Experimental Investigation of Hardness and Impact Variability in Agricultural Equipment Materials

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ABSTRACT

Aims: To determine the optimal hardness for materials used in agricultural equipment to ensure safety and comfort for animals and humans. The study aims to achieve material hardness values comparable to various types of timber, which are known for their balance of hardness and safety.

Study design: To optimize the hardness of materials used in agricultural equipment to ensure they are safe and comfortable for contact with animals and humans, without causing adverse effects such as injuries. The goal is to achieve hardness values similar to those of various timber types.

Place and Duration of Study: This study was conducted to determine the hardness testingand Impact testing of selected Timbers to be used in agricultural implements in Pantnagar, Udam Singh Nagar, between September 2015 and April 2016.

Methodology: The Rockwell hardness test is generally performed when quick and direct reading is desirable. The Rockwell hardness test was carried on the Digital Hardness testing machine on HRV-Scale. The impact strength of a material is determined with a Charpy or Izod impact test named after their inventors.

Results: the hardness of different types of timber Teak, Sal, Java plum, Eucalyptus, Yellow teak, North Indian Rose timber, red cedar, Mango, Margosa and Lebbeck was found 75.4, 79.1, 68.2, 69.1, 64.0, 87.1, 30.8, 63.2, 61.7 and 64.3. the Impact Strength of different types of timber Eucalyptus, Yellow teak, Teak, Lebbeck, Java plum, Mango, Red cedar, North Indian Rose timber, Margosa and Sal was found 49.2, 39.23, 56.71, 52.21, 46.3, 48.37, 49.2, 45.23, 41.6 and 58.89 KJ/m^2. And their standard deviations were as follows yellow teak (0.67), Red cedar (1.09), North Indian Rose timber (2.12), Teak (0.23), Lebbeck (7.95), Java plum (0.34), Eucalyptus (0.34), Margosa (0.71), Mango (0.87) and Sal (1.36) respectively.

Conclusion: The timber of North Indian rose timber and Sal was found suitable for making Plankar, pulley and bearing block. The timber of North Indian rose timber, Sal and Eucalyptus was found best for making plough bottom.

Keywords: Hardness, Indentation resistance,Plastic deformation, Agricultural equipment, Material performance, Animal safety, Human safety, Optimum hardness, Timber material, Rockwell HRV-Scale, Impact strength, Material properties

1. INTRODUCTION

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, 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 **(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 timber for as a construction material, if yoke for animal, are developed using locally available timber all the regions India.

The strength of a timber depends on its species and the effects of certain growth characteristics **(Yeomans 2003)**. 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 **Fuwape (2000)**, 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 is mainly used for structural application because of their high strength and durability. Soft timber is obtained from coniferous trees, which have needle-like leaves. Examples of soft timber trees are: Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*), and Douglas fir (*Pseudotsugamenziessii*).

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Mechanical property values are given in terms of stress (force per unit area) and strain (deformation resulting from the applied stress). The mechanical property values of timber are obtained from laboratory tests of lumber of straight-grained clear timber samples (without natural defects that would reduce strength, such as knots, checks, splits, *etc*. **(ASTM 1991)**. Strength properties mean the ultimate resistance of a material to applied loads. With timber, strength varies significantly depending on species, loading condition, load duration, and a number of assorted material and environmental factors. Because timber is anisotropic, mechanical properties also vary in the three principals. axes. Property values in the longitudinal axis are generally significantly higher than those in the tangential or radial axes.it is a good index of mechanical properties as long as the timber is clear, straight grained, and free from defects. However, specific gravity values also reflect the presence of gums, resins, and extractives, which contribute little to mechanical properties. Some property relationships are nearly linear and others exponential. In fact, mechanical properties within a species tend to be linearly, rather than curvilinear, related to specific gravity; where data are available for individual species, linear analysis is suggested **(Green *et al*., 2003)**.

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Observing the above facts, the Hardness and Impact testing of timber are important factors used in determining the suitability and application of timber material, these in turn depends on the timber species.

2. EXPERIMENTAL DETAILS

2.1 Hardness testing

The Rockwell hardness testing is generally performed when quick and direct reading is desirable. The Rockwell hardness test was carried on the Digital Hardness testing machine on HRV-Scale.

The load in kg required to penetrate a steel ball of 1.128 cm diameter into the specimen to half its diameter (0.564 cm) was taken as hardness. The ball indenters are generally built of hardened tool steel or Red cedargsten carbide. The indicator is then set at zero and a major load of 150 kg enforced to the indenter and is allowed to continue for a few seconds. Hardness was taken at various points on the specimen and the average value was recorded. The Rockwell Hardness Machine used for present investigation is presented in Figure 2.

