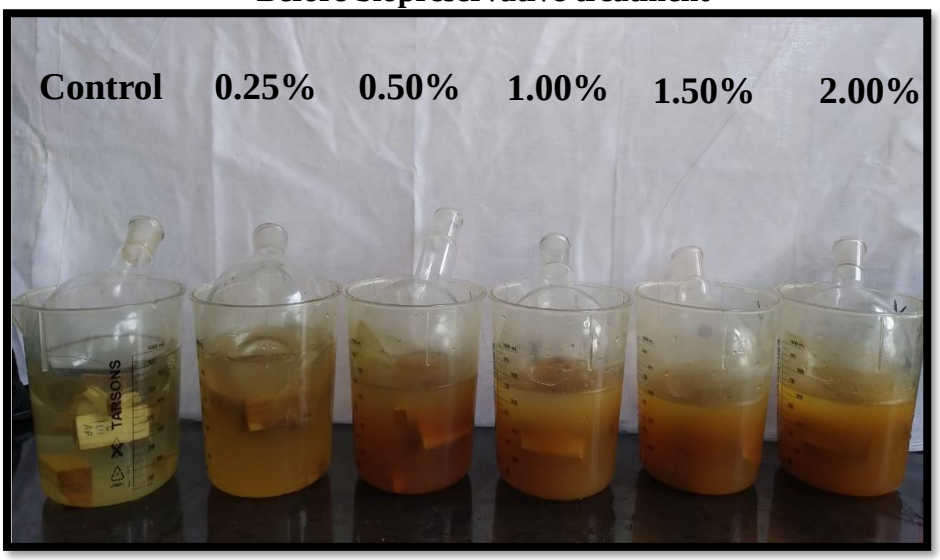
Rotary evaporation of *Acorus calamus* L. water extract

Distillation of methanol extract

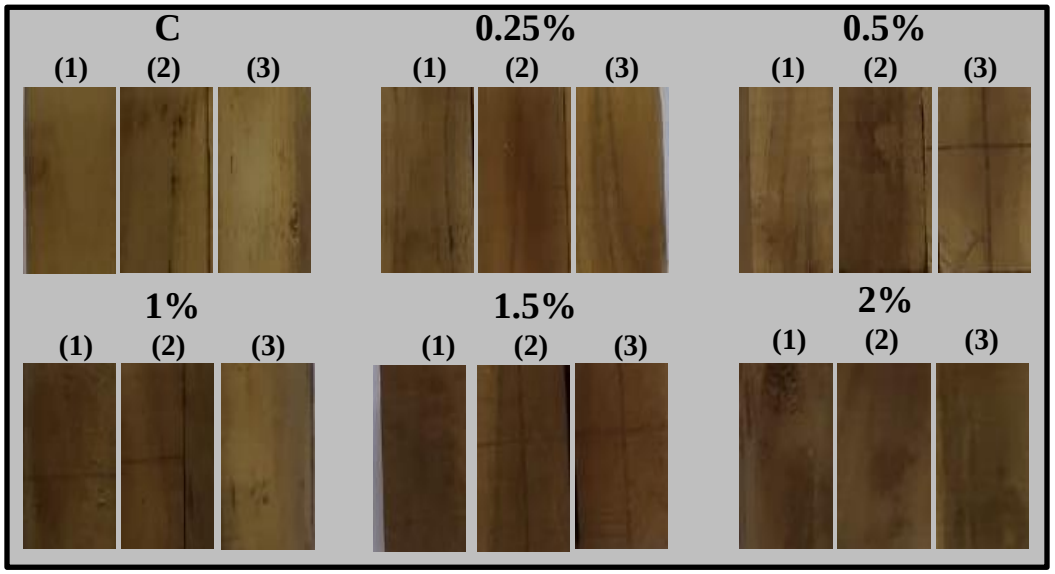
Plate 1. Extraction process of *Acorus calamus* L. rhizome extract



Before biopreservative treatment



***Acorus calamus* L. extract treatment**



After biopreservative treatment

Plate 2. *Acorus calamus* L. extract treatment on wood samples

Observation recorded

i) Maximum Moisture Content (MMC) %

Maximum Moisture Content (MMC) of the wood samples was determined as per the Indian Standard IS: 1708 (BIS, 1986). The wood samples were submerged in distilled water, to ensure complete saturation. The saturated samples were taken out and weighed. Samples were dried first in air and then at 105±2ºC till constant weight. The Maximum Moisture Content (%) was calculated by using the following formula:

$$\text{Maximum Moisture Content (MMC)\%} = \left\{\frac{Mm - Mo}{Mo} \times 100\right\}$$

Where,

Mm= Saturated wet weight of wood samples (g)

Mo= Oven dried weight of wood samples (g)

ii) Specific gravity

Specific gravity (also known as relative density or basic density) is the ratio of density of a substance to that of a standard substance (usually water at 4ºC). Specific gravity was determined by the maximum moisture content method (Smith, 1954). The wood samples of the size 1 cm×1 cm×1 cm were oven dried at 105± 2°C until a constant weight was obtained. The weights of the samples at this point were recorded and then calculated using formula:

$$\text{Specific Gravity} = \frac{1}{\frac{Mm - Mo}{Mo} + \frac{1}{GS}}$$

Where,

Mm= Saturated wet weight of samples (g)

Mo= Oven dried constant weight of the samples (g)

GS= Average density of wood substance, a constant, having value of 1.53

iii) Volumetric Swelling Co-efficient (%)

Volumetric swelling co-efficient is defined as the cumulative rise in all three planes (Longitudinal, Radial and Tangential) caused by the addition of water.

Volumetric Swelling Co-efficient (%) was calculated as follows:

$$S = \frac{V_2 - V_1}{V_1} \times 100$$

Where,

S = Volumetric swelling co-efficient

V_1 = Wood volume of a oven-dried wood sample before treatment (cc)

V_2 = Wood volume with treatment (cc)

iv) Volumetric Shrinkage Co-efficient (%)

Volumetric shrinkage co-efficient is defined as the overall decline in all three wood planes (Longitudinal, Radial and Tangential) caused by the elimination of bound water.

Volumetric shrinkage co-efficient was calculated as:

$$S=\frac{V_2-V_1}{V_1} \times 100$$

Where,

S = Volumetric shrinkage co-efficient

V_1 = Wood volume of oven dried sample after treatment (cc)

V_2 = Wood volume (wet) with treatment (cc)

3.5 DETERMINATION OF CHEMICAL CHARACTERSTICS OF WOOD

The chemical analysis of the wood samples of given species was being performed by applying TAPPI (Technical Association of Pulp and Paper Industry) standard methods.

Observation Recorded

i) Determination of Water-Soluble Extractives

The water-soluble extractives were determined by employing the following methods:

a) Cold water-soluble extractives (%)

Two gram of oven dried coarsely ground wood was weighed and transferred into a conical flask containing 300 ml of distilled water. The mixture was digested at room temperature with frequent stirring for 48 hours. The material was then filtered through IG-1 crucible and washed thoroughly with cold distilled water and dried to a constant weight in an oven at 105±2ºC. The cold-water solubility was determined by calculating the loss in weight of sample taken and was expressed as percentage on the basis of oven dry weight of wood (T1m-59-Anonymous, 1959a).

b) Hot water-soluble extractives (%)

Two grams of oven dried coarsely ground wood was taken in a flask having 100 ml of double distilled water fitted with reflux condenser. It was digested on boiling water bath for 3 hours. The contents were then filtered through IG-1 crucible and residue was dried in an oven at 105±2ºC till constant weight. The solubility was determined by calculating the loss in weight of the sample taken and expressed as percentage (T1m-59-Anonymous, 1959a).

c) Alcohol-Benzene soluble extractives (%)

Ten gram of oven dried coarsely ground wood was placed in a porous thimble (oven dried and weighed). The thimble was placed in a soxhlet apparatus extracted with 200 ml of alcohol-benzene (1:2 v/v) for six hours. The porous thimble was then taken out and allowed to dry in open air and finally in an oven at 105±2ºC till constant weight. The alcohol-benzene solubility was determined by calculating the loss in weight of the sample taken and expressed in percentage (T6m-59-Anonymous, 1959b).

d) Holocellulose content (%)

Five gram of oven dried sample pre-extracted with alcohol-benzene (1:2 v/v) was taken in a conical flask and 160 ml of distilled water was added to it. The contents were treated with 1.5 gm of sodium chlorite and 10 drops of acetic acid at 70-80ºC on a water bath for one hour. The process was repeated four times till the meal became white. The contents were then filtered through IG-1 crucible, washed with water and finally with acetone. The sample was dried in an oven at 105±2ºC to a constant weight. The extracted holocellulose content was calculated on the basis of the oven dry weight (T9m-59-Anonymous, 1959).

e) Klason-Lignin Content (%)

Two grams of oven dried samples pre-extracted with alcohol-benzene (1:2 v/v) was treated with 15ml of 72 per cent sulphuric acid for 2 hours at 18-20ºC with constant stirring. The material was brought down to 3 per cent by 545 ml of double distilled water. The solution was refluxed for 4 hours and then allowed to settle. The contents were filtered and washed with hot distilled water. The material was then dried in an oven at 105±2ºC till constant weight and expressed in percentage (T12m-59-Anonymous, 1959c).

