Evaluating the Tension Properties of Timber in Traditional and Modern Agricultural Implements: A Study on Species Selection, Moisture Content, and Grain Orientation

Abstract

This study evaluates the tensile properties of various timber species used in agricultural implements, focusing on their tensile strength and elongation characteristics. Understanding these properties is crucial for selecting suitable wood for different applications, ensuring durability and performance under mechanical stress. The species analyzed include Yellow Teak, Red Cedar, Teak, Lebbeck, Java Plum, Eucalyptus, Margosa, Mango, Sal, and North Indian Rosewood. The tensile properties were determined using the IS 1708 standard on a servo-controlled universal testing machine. Results showed that Sal exhibited the highest tensile strength and elongation, making it the strongest and most flexible wood with consistent properties. Margosa also demonstrated high tensile strength and moderate elongation with very low variability, indicating reliable performance. Eucalyptus and North Indian Rosewood presented strong and moderately flexible properties with consistent material characteristics. Teak, known for its strength and high elongation, combines robustness and flexibility, while Red Cedar showed moderate tensile strength but higher elongation, offering greater flexibility. Yellow Teak, although reasonably strong, had lower elongation, indicating less flexibility. Lebbeck was strong and highly flexible but showed significant variability in tensile strength. Mango exhibited moderate tensile strength and elongation with low variability, suggesting consistent performance. Java Plum had the lowest tensile strength and moderate elongation, indicating it is less strong and not very flexible. The findings emphasize the influence of environmental conditions, soil type, silvicultural factors, tree age, anatomy, and the position of the test piece within the tree on the physical and mechanical properties of wood. This comprehensive analysis aids in the selection of optimal timber for agricultural applications, enhancing the efficiency, reliability, and sustainability of agricultural implements.

***Keywords*:** Timber tensile properties, Agricultural implements, Tensile strength, Elongation characteristics, Universal testing machine, Wood durability, Mechanical stress

1. Introduction

Timber has been a foundational material in agriculture for centuries, providing essential structural components for a variety of implements and machinery. The evolution of agricultural practices has led to an increased demand for materials that are not only durable but also capable of withstanding significant mechanical stresses. Among the various mechanical properties of timber, tension properties are particularly critical for the performance and longevity of agricultural implements.

Tension properties refer to the ability of a material to withstand forces that attempt to elongate or pull it apart. In the context of agricultural timber, these properties are essential for ensuring that the implements can endure the dynamic and often harsh working conditions they are subjected to. From plow beams and tool handles to structural components of barns and storage facilities, timber's ability to resist tensile forces directly impacts the effectiveness and safety of agricultural operations. Understanding the tension properties of timber involves examining several factors, including species selection, moisture content, grain orientation, and the presence of defects such as knots and splits. Different species of wood exhibit varying levels of tensile strength, which is influenced by their cellular structure and density. Additionally, the moisture content of timber plays a crucial role in its mechanical behavior; wood with high moisture content tends to be weaker and more prone to deformation under tensile stress. Grain orientation is another critical aspect, as wood is anisotropic, meaning its strength varies with direction relative to the grain. Timber exhibits the highest tensile strength when the load is applied parallel to the grain, making this an important consideration in the design and manufacture of agricultural implements. Furthermore, imperfections like knots, which are common in timber, can significantly reduce its tensile strength by creating stress concentrations that can lead to failure under load.

