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The Comparison of Tensile Strengths of Different Tree Species and Their Evaluation in Agricultural Tools

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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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 timber 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 Rosetimber. 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 Most Intense and flexible timber with consistent properties. Margosa also demonstrated high tensile strength and moderate elongation with very low variability, indicating

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reliable performance. Eucalyptus and North Indian Rose timber presented Intense 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 Intense, had lower elongation, indicating less flexibility. Lebbeck was Intense 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 Intense and not very flexible. 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; timber 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, tensile properties are particularly critical for the performance and longevity of agricultural implements.

Tensile 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, tensile properties are essential for ensuring that the implements can endure the Foremost and often harsh working condition. 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 [1,2]. 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 timber 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; timber with high moisture content tends to be weaker and more prone to deformation under tensile stress. Grain orientation is another critical aspect, as timber is anisotropic, meaning its strength varies with direction relative to the grain [3,4]. 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 tensile 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 tensile properties of agricultural timber is essential for engineers, farmers, and manufacturers to make informed decisions regarding material selection and implement design [5-7]. 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 act as 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 calculate the tensile properties of different types of timber which is used in agricultural implements and tools [8,9]. Traditional agricultural tools and implements were made up of locally available materials like stone, timber and iron, constructed at local level or standardized factory-made implements. These tools and implements were economical in term of labor, money and time saving [10]. 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. The strength of a timber depends on its species and the effects of certain growth characteristics. Different timber 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 [11], timber is a fibrous rigid material of plant origin. It is broadly classified as hard timber and soft timber. Hard timber is derived from angiosperm or broad-leaved trees such as Mango (*Mangifera indica*), Sal (*Shorea robusta*), Lebbeck (*Albizia*), North Indian rose timber (*Dalbergia sissoo*), Red Cedar (*Toona ciliate*) and Teak (*Tectona grandis*). Hard timber timbers are mainly used for structural application because of their high strength and durability.

2. EXPERIMENTAL DETAILS

2.1 Timber

Timber is regarded as one of the most sustainable materials, requiring less energy for processing into finished products compared to many other materials. It is readily available in India and boasts a high strength-to-weight ratio, making it an ideal choice for framing. Certain species are notably resistant to rot. Timber withstands humidity with minimal structural changes compared to other building materials, is highly durable.

Timber is easily shaped and cut with simple hand tools and chisels, offering numerous design possibilities. It can be framed or shaped in various ways due to its flexibility. The key environmental benefits of timber include its renewability and biodegradability. Timber also provides excellent insulation against both hot and cold weather. When properly preserved to resist decay and rot, timber structures can have extended lifespans. Additionally, timber is a flexible material that is easy to work with and handle.

2.2 Collection of Various Types of Timber

Ten representative trees of average growth and health of timber *i.e.* 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 which is shown in Table 1.

2.3 Stress- Strain Curve

A Stress-Strain curve (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) shown in Fig. 1.

2.4 Mechanical Properties

2.4.1 Tensile strength testing

Testing specimen were prepared per IS 1708 (part - 5:1986) for tensile as shown in Fig. 2. The L_0 gauge length was taken as $5.65\sqrt{(A_0)}$. A Test was conducted using 25 kN servo hydraulic UTM machine (AMT-SC, A.S.I make).

Table 1. Nomenclature of various types of timber used in agricultural Implements

S.No.	Trade Name	Hindi name	English name	Botanical name
1	Haldu	Haldu	Yellow teak	*Haldinia Cardifolia*
2	Toon	Tun	Red cedar	*Toona ciliate*
3	Sissoo	Sheesham	North Indian rosetimber	*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	*Syzygium cumini*
9	Lebbeck	Siris	Lebbeck	*Albizia lebbeck*
10	Balau	Sal	Sal	*Shorea robusta*

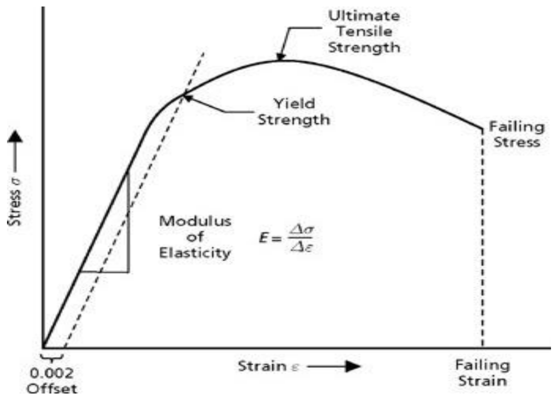


Fig. 1. Engineering stress-strain curve with key points labeled, Thomas [12]