3.6 DETERMINATION OF MECHANICAL STRENGTH PROPERTIES

The mechanical properties of wood were determined as per the procedure followed for testing in Universal Testing Machine (Model: UTN-10) in the Wood Workshop of the Department of Forest Products, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (H.P). The process given by Indian Standard IS: 1708 was used to determined mechanical test of wood samples (BIS. 1986). All of the tests were carried out on standard-sized wood samples with a moisture content of 8-12 per cent at room temperature. The experiment was set up in a factorial CRD format. Three replicates of each treatment were taken in total.

Observation Recorded

i) Tensile Strength (kN/mm^2)

The standard size of the specimens taken for conducting this test was 300 mm×10 mm×10 mm. The computer data and graph were generated as per the software, so as the values of maximum load, maximum displacement and breaking pattern of extract treated wood samples. Proper care was taken so that each samples faced similar type of test measures.

ii) Bending Strength (kN/mm^2)

The standard size of the specimen taken for this test was 300 mm×20 mm×20 mm. Proper care was taken so that each specimen faced similar type of test measures. The information gathered was put to use for additional study and comparision.

iii) Compression Strength

a) Compression Strength Parallel to the Grain (kN/mm^2)

This test was done in the direction along the grain and the data was generated in Universal Testing Machine (Model: UTM-10). The standard size of specimens for this compression test was 50 mm×20 mm×20 mm.

b) Compression Strength Perpendicular to the Grain (kN/mm^2)

The specimen size of 50 mm×20 mm×20 mm was taken across the direction of grain for carrying out this test. The information gathered was used to conduct further research and interpretation of the findings.

3.6 EFFECT OF PAINT CONCENTRATION ON PHYSICAL PROPERTIES OF *Morus alba* L. WOOD TREATED WITH *Acorus calamus* L. EXTRACT

The experiment was conducted by using nerolac brill white paint and turpentine thinner at different concentrations. The wood samples used for this experiment are those treated with petroleum ether extract at 2 per cent concentration has shown best results from previous experiment. The Completely Randomized Design (CRD) was used for the analysis of data for 7 paint concentrations and 2 controls. The following paint concentrations were given to wood samples.

T_1 = 100%

T_2 = 95%

T_3 = 90%

T_4 = 85%

T_5 = 80%

T_6 = 75%

T_7 = 70%

T_0 = Control

T_1 = Control

Where,

T_0 (Control): Absolute control (untreated samples)

T_1 (Control): Control with dip treatment of 2 per cent petroleum ether extract

Observation recorded:

1. Maximum moisture content (%)
2. Volumetric swelling co-efficient (%)
3. Volumetric shrinkage co-efficient (%)

3.7 Statistical Analysis

The data collected from treated wood samples was collated to estimated the results in standard terms for a particular parameter.

ANOVA for characters under study for Completely Randomized design (CRD factorial)

1) One factor CRD

Source of Variation	Degree of Freedom	Sum of Squares	Mean sum of square	Variance ratio
Replication	(r-1)	Sr	Sr/(r-1)= Mr	Mr/MSe
Treatment combination (N)	(n-1)	Sn	Sn/(n-1)= Mn	Mn/MSe
Treatment (T)	(t-1)	St	St/(t-1)=Mt	Mt/MSe
Error	t(r-1)	Snr	Snr/(t)(r-1)Mse	

2) Two factor CRD

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	Variance ratio
Replication	(r-1)	Sr	Sr/(r-1)=Mr	Mr/MSe
Treatment combinations (N)	(n-1)	Sn	Sn/(n-1)=Mn	Mn/MSe
Extract (E)	(e-1)	Se	Se/(e-1)= Me	Me/MSe
Treatment (T)	(t-1)	St	St/(t-1)=Mt	Mt/MSe
E×T	(e-1) (t-1)	Set	Set/(e-1) (t-1)= Met	Met/MSe
Error	(r-1) (et-1)	Snr	Snr/(et-1) (r-1)=MSe	

The collected data were subjected to Completely Randomized Block Design factorial analysis as described by Panse and Sukhatme (1978) and Chandel (1984).

where,

r = Replications
n = Treatment Combinations
e = Extract
t = Treatments
et = Interactions between extract and treatments
Sr = Sum of squares due to replications
Sn = Sum of squares due to treatment combinations
Se = Sum of squares due to extract
St = Sum of squares due to treatments
Set = Sum of squares due to interaction of extract and treatments
Mr = Mean sum of squares due to replication
Mn = Mean sum of squares due to treatment combination
Me = Mean sum of squares due to extracts
Mt = Mean sum of squares due to treatments

Met = Mean sum of squares due to interaction of extracts and treatments

MSe = Mean sum of squares due to error

df = Degree of freedom

The treatments were tested at 5 per cent level of significance. The characters showing significant differences in the analysis of variance were used for the calculation of critical difference (CD). The standard error, critical difference (CD) and co-efficient of variation (CV) were calculated as follow:

where,

SE (mean)±= Standard error of mean

SE (d)= Standard error of difference

SE (t)= Standard error of treatments

SE (e)= Standard error of extract

SE (et)= Standard error of interaction between extract and treatments

SE (ec)= Standard error of interaction between extract and concentrations

$$\text{SE (mean)} = \sqrt{2 \times \frac{MSe}{tr}}$$

$$\text{SE (t)} = \sqrt{2 \times \frac{MSe}{tr}}$$

$$\text{SE (e)} = \sqrt{2 \times \frac{MSe}{er}}$$

$$\text{SE (tc)} = \sqrt{2 \times \frac{MSe}{tcr}}$$

$$\text{SE (te)} = \sqrt{2 \times \frac{MSe}{ter}}$$

$CD_{0.05}$ = SE (d) × $t_{0.05}$ at error df

$$\text{CV} = \sqrt{\frac{MSe}{Mean}} \times 100$$

Chapter-4

RESULTS AND DISCUSSION

The present study entitled **"Studies on effect of *Acorus calamus* L. extract on wood characterstics of *Morus alba* L."** was carried out in the laboratory of Department of Forest Products, College of Forestry, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (H.P) during the session 2021-2022 and 2022-2023. The main objective of the study was to evaluate the effects of *Acorus calamus* L. rhizome extract treatments on wood characterstics of *Morus alba* L. The data pertaining to results obtained during present investigation followed under appropriate statistical analysis and discussed under the following headings:

4.1 PHYSICAL PROPERTIES OF WOOD

4.2 CHEMICAL PROPERTIES OF WOOD

4.3 MECHANICAL PROPERTIES OF WOOD

4.4 PAINT APPLICATION

4.1 PHYSICAL PROPERTIES OF WOOD

4.1.1 Maximum moisture content (%)

The perusal of data in Table-1 has shown significant variation on maximum moisture content of wood for different concentrations and solvents. Among the solvents, the highest maximum moisture content (119.67%) was recorded in aqueous extract treated wood samples and the lowest (114.45%) was observed in petroleum ether extract treated wood samples. In different concentrations, the highest maximum moisture content (133.75%) was obtained in T_6 (control) and the lowest (105.30%) was recorded in T_5 (2.00%). The interaction between the solvents and concentrations was also found to be significant where the maximum value (133.75%) was recorded in untreated wood samples and minimum value (102.57%) was observed in $T_5 \times S_1$ (2.00% concentration) treatment combination.

Wood is hygroscopic in nature which absorbs moisture from its surrounding. The moisture content varies in different wood species because the cell wall polymer contain the hydroxyl group which attracts moisture through hydrogen bonding where moisture swells the cell wall and wood expands until the cell wall becomes saturated.

Table 1: Effect of different concentration of *Acorus calamus* L. rhizome extract on Maximum Moisture Content (MMC%) of *Morus alba* L. wood

Concentrations	EXTRACTS (E)			
	Petroleum Ether (S_1)	Methanol (S_2)	Aqueous (S_3)	Mean
T_1 (0.25%)	122.55	125.31	129.45	125.77
T_2 (0.50%)	114.43	117.97	120.86	117.75
T_3 (1.00%)	109.20	112.72	114.89	112.27
T_4 (1.50%)	104.16	108.44	110.38	107.66
T_5 (2.00%)	102.57	104.65	108.69	105.30
T_6 (Control)	133.75	133.75	133.75	133.75
Mean	114.45	117.26	119.67	
CD $_{0.05}$	**T 0.81** **E 0.58** **T×E 1.41**			

In present study, the maximum moisture content of bio-preservative treated wood decreased with increasing concentration of plant extract and the untreated wood samples displayed a higher percentage of maximum moisture content. Halverson and Lebow, (2011) found a negative correlation between wood density and solution absorption while researching the relationship between wood properties and solution uptake of various hardwood and softwood species during pressure treatment, stated that more dense specimens have lower uptakes.

According to Devi and Maji, (2012) the wood components and preservative solution form a cross link with a double bond as a result of preservative treatment, which increases water resistant capabilities. Similarily, Islam *et al*. (2012) observed that the preservative treatments also inhibits the formation of hydroxyl groups in wood and increases its water resistance properties. The lessening in moisture absorption for extract treated wood samples could be attributed to reduction and blockage in sorption sites (Gindl and Gupta, 2002) whereas the number of hydroxyl group in wood increases the moisture absorption (Haque *et al*., 2009).

4.1.2 Specific gravity of wood

The data revealed significant variation in Table-2 for specific gravity of wood between solvents and different concentrations. Among the solvents, the highest value (0.557) for specific gravity was recorded in petroleum ether extract treated wood samples and the lowest (0.546) was observed in aqueous extract treated wood samples. Between different

concentrations, the highest value (0.586) was obtained in T_5 (2.00%) for specific gravity and the lowest value (0.502) was recorded in T_6 (control). The interaction between the solvents and concentrations were statistically significant where the maximum value (0.595) was recorded in $T_5 \times S_1$ (2.00% concentration) and minimum value (0.502) was observed in untreated wood samples.