In agricultural applications, where implements are often exposed to variable and sometimes extreme environmental conditions, the selection of timber with optimal tension properties is vital. This ensures that the tools and structures not only perform efficiently but also have a prolonged service life, reducing the need for frequent replacements and repairs. Overall, a comprehensive understanding of the tension properties of agricultural timber is essential for engineers, farmers, and manufacturers to make informed decisions regarding material selection and implement design. This knowledge helps in enhancing the reliability and effectiveness of agricultural operations, ultimately contributing to more sustainable and productive farming practices. The main occupation of people residing in this region is traditional agriculture which that acts a major source of income. Agricultural practices require certain traditional techniques including tools and implements due to steep and hilly terrain comprising of shallow and stony soils. Present study has been undertaken to describe agriculture tools and implements from the local plants to facilitate the agriculture during harsh condition. Besides these agricultural tools and implements, author documented the traditional knowledge of locals about the use of plants in making the handles of harvesting tools on the basis of their preference and choice. Traditional agricultural tools and implements were made up of locally available materials like stone, wood and iron, constructed at local level or standardized factory-made implements. These tools and implements were economical in term of labour, money and time saving **(Karthikeyan et al. 2009).** Also, they are operated easily without any special skills. Each of these tools and implements are usually used in connection with specific operation in the sequence of agricultural operations; land preparation, sowing, weeding, irrigation, harvesting, post-harvesting operations and transportation. Mostly all the animal drawn implements utilize wood for as a construction material, if we say about harnessing system which yoke for animal, are developed using locally available woods all the regions India. The strength of a timber depends on its species and the effects of certain growth characteristics (Yeomans 2003). Different wood species have different strength characteristics, and also within a species these characteristics may vary. Therefore, in practice, a classification system of strength classes is used. According Fuwape (2000), wood is a fibrous rigid material of plant origin. It is broadly classified as hardwood and softwood. Hardwood is derived from angiosperm or broad-leaved trees such as Mango (Mangifera indica), Sal (Shorea robusta), Lebbeck(Albizia), North Indian rosewood (Dalbergia sissoo), Red Cedar (Toona ciliate) and Teak (Tectona grandis). Hardwood timbers are mainly used for structural application because of their high strength and durability.

2.1 Wood

Wood is a natural polymer and its molecular structure is established on the cellulose chain whose cell wall comprises cellulose fibers which were laterally arranged to its axis. The wood is the intermediate and in fact the main zone of the tree.

2.2 Collection of various types of wood

Ten representative trees of average growth and health of wood Yellow Teak, Red cedar, Sheesham, Lebbeck, Java plum, Mango, Margosa, Eucalyptus, Teak and Sal from mixed and monoculture plantation were compiled from Pantnagar, District of Udam Singh Nagar.

Table 1: Nomenclature of different types of wood

S.No.	Trade Name	Hindi name	English name	Botanical name
1	Haldu	Haldu	Yellow teak	*HaldiniaCardifolia*
2	Toon	Tun	Red cedar	*Toona ciliate*
3	Sissoo	Sheesham	North Indian rosewood	*Dalbergia sissoo*
4	Mysore gum	Eucalyptus	Eucalyptus	*Eucalyptus tereticornis*
5	Margosa	Neem	Margosa	*Azadirachta indica*
6	Teak	Sagun	Teak	*Tectona grandis*
7	Mango	Aam	Mango	*Mangifera indica*
8	Jamun	Jamun	Java Plum	*Syzygiumcumini*
9	Lebbeck	Siris	Lebbeck	*Albizia lebbeck*
10	Balau	Sal	Sal	*Shorea robusta*

2.3 Stress- strain curve

A Stress-Strain curve (or when implying to the true stress-strain curve, a “flow-stress” curve) could theoretically come from a number of metal deformation procedure. However, the most familiar source of this kind of material data is obtained from a standard tensile test. Stress-Strain curves are possibly the single most widely used material test for different materials. The reason for this is that many prognostications can be made about the behavior of a big piece of metal under various loading and deformation condition based totally on the results found from a simple tensile test **(Kweon, 2001)**.