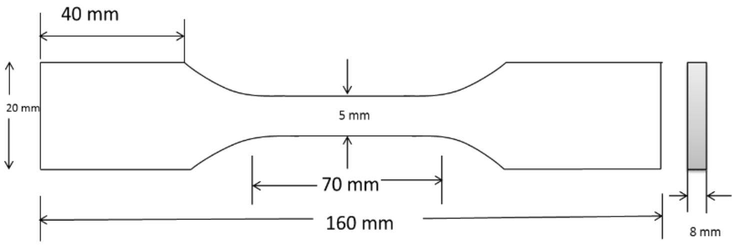


Fig. 2. Specimen geometry of tensile test (IS 1708 (part - 5:1986))

Fig. 3. Universal testing machine

2.5 Statistical Analysis

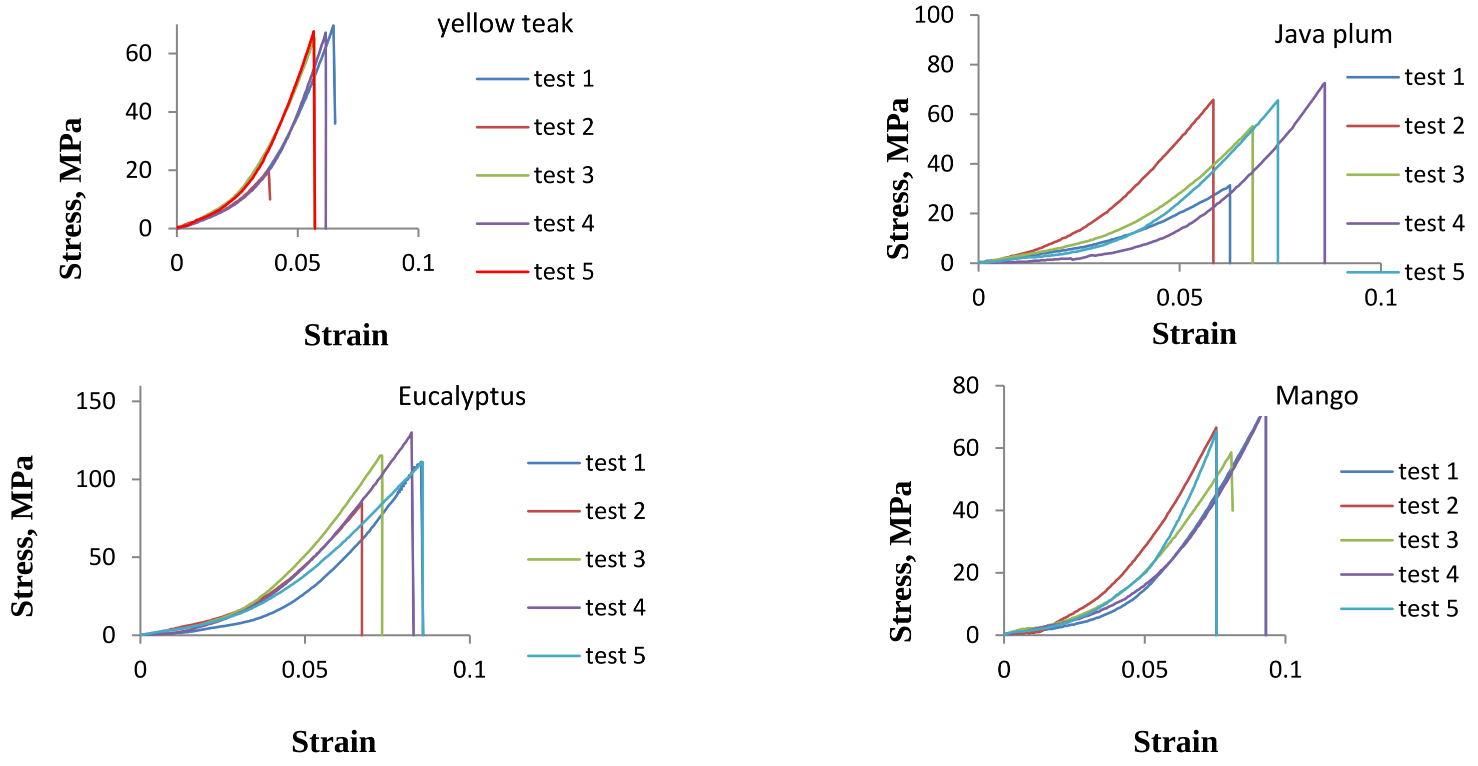
2.5.1. One-way Anova analysis