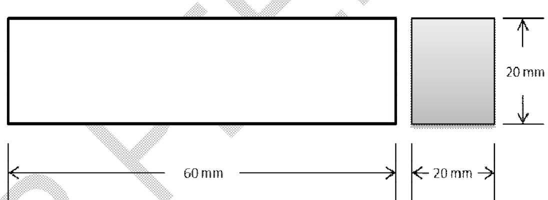

Figure 1: Specimen geometry of the Hardness test (IS 1708 (part-10:1986))

Figure 2: Digital Rockwell Hardness tester

Figure 3: Prepared specimens for Hardness test

2.2 Impact testing

The impact strength of a material is determined with a Charpy or Izod impact test named after their inventors and were developed in the early 1900's before fracture mechanics theory was available. Impact properties are not precisely used in fracture mechanic estimates, but the commercially impact tests extended to be used as a quality control mechanism to assess notch sensitivity. Notch toughness is the capability that a material possesses to absorb energy in the existence of a flaw.The impact strength of a material is typically calculated using the formula:

$$\text{Impact Strength}=\frac{E}{A} \quad \dots (1)$$

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Where, E is the energy absorbed by the material during fracture (usually measured in joules, J) and Ais the cross-sectional area of the material (usually measured in square meters, m² or square millimetres, mm²). This formula essentially measures the energy absorbed per unit area, indicating how much energy a material can absorb before fracturing, which is a measure of its toughness.

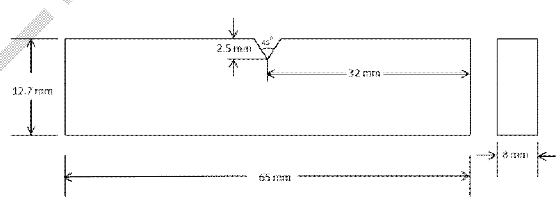

Figure 4: Specimen geometry of the Impact test (IS 1708 (part-16:1986))

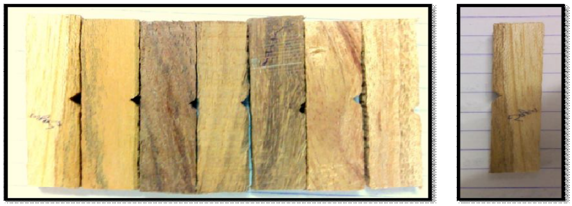

Figure 5: Prepared specimens for Impact test

Figure 6: Impact Testing Machine

3. RESULTS AND DISCUSSION

3.1 Hardness

Hardness implies a resistance to indentation, permanent or plastic deformation of materials. In agricultural equipment the optimum amount of hardness is required for better performance as they come directly in contact with animal and human body. The inauspicious hardness causes adverse effect which causes many health problems to animals like gal or injuries. Our main aim is to optimize the hardness value up to the hardness of timber material. Hardness values measured on the Rockwell HRV-Scale at load H_3 are presented in Table 1 and the effect of timber on the hardness are presented in Figure 7.

It was concluded from table 1 that the hardness of different types of timber Teak, Sal, Java plum, Eucalyptus, Yellow teak, North Indian Rose timber, red cedar, Mango, Margosa and Lebbeck was found 75.4, 79.1, 68.2, 69.1, 64.0, 87.1, 30.8, 63.2, 61.7 and 64.3. And their standard deviations were as follows North Indian Rose timber (0.311), Yellow teak (0.194), Red cedar (0.164), Teak (0.182), Lebbeck (0.162), Margosa (0.173), Java plum (0.193), Eucalyptus (0.172), Mango (0.182), and Sal (0.192) respectively (Table 1). It was clear that the North Indian Rose timber has higher hardness value as compared to other various types of timber and red cedar has less value of hardness. North Indian Rose timber has a greater standard deviation as compared to other various types of timber. The Hardness at different Types of timber was compared presented in Fig 7.

The effects of timber on Hardness were analyzed using Analysis of Variance. The results of Statistical analysis are presented in Appendix-A-1. Shows significant effect timber significant effects on the Hardness at the 5% level of significance. There was significant difference observed between the Hardness of (yellow Teak and Red cedar), (yellow teak and North Indian rose timber), (Yellow Teak and Teak), (Yellow Teak and Teak), (yellow Teak and Lebbeck), (yellow teak and Java Plum), (Yellow Teak and Eucalyptus), (Yellow Teak and Margosa), (Yellow Teak and Mango), (Yellow Teak and Sal), (Red cedar and North Indian rose timber), (Red cedar and Teak), (Red cedar and Teak), (Red cedar and Lebbeck), (Red cedar and Java Plum), (Red cedar and Eucalyptus), (Red cedar and Margosa), (Red cedar and Mango) and (Red cedar and Sal) and other types of timber have no significant difference.