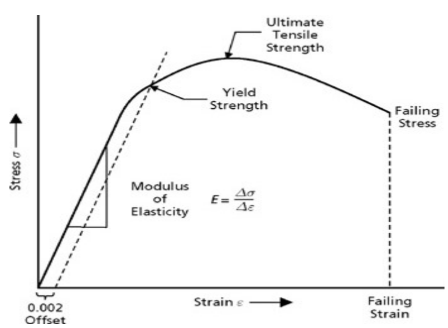


Figure 1: Typical engineering stress-strain curve with key points labeled

2.4 Mechanical Properties

2.4.1 Tensile strength

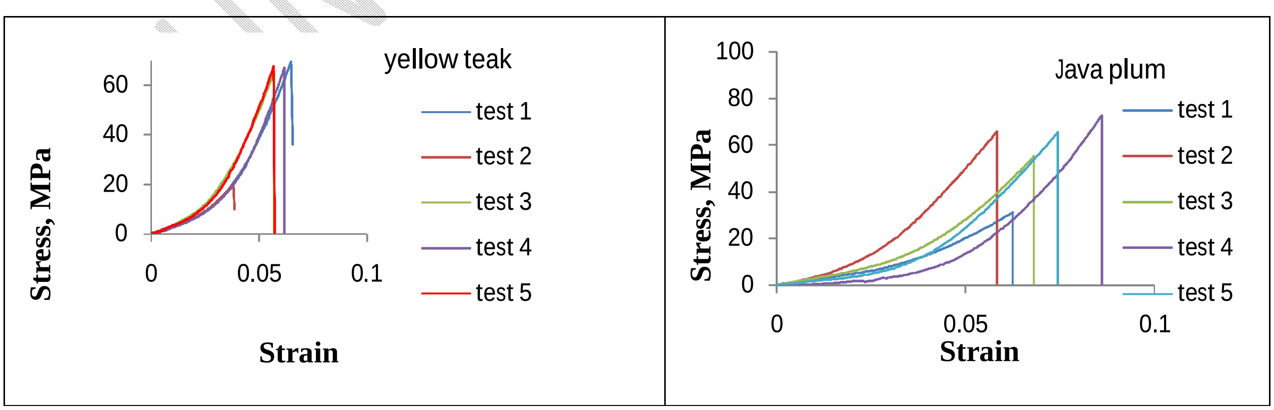
The mechanical properties of the various woods were determined by 25 kN AMT-SC, A.S.I make servo hydraulic UTM machine. The results are presented in Table 2. The Mechanical properties of particles of wood were also important factors in term of strength.