Table 2: Effect of different concentration of *Acorus calamus* L. rhizome extract on specific gravity of *Morus alba* L. wood

Concentrations	EXTRACTS (E)			
	Petroleum Ether (S_1)	**Methanol (S_2)**	**Aqueous (S_3)**	**Mean**
T_1 (0.25%)	0.532	0.524	0.513	0.523
T_2 (0.50%)	0.557	0.545	0.536	0.546
T_3 (1.00%)	0.573	0.562	0.555	0.563
T_4 (1.50%)	0.590	0.575	0.569	0.578
T_5 (2.00%)	0.595	0.589	0.575	0.586
T_6 (Control)	0.502	0.502	0.502	0.502
Mean	0.557	0.551	0.546	
CD $_{0.05}$	**T 0.002** **E 0.001** **T×E 0.004**			

Specific gravity of wood is a measure of the density of a wood relative to the density of water (4°C) as wood is subjected to an increase in the concentration of extractives, by absorption of extract that enters the void spaces in the wood and results higher specific gravity as well as density. Dhiman, (2014) used *Acorus calamus* extract as a biopreservative in three wood species, *Pinus roxburghii*, *Celtis australis*, and *Bombax ceiba*, and reported there was increase in specific gravity of wood as the concentration of extract increased and values of these wood i.e 0.544, 0.586, and 0.465, respectively. The current study is congruous with Gupta, (2012); Chauhan, (2013); Kumar, (2013); Devi, (2013); Chandel, (2016) and Pawar, (2020) who used wood samples of *Pinus roxburghii* Sargent, *Celtis australis* L., *Bombax ceiba* L., and *Toona ciliata* M. Roem which were treated with *Lantana camara* L., *Parthenium hysterophorus* L., *Melia azedarach* L., *Nerium oleander* L. and *Melia composita* Willd., respectively and found that the specific gravity of wood increased as extract concentration increased.

According to Li and Wah, (2017) the *Acorus calamus* L. having alpha asarone content (non-polar compound) shows high affinity towards non-polar solvent. So that

could also be the reason that in this present study the highest specific gravity was recorded for petroleum ether extract treated wood samples as compared to untreated wood samples.

4.1.3 Volumetric swelling co-efficient (%)

The (Table-3) data showed significant variation for volumetric swelling co-efficient of wood between different concentrations and solvents at 5 per cent level of significance. Among the solvents, the highest volumetric swelling co-efficient value (8.90%) was obtained in aqueous extract treated wood samples and the lowest (8.27%) was observed in petroleum ether extract treated wood samples. For different concentrations, the highest value for volumetric swelling co-efficient (10.59%) was recorded in T_6 (control) while the lowest value (6.43%) was in T_5 (2%). The interaction between the solvents and concentrations were also found to be significant where the maximum value (10.59%) was recorded in untreated wood samples and minimum value (6.13%) was observed in $T_5 \times S_1$ (2.00 per cent concentration) which was statistically at par with $T_5 \times S_2$ (2.00 % concentration) treatment combination.

Table 3: Effect of different concentration of *Acorus calamus* L. rhizome extract on Volumetric swelling co-efficient (%) of *Morus alba* L. wood

Concentrations	EXTRACTS (E)			
	Petroleum Ether (S_1)	Methanol (S_2)	Aqueous (S_3)	Mean
T_1 (0.25%)	9.73	10.03	10.22	9.99
T_2 (0.50%)	8.71	9.28	9.80	9.26
T_3 (1.00%)	7.65	8.02	8.44	8.04
T_4 (1.50%)	6.77	7.29	7.62	7.23
T_5 (2.00%)	6.13	6.40	6.75	6.43
T_6 (Control)	10.59	10.59	10.59	10.59
Mean	8.27	8.60	8.90	
CD $_{0.05}$	**T 0.17** **E 0.12** **T×E 0.29**			

Wood being an anisotropic material, has free hydroxyl group and other oxygen containing group in cell wall, which attract moisture through hydrogen bonding. Wood's cell wall absorbs moisture to its fibre saturation point (Meena, 2017). The swelling continues

until the cell wall becomes saturated with moisture. The dimensional changes in wood are caused by moisture absorption, which can be quantified volumetrically in all three planes of the wood.

Dhiman, (2014) studied the effect of *Acorus calamus* L. on *Celtis australis* L., *Pinus roxburghii* Sargent and *Bombax ceiba* L. wood and found that with an increase in concentration of extract, the volumetric swelling co-efficient decreased. Meena, (2017) studied the effect of *Acorus calamus* L. and *Parthenium hysterophorus* L. extract on dimensional stability of *Pinus roxburghii* Sargent wood and found that the wood exhibited lesser volumetric swelling which were treated with higher extract concentration. Similarily, Gupta, (2012); Chauhan, (2013) and Devi, (2013) found that *Lantana camara* L., *Melia azedarach* L., and *Ageratum conyzoides* L. extract treatments indicated a similar results for wood samples of *Pinus roxburghii* Sargent, *Celtis australis* L., and *Bombax ceiba* L., respectively. The outcomes of present investigation have been in line with the results mentioned above.

4.1.4 Volumetric Shrinkage Co-efficient

The data presented in Table-5 showed the volumetric shrinkage co-efficient of wood for different concentrations and solvents were statistically significant. Among the solvents, the highest volumetric shrinkage co-efficient (6.66%) was observed in aqueous extract treated wood samples and the lowest (6.31%) was recorded in petroleum ether extract treated wood samples. Between different concentrations, the highest value (8.16%) for volumetric shrinkage co-efficient was recorded in T_6 (control) where the lowest value (4.73%) was in T_5 (2.00%). The interaction between the solvents and concentrations were also significant where the maximum value (8.16%) was recorded in untreated wood samples and minimum value (4.39%) was observed in $T_5 \times S_1$ (2.00 % concentration).

The shrinkage of wood starts when moisture content of wood falls below the fibre saturation point (Hernanendz and Pontin, 2005). The wood looses bound water from its cell wall so moisture reduction of wood causes dimensional instability. The dimensional changes of wood due to atmospheric moisture can be minimized by appropriate chemical treatment, which improves wood properties (Pandey *et al*., 2009).

Table 4: Effect of different concentration of *Acorus calamus* L. rhizome extract on Volumetric shrinkage co-efficient (%) of *Morus alba* L. wood

Concentrations	EXTRACTS (E)			
	Petroleum Ether (S_1)	Methanol (S_2)	Aqueous (S_3)	Mean
T_1 (0.25%)	7.51	7.71	7.82	7.68
T_2 (0.50%)	6.43	6.66	6.82	6.64
T_3 (1.00%)	5.95	6.15	6.33	6.14
T_4 (1.50%)	5.43	5.62	5.81	5.62
T_5 (2.00%)	4.39	4.78	5.02	4.73
T_6 (Control)	8.16	8.16	8.16	8.16
Mean	6.31	6.51	6.66	
$CD_{0.05}$	T 0.05 E 0.03 T×E 0.08			

Wu *et al*. (2012) reported that eucalyptus wood impregnated with chemicals shrinks significantly less in volume than untreated wood. Chauhan, (2016) observed the effect of *Melia azedarach* L. fruit extract on *Bombax ceiba* and *Pinus roxburghii* wood and found that the higher concentration of extract on wood samples showed less effect on volumetric shrinkage co-efficient as compared to untreated wood samples. Dhiman, (2014); Chandel, (2016) and Pawar, (2020) used *Acorus calamus* L., *Nerium oleander* L., and *Melia composite* Willd. extract on *Celtis australis* L., *Pinus roxburghii* Sargent, *Bombax ceiba* L., wood and *Toona ciliata* M. Roem, repectively and reported highest value of volumetric shrinkage in untreated wood samples and the lowest in wood samples treated with higher concentration of extract. This might be due to the extract's bulking impact on the wood, which may have blocked the wood's water-sensitive area and enhanced wood's dimensional stability. These results are also consistent with the current study.

4.2 CHEMICAL PROPERTIES

4.2.1 Cold Water Extractives (%)

The data in Table-5 depicted the significant variations for different concentrations and solvents at 5 per cent level of significance. Among the solvents, the maximum value (4.75%) for cold water extractives was observed in aqueous extract treated wood samples and minimum value (4.46%) was obtained in petroleum ether extract treated wood samples. For different concentrations, the highest value (5.20%) for cold water extractives was recorded in T_5 (2.00%) where the lowest value (3.94%) was in T_6 (control). The interaction between the

solvents and concentrations were also found to be significant where the maximum value (5.37%) was recorded in $T_5 \times S_3$ (2.00% concentration) and minimum value (3.94%) was observed in untreated wood samples.

Table 5: Effect of different concentration of *Acorus calamus* L. rhizome extract on cold water-soluble extractives (%) of *Morus alba* L. wood

Concentrations	EXTRACTS (E)			
	Petroleum Ether (S_1)	Methanol (S_2)	Aqueous (S_3)	Mean
T_1 (0.25%)	4.22	4.35	4.47	4.35
T_2 (0.50%)	4.32	4.57	4.66	4.51
T_3 (1.00%)	4.58	4.73	4.90	4.74
T_4 (1.50%)	4.73	4.92	5.17	4.96
T_5 (2.00%)	4.97	5.26	5.37	5.20
T_6 (Control)	3.94	3.94	3.94	3.94
Mean	4.46	4.53	4.75	
$CD_{0.05}$	T 0.01 E 0.01 T×E 0.02			

Tannins, salts, sugars and gums are the most common cold water soluble extractives components in wood. Species with a high concentration of extractives have higher durability, dimensional stability, and plasticization.