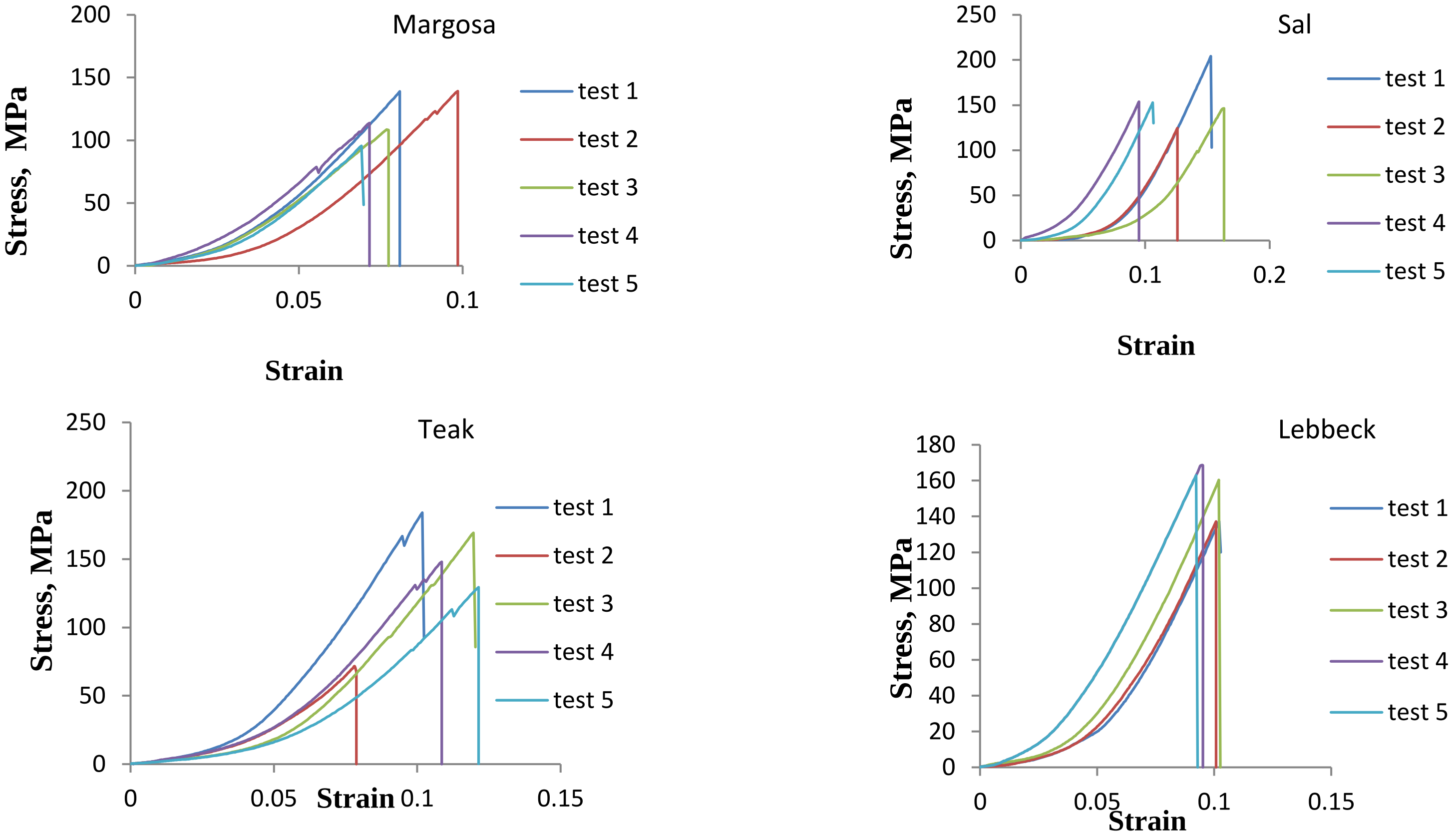
The differences in tensile strength between different types of timber were analyzed by one-way analysis of variance (ANOVA). All statistical analysis was performed by using SigmaStat® 3.1 statistical software (Systat www.systat.com).