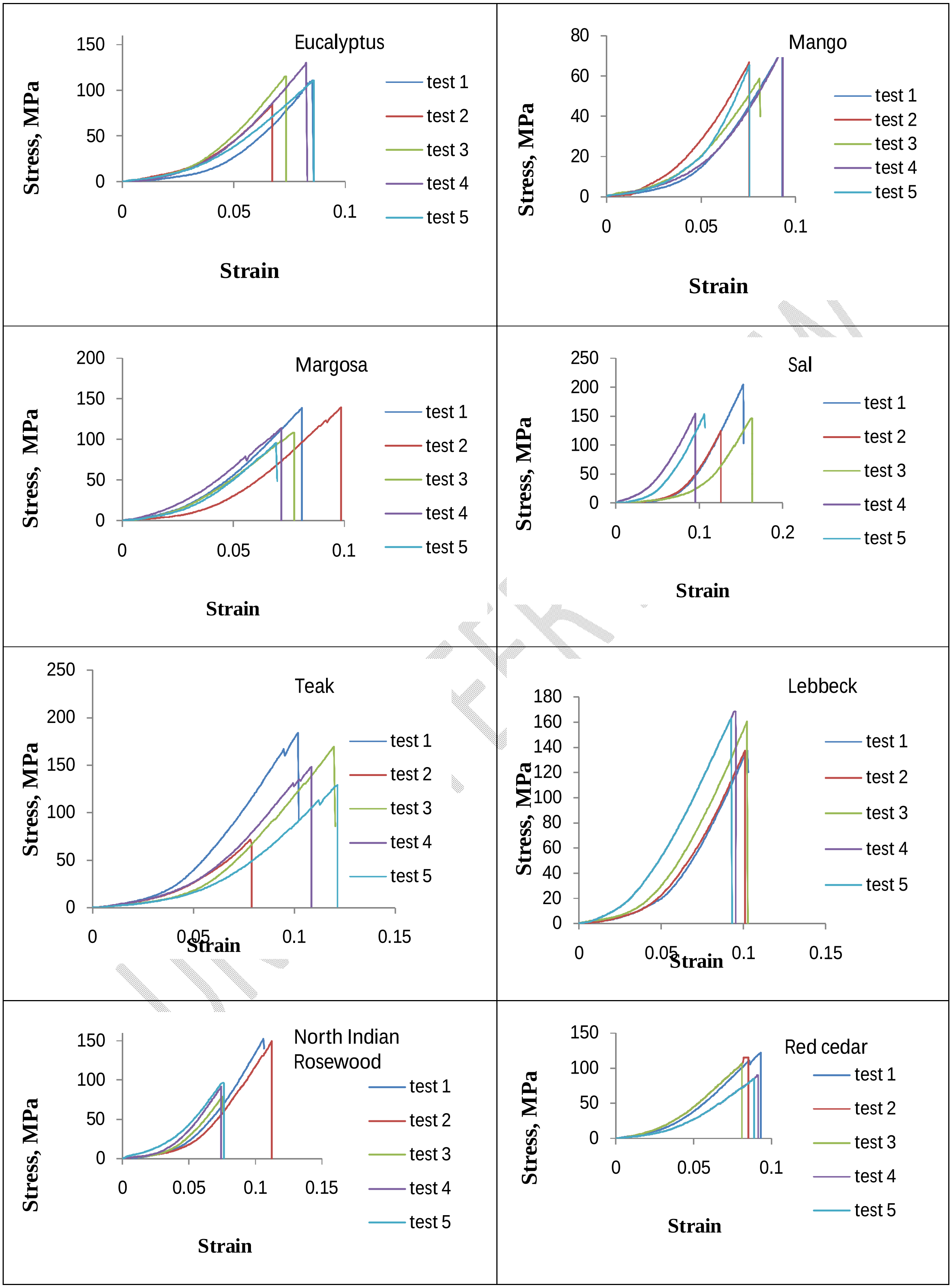
2.4.1.1 Tensile stress- strain curve

The tensile stress- strain curve for various types of wood is presented in Figure 2. All the tests were carried out as per the IS 1708 (part - 5:1986) Standards in 25 KN servo hydraulic UTM machine (AMT-SC, A.S.I make) at a crosshead speed of 1mm/min. This machine permits using displacement rather than load as the controlled variable would be monitored as a function of displacement. The stress-strain diagram is the basis for evaluating mechanical properties of materials. Possibility of recording and evaluation of stress-strain diagrams adequate to applied techniques. In relation to the application of this method of the recording and evaluation of the stress-strain diagram for wood it is fundamental to remind the different wood behavior at tension and compression loading.

This problem is very specific for wood in relation to specimen shape for tension perpendicular to grain. The cross-sectional area is determined by the dimensions 5×5 mm^2. The applied method of recording and evaluation of the stress-strain diagram have been developed gradually until the present configuration.

The aim of this contribution is to give the newest information about experimental verification of the method of recording and evaluation of the stress- Strain diagrams at the tension loading. Further, want to inform which characteristics can be calculated from the stress-strain diagram and used for evaluation of the basic mechanical properties, elasticity, plasticity, toughness and strength.