Jayara, (2022) observed *Toona ciliata* M. Roem wood by using *Acorus calamus* L. (rhizome) extract and reported that the aqueous extract treated wood samples had higher value for cold water soluble extractives than untreated wood samples. More polar solvents are expected to remove a greater amount of cell wall extractives (Golpayegani *et al*., 2012). The present study reported the maximum value for cold water soluble extractives at 2 per cent extract concentration which has been supported by above mentioned study. This might be due to the leachable nature of *Acorus calamus* L. rhizome extract which have effected the extractive percentage of wood.

4.2.2 Hot Water Soluble Extractives (%)

The data for hot water soluble extractives presented in Table-6 was found statistically significant for different concentrations and solvents. Among the solvents, the highest value (6.50%) for hot water extractives was recorded in aqueous extract treated wood samples and the lowest value (6.16%) was observed in petroleum ether extract treated wood samples.

Between different concentrations, the maximum value for hot water extractives (7.71%) was recorded in T_5 (2.00%) and minimum value (4.94%) was in T_6 (control). The interaction between the solvents and concentrations were significant where the maximum value (7.94%) was recorded in $T_5 \times S_3$ (2.00% concentration) and minimum value (4.94%) was observed in untreated wood samples.

Table 6: Effect of different concentration of *Acorus calamus* L. rhizome extract on hot water-soluble extractives (%) of *Morus alba* L. wood

Concentrations	EXTRACTS (E)			
	Petroleum Ether (S_1)	Methanol (S_2)	Aqueous (S_3)	Mean
T_1 (0.25%)	5.42	5.56	5.73	5.57
T_2 (0.50%)	5.87	5.96	6.23	6.02
T_3 (1.00%)	6.36	6.50	6.78	6.55
T_4 (1.50%)	6.88	7.15	7.38	7.14
T_5 (2.00%)	7.47	7.70	7.94	7.71
T_6 (Control)	4.94	4.94	4.94	4.94
Mean	6.16	6.30	6.50	
CD $_{0.05}$	**T 0.02** **E 0.01** **T×E 0.04**			

Wood having a higher extractive content, are more durable and dimensionally stable (Dhiman, 2014). The wood contains extractives in the form of organic substances such as fats, waxes, alkaloids, and phenols which are soluble in hot water. The difference in solubility is due to hydrolysis and the resulting increase in solubility of wood material while boiling with water (Chauhan *et al*., 2020).

According to Shebani *et al*. (2009) maximum value for hot water extractives was due to the reason that hot-water extraction removes higher amount of materials, eliminates a portion of the cell structure and extracts some inorganic extracts. Nazri *et al*. (2009) reported the hot water-soluble extractives were higher than those of cold water. Jayara, (2022) reported the highest values for hot water soluble extractives in aqueous extract treated wood samples than untreated wood samples. In this current investigation the higher values for hot water soluble extractives are likewise observed in aqueous extract treated wood samples as compared to untreated wood samples. This could be due to the leachable nature of *Acorus calamus* L. rhizome extract which influenced the amount of hot water extractives in *Morus alba* L. wood.

4.2.3 Alcohol-Benzene Soluble Extractives (%)

Data pertaining to alcohol benzene soluble extractives in Table-7 had significant effect on different solvents and concentrations. Among the solvents, the highest value (11.10%) for alcohol-benzene soluble extractives was recorded in aqueous extract treated wood samples and the lowest value (10.66%) was observed in petroleum ether extract treated wood samples. Between different concentrations, the maximum value for alcohol-benzene soluble extractives (12.66%) was recorded in T_5 (2.00%) and minimum value (8.96%) was in T_6 (control). The interaction between the solvents and concentrations were found to be significant where the maximum value (12.87%) was recorded in $T_5 \times S_3$ (2.00% concentration) and minimum value (8.96%) was observed in untreated wood samples.

Table 7: Effect of different concentration of *Acorus calamus* L. rhizome extract on alcohol-benzene soluble extractives (%) of *Morus alba* L. wood

Concentrations	EXTRACTS (E)			
	Petroleum Ether (S_1)	Methanol (S_2)	Aqueous (S_3)	Mean
T_1 (0.25%)	9.58	9.75	9.97	9.77
T_2 (0.50%)	10.18	10.56	10.88	10.54
T_3 (1.00%)	10.95	11.40	11.63	11.33
T_4 (1.50%)	11.82	12.13	12.30	12.08
T_5 (2.00%)	12.47	12.65	12.87	12.66
T_6 (Control)	8.96	8.96	8.96	8.96
Mean	10.66	10.91	11.10	
CD $_{0.05}$	**T 0.12** **E 0.08** **T×E 0.21**			

The most common alcohol-benzene soluble extractives present in wood are oleoresins, fats, waxes, and oils. These involved in the metabolism, energy storage, and defence systems of trees, as well as the influence of wood pulping quality. In the current investigation, the alcohol-benzene soluble extractives were increases as concentration of extract increased than untreated wood samples.

Sharma, (2022) studied the effect of *Lantana camara* L. extract on *Salix tetrasperma* Roxb wood and observed the alcohol benzene soluble extractives in aqueous extract treated wood samples were higher than untreated wood samples. Jayara, (2022) reported same results by using *Acorus calamus* L. extract on *Toona ciliata* M. Roem wood. The results of the present study are in conformity with previous studies.

4.2.4 Holocellulose content (%)

The critical scrutiny obtained in Table-8 for holocellulose content for different concentrations and solvents had non significant variation. The values were ranged between 69.31 per cent to 69.95 per cent. Holocellulose is a specific fraction of the plant cell wall composed of cellulose and hemicelluloses. The holocellulose content is determined by chemically removing lignin from the wood sample, leaving behind the cellulose and hemicellulose components. The current study showed that the plant extract have no direct effect on holocellulose content of *Morus alba* L. wood which may remain largely unaffected by it. The effect of *Acorus calamus* L. rhizome extract didn't build any new structural component of wood, so there is no effect of any extract concentration on holocellulose content of *Morus alba* L. wood.

Table 8: Effect of different concentration of *Acorus calamus* L. rhizome extract on holocellulose content (%) of *Morus alba* L. wood

Concentrations	EXTRACTS (E)			
	Petroleum Ether (S_1)	Methanol (S_2)	Aqueous (S_3)	Mean
T_1 (0.25%)	69.45	69.63	69.56	69.55
T_2 (0.50%)	69.67	69.70	69.72	69.72
T_3 (1.00%)	69.78	69.75	69.86	69.83
T_4 (1.50%)	69.91	69.79	69.95	69.84
T_5 (2.00%)	69.83	69.84	69.90	69.87
T_6 (Control)	69.31	69.31	69.31	69.31
Mean	69.66	69.67	69.72	
CD $_{0.05}$	T NS E NS T×E NS			

4.2.5 Klason-Lignin Content (%)

It is apparent in the Table-9 that lignin content between different solvents and concentrations has non-significant. The values were ranged between 21.30 per cent to 22.24 per cent. Lignin is a complex polymer made up of phenolic compounds, primarily coniferyl, sinapyl, and p-coumaryl alcohol. These compounds are cross-linked through various chemical bonds, creating a highly irregular and complex three-dimensional structure. It provides rigidity, strength, and resistance to decay in plant cell walls and also acts as a binding agent, cementing together the cellulose and hemicellulose fibers. The rhizome extract of *Acorus calamus* L. in this investigation have not effected the lignin content because the

biopreservatives do not possess the enzymatic capability to break down lignin or modify its content. Consequently, despite the fact that biopreservatives can enhance shelf life wood and provide dimensional stability, they do not change the wood's natural chemical makeup, including the amount of lignin in it.

Table 9: Effect of different concentration of *Acorus calamus* L. rhizome extract on klason-lignin content (%) of *Morus alba* L. wood

Concentrations	EXTRACTS (E)			
	Petroleum Ether (S_1)	Methanol (S_2)	Aqueous (S_3)	Mean
T_1 (0.25%)	21.37	21.52	21.44	21.44
T_2 (0.50%)	21.62	21.65	21.78	21.68
T_3 (1.00%)	21.70	21.87	21.93	21.83
T_4 (1.50%)	22.13	22.06	22.21	22.14
T_5 (2.00%)	21.96	22.24	22.16	22.13
T_6 (Control)	21.30	21.30	21.30	21.30
Mean	21.68	21.79	21.78	
CD $_{0.05}$	T NS E NS T×E NS			

4.3 MECHANICAL PROPERTIES OF WOOD

4.3.1 Tensile strength of wood (kN/mm^2)

The data in Table-10 depicted the effect of extract on tensile strength for different concentrations and solvents at 5 per cent level of significance was statistically significant. Among the solvents, the maximum value (0.074 kN/mm^2) for tensile strength was observed in petroleum ether extract (S_1) treated wood samples and minimum value (0.071 kN/mm^2) was obtained in aqueous extract (S_3) treated wood samples. For different concentrations, the highest value (0.084 kN/mm^2) for tensile strength was recorded in T_5 (2.00%) where the lowest value (0.062 kN/mm^2) was in T_6 (control)). The interaction between the solvents and concentrations were found to be significant where the maximum value (0.088 kN/mm^2) was recorded in $T_5 \times S_1$ (2.00% concentration) and minimum value (0.062 kN/mm^2) was observed in untreated wood samples.