3. RESULTS AND DISCUSSION

3.1 Tensile Stress- Strain Curve

The tensile stress- strain curve for various types of timber is presented in Fig. 2. This UTM 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.


yellow teak
Stress, MPa
Strain
test 1
test 2
test 3
test 4
test 5
Java plum
Stress, MPa
Strain
test 1
test 2
test 3
test 4
test 5
Eucalyptus
Stress, MPa
Strain
test 1
test 2
test 3
test 4
test 5
Mango
Stress, MPa
Strain
test 1
test 2
test 3
test 4
test 5


Margosa
Stress, MPa
Strain
test 1
test 2
test 3
test 4
test 5
Sal
Stress, MPa
Strain
test 1
test 2
test 3
test 4
test 5
Teak
Stress, MPa
Strain
test 1
test 2
test 3
test 4
test 5
Lebbeck
Stress, MPa
Strain
test 1
test 2
test 3
test 4
test 5

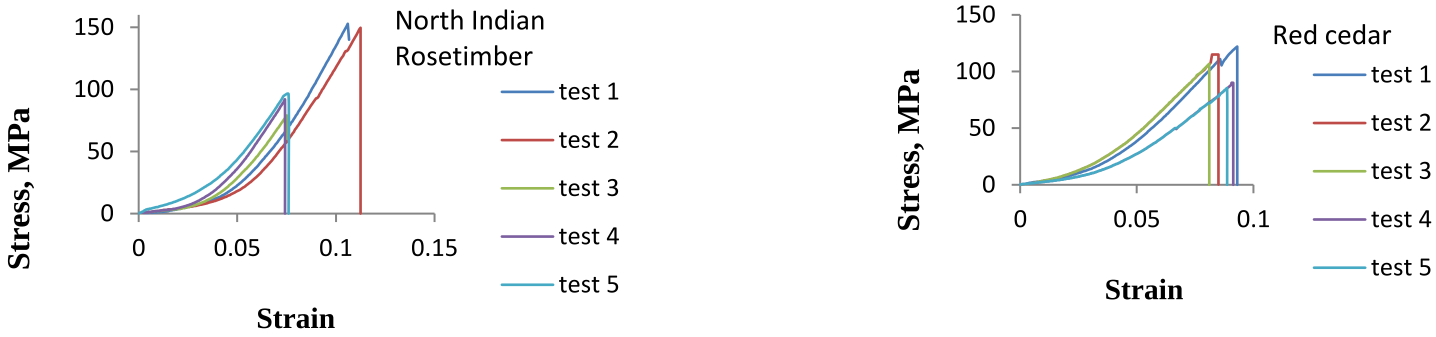


Fig. 4. Engineering stress-strain curve for different types of timbers

Table 2. Tensile properties of various types of timber

S. No.	Types of timber	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 rose timber	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

Table 3. Analysis of variance

Source	DF	Adj	SS	Adj	MS	F-Value	p-Value
Factor	4	1153	8921	2890	232	**760**	0.000
Error	95	362	205	3789			
Total	99	1192	9121				

Table 4. Model summary

S	R-sq	R-sq (adj)	R-sq (pred)
62.3	97.1%	97.1 %	97.1 %

In relation to the application of this method of the recording and evaluation of the stress-strain diagram for timber it is fundamental to remind the different timber behavior at tension and compression loading. This problem is very specific for timber 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. Fig. 4 shows the engineering stress-strain curve for different types of timber and strains from zero up to the specimen fracture.

Table 2 shows Sal has the highest tensile ultimate strength and elongation percentage, making it very hard and flexible. North Indian Rose timber and Margosa also have high tensile strengths, indicating good resistance to tension. Teak and Lebbeck show high elongation percentages, suggesting good flexibility. Yellow Teak and Java Plum have lower tensile strengths and elongations, indicating they might be less suitable for applications requiring high mechanical strength.

Yellow teak has moderate tensile strength and lower elongation, indicating it is reasonably intense but not very flexible. Red cedar has moderate tensile strength but higher elongation, making it more flexible compared to yellow teak. This timber 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 Intense 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 Intense and not very flexible. Eucalyptus is Intense 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 most Intense and flexible timber in the list with consistent properties.

The ANOVA results indicate that there are statistically significant differences among the means of the groups for the factor being tested, as evidenced by the large F-value and the p-value less than 0.001. This suggests that the factor has a significant effect on the dependent variable.

4. 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 crucial for selecting the appropriate type of timber for various applications, ensuring a balance between strength and flexibility needs. Indian Rosewood is particularly valued for its durability, strength, and resistance to pests and decay, making it a superb choice for agricultural tools and implements. Sheesham is commonly used for plow handles because of its strength and ability to endure heavy use and harsh conditions. It's also popular for making handles for tools like hoes, sickles, and spades due to its comfortable grip and durability. In traditional ox-carts, Sheesham is used for axles and wheels because of its high strength and resilience. Teak's natural oils provide resistance to rot and insects, making it ideal for Plows and harrows used in wet conditions. Teak is also favoured for high-quality tool handles due to its durability and smooth finish. Neem wood is chosen for parts of seed drills and grain storage bins because of its pest-resistant properties. Lastly, mango wood is used for tool handles due to its workability and availability.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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