Eucalyptus
Stress, MPa
Strain
0
50
100
150
0
0.05
0.1
test 1
test 2
test 3
test 4
test 5
Mango
Stress, MPa
Strain
0
20
40
60
80
0
0.05
0.1
test 1
test 2
test 3
test 4
test 5
Margosa
Stress, MPa
Strain
0
50
100
150
200
0
0.05
0.1
test 1
test 2
test 3
test 4
test 5
Sal
Stress, MPa
Strain
0
50
100
150
200
250
0
0.1
0.2
test 1
test 2
test 3
test 4
test 5
Teak
Stress, MPa
Strain
0
50
100
150
200
250
0
0.05
0.1
0.15
test 1
test 2
test 3
test 4
test 5
Lebbeck
Stress, MPa
Strain
0
20
40
60
80
100
120
140
160
180
0
0.05
0.1
0.15
test 1
test 2
test 3
test 4
test 5
North Indian Rosewood
Stress, MPa
Strain
0
50
100
150
0
0.05
0.1
0.15
test 1
test 2
test 3
test 4
test 5
Red cedar
Stress, MPa
Strain
0
50
100
150
0
0.05
0.1
test 1
test 2
test 3
test 4
test 5

Figure 2: shows the engineering stress-strain curve for different types of wood and strains from zero up to the specimen fracture.

Yellow teak has moderate tensile strength and lower elongation, indicating it is reasonably strong but not very flexible. Red cedar has moderate tensile strength but higher elongation, making it more flexible compared to yellow teak. This wood has high tensile strength and moderate elongation, making it very strong and reasonably flexible. Teak is strong with high elongation, indicating both strength and good flexibility. Lebbeck is strong and highly flexible, but the high standard deviation in tensile strength suggests variability in strength. Java plum has the lowest tensile strength and moderate elongation, indicating it is less strong and not very flexible. Eucalyptus is strong and moderately flexible with consistent material properties. Margosa has high tensile strength and moderate elongation with very low variability, indicating reliable performance. Mango has moderate tensile strength and elongation with low variability, suggesting consistent performance. Sal has the highest tensile strength and elongation, making it the strongest and most flexible wood in the list with consistent properties.

Table 2: Tensile properties of different types of wood

S.No	Types of wood	Tensile ultimate Strength (MPa)		(%) Elongation	
		Mean	S.D.	Mean	S.D.
1.	Yellow teak	66.8	1.86	5.95	0.44
2.	Red cedar	79.2	1.83	9.76	1.34
3.	North Indian rosewood	140.94	3.91	8.25	0.44
4.	Teak	96.5	1.12	10.25	0.34
5.	Lebbeck	101.2	4.61	10.62	0.15
6.	Java plum	63.8	0.84	6.95	0.39
7.	Eucalyptus	113.8	1.59	8.92	0.18
8.	Margosa	125.14	0.50	8.16	0.18
9.	Mango	79.2	0.55	8.23	0.12
10.	Sal	151.36	0.74	12.09	0.19

The physical and mechanical properties of wood can vary as a result of environmental conditions, soil type silvicultural factors, tree age, tree anatomy and even the position of the test piece within the tree **(Awan A. R. *et al.* 2012)**.The tensile test was carried out as per IS

1708 standard on servo controlled universal testing machine (AMT-SC, A.S.I) Table 2 shows the ultimate tensile strength for Lebbeck, Sal, Teak, Red cedar, Margosa, North Indian Rosewood, Yellow teak, Mango, Eucalyptus and Java plum wood were 101.2, 151.36, 96.5, 79.2, 125.14, 140.94, 66.68, 78.43, 113.8 and 63.8 MPa respectively. The standard deviation was found for the different woods as yellow teak (1.86), Red cedar (1.83), North Indian Rosewood (3.91), Teak (1.12), Lebbeck (4.61), Java plum (0.84), Eucalyptus (1.59), Margosa (0.50), Mango (0.55) and Sal (0.74) respectively.

3.0 Summary and conclusion

- Highest Tensile Strength: Sal (151.36 MPa) - most suitable for high-stress applications.
- Lowest Tensile Strength: Java Plum (63.8 MPa) - least suitable for high-stress applications.
- Highest Elongation: Sal (12.09%) - most suitable for applications requiring flexibility.
- Lowest Elongation: Yellow Teak (5.95%) - least suitable for applications requiring flexibility.

These properties are essential for choosing the right type of wood for specific applications, balancing between strength and flexibility requirements.

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