Tensile strength is the ability of material to withstand stretching when external forces act on a piece in opposite direction that the fibres are forced to pull apart. Higher the specific gravity of wood can be used as a measure for tensile strength of wood because specific gravity is an indicator of strength.

Table 10: Effect of different concentration of *Acorus calamus* L. rhizome extract on tensile strength (kN/mm^2) of *Morus alba* L. wood

Concentrations	EXTRACTS (E)			
	Petroleum Ether (S_1)	Methanol (S_2)	Water (S_3)	Mean
T_1 (0.25%)	0.067	0.068	0.068	0.067
T_2 (0.50%)	0.073	0.072	0.070	0.072
T_3 (1.00%)	0.079	0.073	0.071	0.074
T_4 (1.50%)	0.078	0.077	0.077	0.077
T_5 (2.00%)	0.088	0.084	0.081	0.084
T_6 (Control)	0.062	0.062	0.062	0.062
Mean	0.074	0.073	0.071	
CD $_{0.05}$	T 0.001 E 0.001 T×E 0.001			

Devi, (2003) observed that the tensile strength had risen due to solution and wood cross-linking, which strengthened the inter-linkage between preservative and wood. Similarly, Wu *et al*. (2010); Jayara, (2022) and Sharma, (2022) also reported that increasing the concentration of extract has a significant impact on tensile strength of wood by increasing the density of wood. The current study continues the trend of rising extract concentration raising wood's tensile strength.

4.3.2 Bending strength of wood (kN/mm^2)

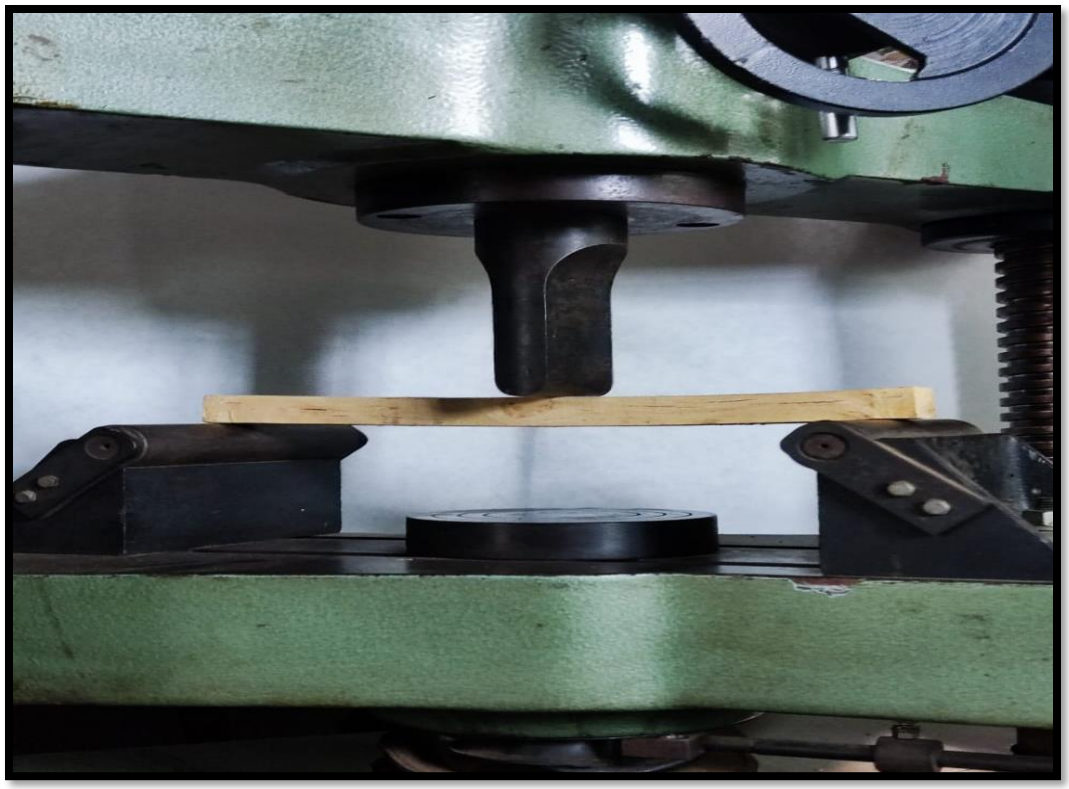
The data for bending strength in Table-11 showed significant variation for different concentrations and solvents at 5 per cent level of significance. Among the solvents, the maximum value (0.011 kN/mm^2) was observed in petroleum ether extract treated wood samples and minimum (0.008 kN/mm^2) was recorded in aqueous extract treated wood samples. Between different concentrations, the highest value (0.011 kN/mm^2) for bending strength was recorded in T_5 (2.00%) where the lowest value (0.06 kN/mm^2) was in T_6 (control). The interaction between the solvents and concentrations were found to be non significant where the values were ranged between 0.006 to 0.020 kN/mm^2.

The bending strength of wood is a measure of wood material's ability to withstand a load or force without breaking or deforming. It quantifies the maximum stress that can be applied to a wooden beam or plank before it fails in bending.

Wood sample before test

Wood sample after test

Plate 3. Determination of Tensile strength (kN/mm^2)



Wood sample before test

Wood sample after test

Plate 4. Determination of Bending strength (kN/mm^2)

Table 11: Effect of different concentration of *Acorus calamus* L. rhizome extract on bending strength (kN/mm^2) of *Morus alba* L. wood

Concentrations	EXTRACTS (E)			
	Petroleum Ether (S_1)	Methanol (S_2)	Aqueous (S_3)	Mean
T_1 (0.25%)	0.008	0.007	0.006	0.007
T_2 (0.50%)	0.009	0.008	0.008	0.008
T_3 (1.00%)	0.012	0.010	0.009	0.010
T_4 (1.50%)	0.014	0.012	0.010	0.012
T_5 (2.00%)	0.020	0.017	0.013	0.017
T_6 (Control)	0.006	0.006	0.006	0.006
Mean	0.011	0.009	0.008	
CD $_{0.05}$	**T 0.001** **E 0.001** **T×E NS**			

According to Deka and Saika, (2000) increasing the concentration of preservative (thermosetting resin) induced a small increase in the bending strength of *Fagus orientalis* wood. Sharma, (2022) and Jayara, (2022) also resulted that increasing the concentration of *Lantana camara* L. and *Acorus calamus* L. extract improved the bending strength of *Salix tetrasperma* Roxb and *Toona ciliata* M. Roem wood. In this study, there is also an increase in bending strength of wood by increasing the extract concentration on *Morus alba* L. wood.

4.3.3 Compression parallel to grain (kN/mm^2)

The data depicted in Table-12 for compression parallel to grain was found to be statistically significant for different solvents and concentrations. Among the solvents, the highest value (0.057 kN/mm^2) for compression parallel to grain was recorded in petroleum ether extract treated wood samples and the lowest in (0.055 kN/mm^2) in both methanol and aqueous extract treated wood samples. Between different concentrations, the maximum value (0.063 kN/mm^2) was obtained in T_5 (2.00%) and the minimum value (0.048 kN/mm^2) was recorded in T_6 (control). The interaction were found to be non significant and the values were ranged between 0.048 to 0.067 kN/mm^2.

The compression strength parallel to grain is a material's ability to withstand compressive forces applied along the direction of the wood grain. It represents the maximum stress that wood can endure when it is compressed in the same direction as the natural alignment of its fibres. Wood is strongest in the direction parallel to its grain because this

direction aligns with the orientation of the cellulose fibres and lignin matrix, which are the primary structural components of wood (Yadavrao, 2018).

Table 12: Effect of different concentration of *Acorus calamus* L. rhizome extract on compression parallel to grain (kN/mm^2) of *Morus alba* L. wood

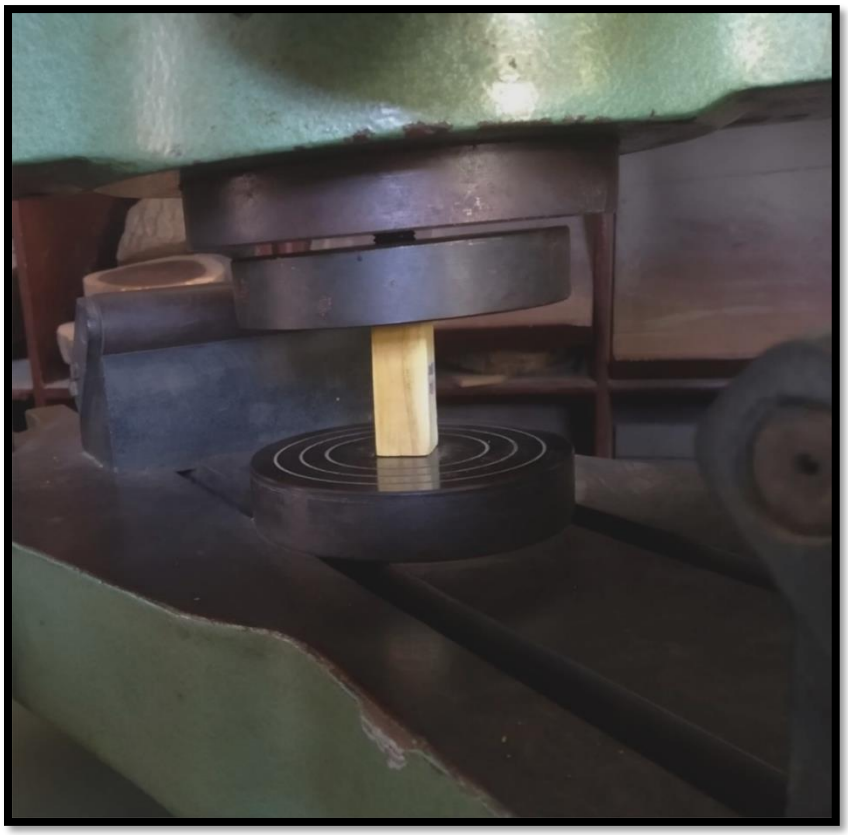
Concentrations	EXTRACTS (E)			
	Petroleum Ether (S_1)	Methanol (S_2)	Aqueous (S_3)	Mean
T_1 (0.25%)	0.052	0.051	0.050	0.051
T_2 (0.50%)	0.056	0.052	0.054	0.054
T_3 (1.00%)	0.059	0.060	0.058	0.059
T_4 (1.50%)	0.065	0.057	0.061	0.061
T_5 (2.00%)	0.067	0.062	0.059	0.063
T_6 (Control)	0.048	0.048	0.048	0.048
Mean	0.057	0.055	0.055	
CD $_{0.05}$	T 0.001 E 0.001 T×E NS			

Jayara, (2022) and Sharma, (2022) reported an increasing trend on wood's compression strength (parallel to grain) using *Acorus calamus* L. and *Lantana camara* L. extract as compared to untreated wood samples. This present study has been corroborated with previous studies.

4.3.4 Compression perpendicular to grain (kN/mm^2)

The data in Table-13 had showed significant results for different solvents and concentrations at 5 per cent level of significance. Among the solvents, the highest value (0.019 kN/mm^2) for compression parallel to grain was recorded in petroleum ether extract treated wood samples and the lowest in (0.018 kN/mm^2) in both methanol and aqueous extract treated wood samples. Between different concentrations, the maximum value (0.028 kN/mm^2) was obtained in T_5 (2.00%) and the minimum value (0.014 kN/mm^2) was recorded in T_6 (control). The interaction was found to be non significant and the values were ranged between 0.014 to 0.024 kN/mm^2.

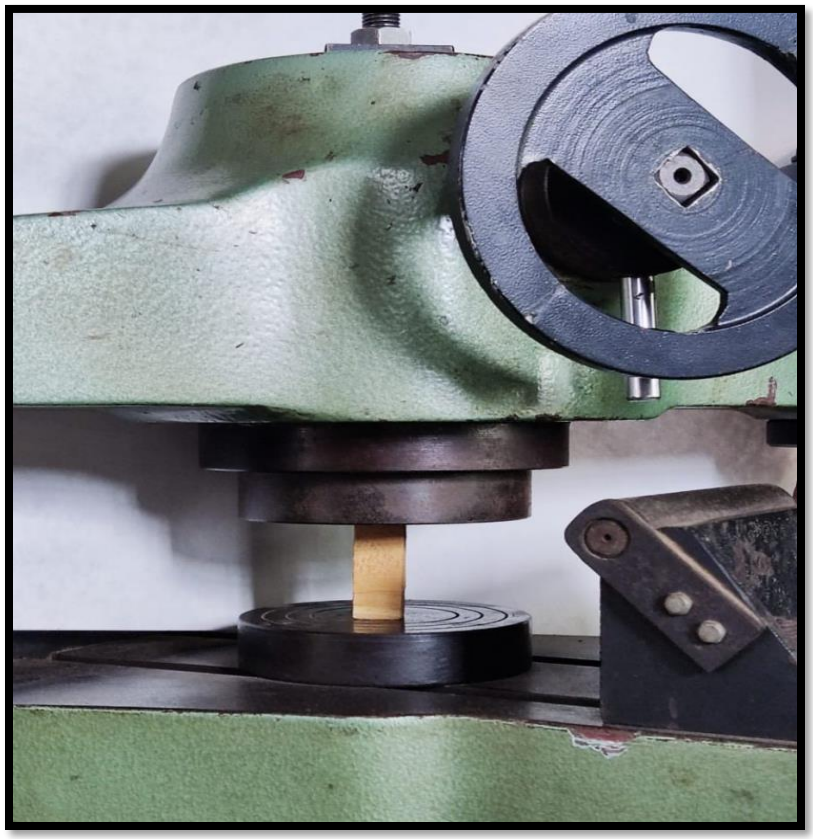
The compression strength perpendicular to grain, measures the wood's ability to resist a force applied perpendicularly to its fibre direction. It determines the maximum stress that a wooden component can withstand in this orientation before failing or crushing particularly when the stress is applied perpendicular to the grain of wood.



Wood sample before test

Wood sample after test

Plate 5. Determination of Compression parallel to grain (kN/mm^2)



Wood sample before test

Wood sample after test

Plate 6. Determination of Compression perpendicular to grain (kN/mm^2)

Table 13: Effect of different concentration of *Acorus calamus* L. rhizome extract on compression perpendicular to grain (kN/mm^2) of *Morus alba* L. wood

Concentrations	EXTRACTS (E)			
	Petroleum Ether (S_1)	Methanol (S_2)	Aqueous (S_3)	Mean
T_1 (0.25%)	0.016	0.017	0.016	0.015
T_2 (0.50%)	0.019	0.018	0.017	0.017
T_3 (1.00%)	0.020	0.018	0.019	0.019
T_4 (1.50%)	0.023	0.019	0.021	0.024
T_5 (2.00%)	0.024	0.022	0.023	0.028
T_6 (Control)	0.014	0.014	0.014	0.014
Mean	0.019	0.018	0.018	
CD $_{0.05}$	**T 0.001** **E 0.001** **T×E NS**			

According to Jayara, (2022) and Sharma, (2022) reported an increase in value for compression perpendicular to grain using *Acorus calamus* L. and *Lantana camara* L. extract wood samples than untreated wood samples. The current investigation is in line with previous findings.

4.4 PAINT APPLICATION

4.4.1 Maximum moisture content (%) of wood

The data illustrated in Table-14 revealed the maximum moisture content (%) present in wood which were pre-treated with petroleum ether extract at 2.00 per cent concentrations and then with different paint concentration. The highest value (134.64%) for maximum moisture content was recorded in T_0 i.e. absolute control and the lowest value (21.55%) at T_2 (100%) treated wood samples which was statistically at par with T_3 (95%). The data was found to be statistically significant, petroleum ether extract treated wood samples with different concentration of paint, has showed better results as compared to untreated wood samples or absolute control.

The wood samples of *Morus alba* L. pre-treated with petroleum ether extract and different paint concentration which serves as a protective layer helps in reducing the wood's ability to absorb moisture from the environment. It might be due to the hydrophobic nature of extract. Also, different paint concentration covers the pores and capillaries of the wood, making it harder for water molecules to penetrate inside wood. The present study exhibited a

significant reduction in maximum moisture content (%) when compared to the untreated, or absolute control.

Table 14: Effect of different paint concentration of pre-treated wood sample with 2 per cent concentration of petroleum ether extract on maximum moisture content (%) of *Morus alba* L. wood

Treatments	Maximum Moisture Content (%)
	Mean
T_2 (100%)	21.55
T_3 (95%)	21.82
T_4 (90%)	22.16
T_5 (85%)	26.70
T_6 (80%)	31.12
T_7 (75%)	34.24
T_8 (70%)	39.07
T_0	134.64
T_1	102.57
C.D $_{0.05}$	0.69

T_0- Absolute control

T_1- Control with 2 per cent petroleum extract treatment

4.4.2 Volumetric swelling co-efficient

The data revealed in Table-15 for volumetric swelling co-efficient (%) showed significant variation for wood which were pre-treated with petroleum ether extract (2.00 % concentrations) and different paint concentration at 5 per cent level of significance. The maximum value for volumetric swelling co-efficient (10.65%) was observed at T_0 i.e absolute control for wood samples and minimum value (2.96%) at T_2 (100%) which was statistically at par with T_3 (95%).

Table 15: Effect of different paint concentration of pre-treated wood sample with 2 per cent concentration of petroleum ether extract on volumetric-swelling co-efficient (%) of *Morus alba* L. wood

Treatments	Volumetric-swelling co-efficient (%)
	Mean
T_2 (100%)	2.96
T_3 (95%)	3.07
T_4 (90%)	3.25
T_5 (85%)	3.38
T_6 (80%)	3.52
T_7 (75%)	3.69
T_8 (70%)	3.72
T_0	10.65
T_1	6.12
C.D $_{0.05}$	0.12

Paint and thinner used

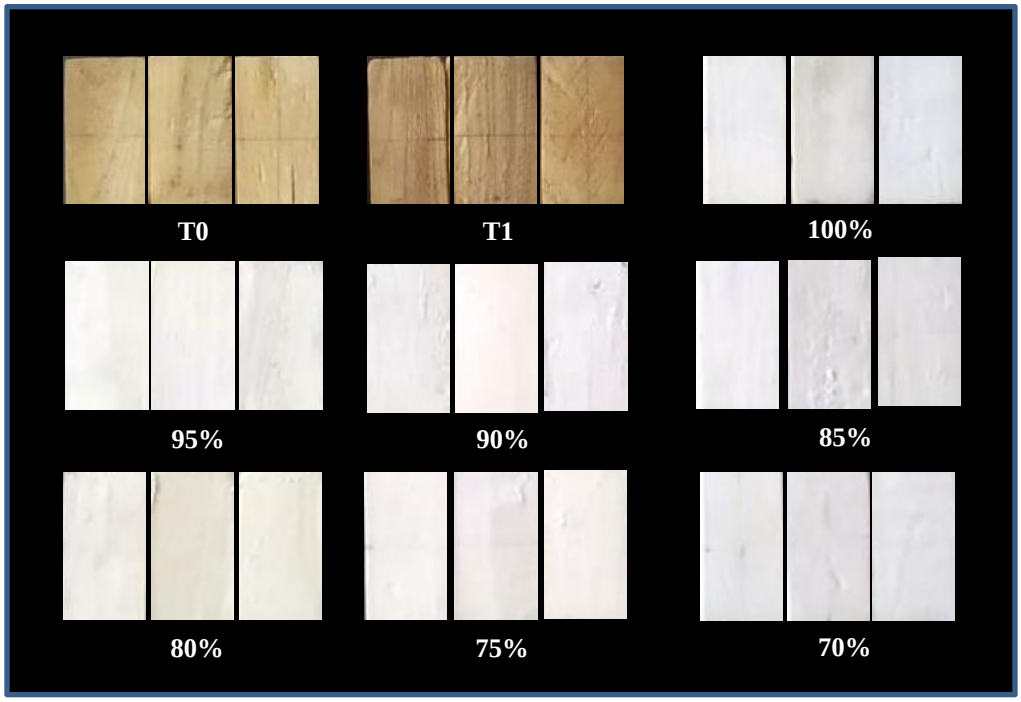


Plate 7. Application of different paint concentration on pre extract (2% petroleum ether) treated wood sample

The volumetric swelling coefficient for all wood samples decreased with increasing paint concentration. When compared to untreated wood samples or absolute control, petroleum ether extract treated wood samples had the lowest volumetric swelling coefficient. The bulking effect of extract with different paint concentration on the voids of wood's cell wall had decreased the ability of wood to attract moisture in all three planes of wood (Sharma, 2021). And the outcomes of this current investigation are supported by the earlier one.

4.4.3 Volumetric shrinkage co-efficient

The data in Table-16 depicted for volumetric shrinkage co-efficient (%) for different paint concentration on wood samples which were pre-treated with petroleum ether extract at 2.00 per cent concentrations. The maximum value for volumetric shrinkage co-efficient (8.24%) was observed at T_0 i.e absolute control for wood samples and minimum value (0.93%) at T_2 (100%) which was statistically at par with T_3 (95%), T_4 (90%), T_5 (85%), T_6 (80%) and T_7 (75%).

Table 16: Effect of different paint concentration of pre-treated wood sample with 2 per cent concentration of petroleum ether extract on volumetric-shrinkage co-efficient (%) of *Morus alba* L. wood

Treatments	Volumetric-shrinkage co-efficient (%)
	Mean
T_2 (100%)	0.93
T_3 (95%)	1.15
T_4 (90%)	1.28
T_5 (85%)	1.46
T_6 (80%)	1.61
T_7 (75%)	1.72
T_8 (70%)	1.78
T_0	8.24
T_1	4.39
C.D $_{0.05}$	0.82

For all wood samples treated with different paint concentrations, the volumetric shrinkage coefficient decreased. The capacity of wood to loose moisture had also decreased. This might be due to the bulking effect of the extract and paint penetration in wood resisting dimensional instability. In this study the different paint concentrations were applied with petroleum ether extract and different paint concentration showed considerable reduction toward shrinkage as compared to untreated, i.e. the absolute control.

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Chapter-5

SUMMARY AND CONCLUSION

The present study entitled **"Studies on effect of *Acorus calamus* L. extract on wood characterstics of *Morus alba* L."** was carried out in the laboratory of the Department of Forest Products, College of Forestry, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) during the academic session 2021-2022 and 2022-2023. The present work had following objective:

- To study the physico-chemical and mechanical properties of *Morus alba* L. wood treated with *Acorus calamus* L. extract
- Wood samples of *Morus alba* L. with different dimensions were obtained from wood workshop of Department of Forest Products and rhizome extract of *Acorus calamus* L. were extracted using solvents such as petroleum ether, methanol and water to further treat the wood samples. The results observed from the study are summarized as under:

5.1 PHYSICAL PROPERTIES OF WOOD

- In maximum moisture content, the highest value (119.67%) was observed in water extract treated samples and the lowest (114.45%) in wood sample treated with petroleum ether extract. Between the concentrations, the highest value (133.75%) was recorded in T_6 (control) and the lowest (105.30%) in T_5 (2.00%).
- The specific gravity had maximum value (0.557) in petroleum ether extract treated samples and minimum value (0.546) in water extract treated wood samples. Among the concentration the highest value (0.586) was recorded in T_5 (2.00%) and the lowest value (0.502) in T_6 (control).
- The maximum volumetric swelling co-efficient (8.90%) was recorded in water extract and minimum (8.27%) in petroleum ether extract treated wood samples. Between the concentrations, the highest value (10.59%) was observed in T_6 (control) and the lowest value (6.43%) in T_5 (2.00%).
- The maximum volumetric shrinkage co-efficient (6.66%) was observed in water extract and minimum value (6.31%) in petroleum ether extract treated wood samples. For different concentrations, the highest value (8.16%) was recorded in T_6 (control) and the lowest value (4.73%) in T_5 (2%).

5.2 CHEMICAL PROPERTIES OF WOOD

- The cold water-soluble extractives had maximum value (4.75%) in water extract treated wood samples and minimum value (4.46%) in petroleum ether extract treated wood samples. Between the concentrations, the highest value (5.20%) was recorded in T_5 (2.00%) and the lowest value (3.94%) in T_6 (control).
- The maximum value (6.50%) for hot water-soluble extractives was observed in water extract treated samples and minimum value (6.16%) in petroleum ether extract treated wood samples. Between the concentrations, the highest value (7.71%) was recorded in T_5 (2.00%) and the lowest value (4.94%) in T_6 (control).
- The maximum value (11.10%) for alcohol-benzene soluble extractives was observed in water extract treated samples and minimum value (10.66%) in petroleum ether extract treated wood samples. Between the concentrations, the highest value (12.66%) was recorded in T_5 (2.00%) and the lowest value (8.96%) in T_6 (control).
- For holocellulose content, and the klason-lignin content the value were ranged between 69.31 per cent to 69.95 per cent and 21.30 per cent to 22.24 per cent, respectively.

5.3 MECHANICAL PROPERTIES OF WOOD

- The maximum value (0.074 kN/mm^2) for tensile strength was observed in petroleum ether extract treated samples and minimum value (0.071 kN/mm^2) in water extract treated wood samples. Among the concentrations, the highest value (0.084 kN/mm^2) was recorded in T_5 (2.00%) and the lowest value (0.062 kN/mm^2) in T_6 (control).
- The maximum value (0.011 kN/mm^2) for bending strength was recorded in petroleum ether extract treated samples and minimum value (0.008 kN/mm^2) in water extract treated wood samples. Among the concentrations, the highest value (0.017 kN/mm^2) was observed in T_5 (2.00%) and the lowest value (0.006 kN/mm^2) in T_6 (control).
- For compression parallel to grain, the maximum value (0.057 kN/mm^2) was recorded in petroleum ether extract treated samples and minimum value (0.055 kN/mm^2) in water extract treated wood samples. Between the concentrations, the highest value (0.063 kN/mm^2) was observed in T_5 (2.00%) and the lowest value (0.048 kN/mm^2) in T_6 (control).
- For compression perpendicular to grain, the maximum value (0.019 kN/mm^2) was observed in petroleum ether extract treated wood samples and minimum value (0.018

kN/mm^2) in water extract treated samples. Between the concentrations, the highest value (0.028 kN/mm^2) was recorded in T_5 (2.00%) and the lowest value (0.014 kN/mm^2) in T_6 (control).

5.4 PAINT APPLICATION

- The highest value for maximum moisture content (134.64%), volumetric swelling co-efficient (10.65%) and volumetric shrinkage co-efficient value (8.24%) was observed in T_0 (absolute control) and the lowest value for maximum moisture content (21.55 %), volumetric swelling co-efficient (2.96%) and volumetric shrinkage co-efficient (0.93) was recorded in T_2 (100%).

CONCLUSION

- Specific gravity of wood increased with an increase in concentration of *Acorus calamus* L. (rhizome) extract whereas the maximum moisture content (%) had an inverse relationship with the concentration of extract.
- The volumetric swelling co-efficient (%) and volumetric shrinkage co-efficient (%) decreased with an increase in concentration of *Acorus calamus* L. extract.
- The cold water soluble extractives (%), hot water soluble extractives (%) and alcohol-benzene soluble extractives showed significant variation for *Acorus calamus* L. extract treated wood samples while for holocellulose content (%) and lignin content (%) was recorded non-significant variation for extract treated wood samples.
- The mechanical properties of wood such as tensile strength, bending strength, compression strength parallel to grain and compression strength perpendicular to grain was observed higher in petroleum ether extract treated wood samples (2.00% concentration) as compared to untreated wood.
- In paint application, the minimum value for volumetric swelling co-efficient and volumetric shrinkage co-efficient was recorded in 100 per cent paint concentration wood samples which was statistically at par with 95 per cent paint with 5 per cent thinner concentration and followed upto 75 per cent paint with 25 per cent thinner concentration while the highest value was observed in untreated wood samples.

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APPENDICES

APPENDIX- I: Analysis of variance table for effect of different concentration of *Acorus calamus* L. rhizome extract on maximum moisture content (%) of *Morus alba* L. wood

Source of Variation	df	Sum of Square	Mean Sum of Square	F- Calculated
Solvent	2	245.869	122.934	169.386
Treatment	5	5438.781	1087.756	1498.769
Treatment×Solvent	10	56.975	5.69750	7.850
Error	36	26.127	0.725	
Total	53	5767.753		

APPENDIX- II: Analysis of variance table for effect of different concentration of *Acorus calamus* L. rhizome extract on specific gravity of *Morus alba* L. wood

Source of Variation	df	Sum of Square	Mean Sum of Square	F- Calculated
Solvent	2	0.007	0.003	960.959
Treatment	5	0.099	0.019	5083.696
Treatment×Solvent	10	0.003	0.000	92.816
Error	36	0.000	0.000	
Total	53	0.110		

APPENDIX- III: Analysis of variance table for effect of different concentration of *Acorus calamus* L. rhizome extract on volumetric swelling co-efficient (%) of *Morus alba* L. wood

Source of Variation	df	Sum of Square	Mean Sum of Square	F- Calculated
Solvent	2	3.669	1.834	61.410
Treatment	5	119.332	23.866	798.745
Treatment×Solvent	10	1.065	0.106	3.566
Error	36	1.075	0.029	
Total	53	125.143		

APPENDIX- IV: Analysis of variance table for effect of different concentration of *Acorus calamus* L. rhizome extract on volumetric shrinkage co-efficient (%) of *Morus alba* L. wood

Source of Variation	df	Sum of Square	Mean Sum of Square	F- Calculated
Solvent	2	1.326	0.663	298.652
Treatment	5	73.898	14.779	6655.36
Treatment×Solvent	10	0.147	0.014	6.659
Error	36	0.079	0.002	
Total	53	75.452		

APPENDIX- V: Analysis of variance table for effect of different concentration of *Acorus calamus* L. rhizome extract on cold water extractives (%) of *Morus alba* L. wood

Source of Variation	df	Sum of Square	Mean Sum of Square	F- Calculated
Solvent	2	0.860	0.430	1381.668
Treatment	5	8.943	1.788	5747.212
Treatment×Solvent	10	0.148	0.0148	47.653
Error	36	0.011	0.000	
Total	53	9.963		

APPENDIX- VI: Analysis of variance table for effect of different concentration of *Acorus calamus* L. rhizome extract on hot water extractives (%) of *Morus alba* L. wood

Source of Variation	df	Sum of Square	Mean Sum of Square	F- Calculated
Solvent	2	1.159	0.579	981.432
Treatment	5	46.742	9.348	15825.19
Treatment×Solvent	10	0.181	0.018	30.686
Error	36	0.021	0.000	
Total	53	48.105		

APPENDIX- VII: Analysis of variance table for effect of different concentration of *Acorus calamus* L. rhizome extract on alcohol benzene soluble extractives (%) of *Morus alba* L. wood

Source of Variation	df	Sum of Square	Mean Sum of Square	F- Calculated
Solvent	2	1.872	0.936	53.932
Treatment	5	89.440	17.888	1030.36
Treatment×Solvent	10	0.468	0.046	2.697
Error	36	0.625	0.017	
Total	53	92.407		

APPENDIX- VIII: Analysis of variance table for effect of different concentration of *Acorus calamus* L. rhizome extract on holocellulose content (%) of *Morus alba* L. wood

Source of Variation	df	Sum of Square	Mean Sum of Square	F- Calculated
Solvent	2	0.043	0.0218	0.020
Treatment	5	2.204	0.440	0.403
Treatment×Solvent	10	0.093	0.009	0.008
Error	36	39.314	1.092	
Total	53	41.655		

APPENDIX- XI: Analysis of variance table for effect of different concentration of *Acorus calamus* L. rhizome extract on lignin content (%) of *Morus alba* L. wood

Source of Variation	df	Sum of Square	Mean Sum of Square	F- Calculated
Solvent	2	0.145	0.072	0.0110
Treatment	5	5.327	1.065	0.162
Treatment×Solvent	10	0.159	0.015	0.002
Error	36	236.06	6.557	
Total	53	241.692		

APPENDIX- X: Analysis of variance table for effect of different concentration of *Acorus calamus* L. rhizome extract on tensile strength (kN/mm^2) of *Morus alba* L. wood

Source of Variation	df	Sum of Square	Mean Sum of Square	F- Calculated
Solvent	2	0.000	0.000	0.916
Treatment	5	0.002	0.000	12.483
Treatment×Solvent	10	0.000	0.000	0.384
Error	36	0.001	0.000	
Total	53	0.004		

APPENDIX- XI: Analysis of variance table for effect of different concentration of *Acorus calamus* L. rhizome extract on bending strength (kN/mm^2) of *Morus alba* L. wood

Source of Variation	df	Sum of Square	Mean Sum of Square	F- Calculated
Solvent	2	0.000	0.000	1.999
Treatment	5	0.000	0.000	39.334
Treatment×Solvent	10	0.000	0.000	5.470
Error	36	0.000	0.000	
Total	53	0.001		

APPENDIX- XII: Analysis of variance table for effect of different concentration of *Acorus calamus* L. rhizome extract on compression strength parallel to grain (kN/mm^2) of *Morus alba* L. wood

Source of Variation	df	Sum of Square	Mean Sum of Square	F- Calculated
Solvent	2	0.000	0.000	106.664
Treatment	5	0.002	0.000	1874.328
Treatment×Solvent	10	0.000	0.000	3.044
Error	36	0.000	0.000	
Total	53	0.002		

APPENDIX- XIII: Analysis of variance table for effect of different concentration of *Acorus calamus* L. rhizome extract on compression strength perpendicular to grain (kN/mm^2) of *Morus alba* L. wood

Source of Variation	df	Sum of Square	Mean Sum of Square	F- Calculated
Solvent	2	0.000	0.000	0.230
Treatment	5	0.001	0.000	7.941
Treatment×Solvent	10	0.000	0.000	0.174
Error	36	0.001	0.000	
Total	53	0.002		

APPENDIX- XIV: Analysis of variance table effect of different paint concentration of pre-treated wood sample with 2 per cent concentration of petroleum ether extract on maximum moisture content (%) of *Morus alba* L. wood

Source of Variation	df	Sum of Square	Mean Sum of Square	F- Calculated
Treatment	8	40572.24	5071.531	30932.33
Error	18	2.951	0.163	
Total	26	40575.2		

APPENDIX- XV: Analysis of variance tableeffect of different paint concentration of pre-treated wood sample with 2 per cent concentration of petroleum ether extract on volumetric swelling co-efficient (%) of *Morus alba* L. wood.

Source of Variation	df	Sum of Square	Mean Sum of Square	F- Calculated
Treatment	8	149.309	18.663	3514.62
Error	18	0.095	0.005	
Total	26	149.405		

APPENDIX- XVI: Analysis of variance tableeffect of different paint concentration of pre-treated wood sample with 2 per cent concentration of petroleum ether extract on volumetric shrinkage co-efficient (%) of *Morus alba* L. wood.

Source of Variation	df	Sum of Square	Mean Sum of Square	F- Calculated
Treatment	8	135.369	16.921	72.352
Error	18	4.209	0.233	
Total	26	139.579		

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Title of the thesis	**:**	**"Studies on effect of *Acorus calamus* L. extract on wood characterstics of *Morus alba* L. wood.**
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ABSTRACT

The present study entitled "Studies on effect of *Acorus calamus* L. extract on wood characterstics of *Morus alba* L. wood was carried out during 2021-2022 and 2022-2023 in the laboratory and wood workshop of the Department of Forest Product, College of Forestry, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan. Wood samples were prepared and dipped in *Acorus calamus* L. (rhizome) extract treated with petroleum ether, methanol and water for 72 hours at different concentration 0.25, 0.50, 1.00, 1.50 and 2.00 per cent to examine the physico-chemical and mechanical properties of *Morus alba* L. wood. The highest value (119.67%) for maximum moisture content (%) was observed in untreated wood samples and the lowest value (114.45%) in wood sample treated with petroleum ether extract at 2 per cent concentration. The maximum specific gravity (0.557) was found in petroleum ether extract treated wood samples at 2 per cent concentration while the minimum (0.546) in untreated wood samples. The maximum volumetric swelling co-efficient (8.90%) and volumetric shrinkage co-efficient (6.66%) was observed in untreated wood samples and minimum volumetric swelling co-efficient (8.27%) and volumetric shrinkage co-efficient (6.31%) was noticed in petroleum ether treated wood samples at 2 per cent concentration. The highest cold water soluble extractives (4.75%), hot water soluble extractives (6.50%) and alcohol benzene soluble extractives (11.10%) was recorded in water extract treated wood samples at 2 per concentration while the lowest cold water soluble extractives (4.46%), hot water soluble extractives (6.16%) and alcohol benzene soluble extractives (10.66%) was observed in untreated wood samples. The maximum tensile strength (0.074 kN/mm^2), bending strength (0.011 kN/mm^2), compression parallel to grain (0.057 kN/mm^2) and compression perpendicular to grain (0.019kN/mm^2) was found in petroleum ether extract treated wood samples at 2 per cent concentration and minimum tensile strength (0.071 kN/mm^2), bending strength (0.008 kN/mm^2), compression parallel to grain (0.055 kN/mm^2) and compression perpendicular to grain (0.018 kN/mm^2) was observed in untreated wood samples. In paint application, the highest maximum moisture content (134.64%), volumetric swelling co-efficient (10.65%) and volumetric shrinkage co-efficient (8.24%) was noticed in absolute control whereas, the lowest was recorded in 100 per concentration which was statistically at par with 95 per cent paint with 5 per cent thinner concentration and upto 75 per cent paint with 25 per cent thinner concentration.

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