Table.1 Hardness value of different types of timber in HRV- Scale

Sl.No	Types of timbers	Hardness	Standard deviation
1	Yellow teak	64	0.19
2	Red cedar	30.8	0.16
3	North Indian rose timber	87.1	0.31
4	Teak	75.4	0.18
5	Lebbeck	64.3	0.16
6	Java plum	68.2	0.19
7	Eucalyptus	69.1	0.17
8	Margosa	61.7	0.17
9	Mango	63.2	0.18
10	Sal	79.1	0.19

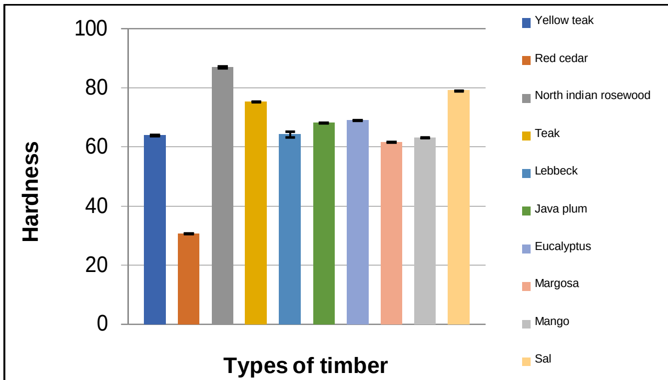

Figure 7: Hardness value of different types of timber

3.2 Impact strength

The impact strength was calculated by the formula given in equation 1.It was concluded from table 2 that the Impact Strength of different types of timber Eucalyptus, Yellow teak, Teak, Lebbeck, Java plum, Mango, Red cedar, North Indian Rose timber, Margosa and Sal was found 49.2, 39.23, 56.71, 52.21, 46.3, 48.37, 49.2, 45.23, 41.6 and 58.89 KJ/m^2. And their standard deviations were as follows yellow teak (0.67), Red cedar (1.09), North Indian Rose timber (2.12), Teak (0.23), Lebbeck (7.95), Java plum (0.34), Eucalyptus (0.34), Margosa (0.71), Mango (0.87) and Sal (1.36) respectively. It was clear from the table 2 that Sal has the highest value of Impact strength compared to other types of different timber and the minimum impact strength of red cedar. The impact strength of different types of timber was compared presented in Fig 8.

The effects of timber on Impact strength were analysed using Analysis of Variance. The results of Statistical analysis are presented in Appendix-A-2. Timber significant effects on the impact strength at the 5% level of significance.There was significant difference observed between the Hardness of (Red cedar and Eucalyptus), (North Indian rose timber and Margosa), (Lebbeck and Java Plum), (Lebbeck and Margosa), (Lebbeck and Sal), (Java Plum and Margosa), (Java Plum and Mango), (Margosa and Sal) and) and (Mango and Sal) and other types of timber have no significant difference.

Table 2: Impact strength of different types of timber

Sl. No	Types of Timber	Impact Strength (kJ/m^2)	Standard deviation
1.	Yellow teak	47.23	0.67
2.	Red cedar	39.23	1.09
3.	North Indian rose timber	56.71	2.13

4.	Teak	52.21	0.24
5.	Lebbeck	46.3	7.96
6.	Java plum	48.37	0.35
7.	Eucalyptus	49.2	0.35
8.	Margosa	45.23	0.71
9.	Mango	41.6	0.88
10.	Sal	58.89	1.37

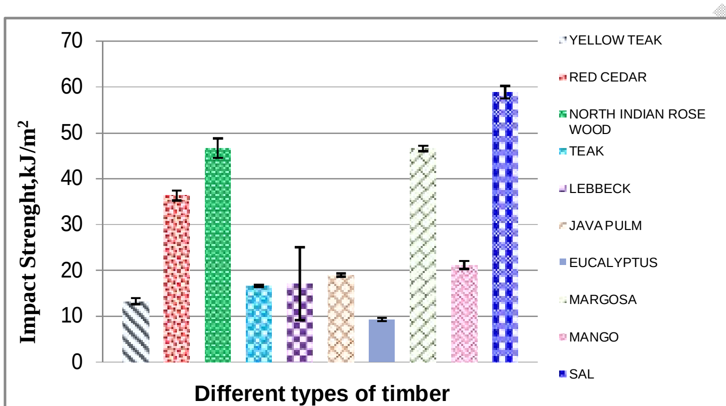

Figure 8: Effect of various types of timber on Impact Strength

4. Conclusion

The Hardness of Yellow Teak, Red cedar, North Indian rose timber, Lebbeck, Java plum, Margosa, Eucalyptus, Teak, Mango and Sal were observed as 64.00, 38.8, 87.1, 64.3, 68.2, 61.7, 69.1, 75.4, 63.2 and 79.1 respectively. ANOVA results show that interactions among the linear term Yellow Teak, Red cedar, North Indian rose timber, Lebbeck, Java plum, Margosa, Eucalyptus, Teak, Mango and Sal timber over the Hardness is significant at 0.05 % level of confidence.The Impact strength of Yellow Teak, Red cedar, North Indian rose timber, Lebbeck, Java plum, Margosa, Eucalyptus, Teak, Mango and Sal were observed as 47.23, 39.23, 56.71, 46.3, 48.37, 45.23, 49.2, 52.21, 45.23 and 58.81 kJ/m^2 respectively. ANOVA results show that interactions among the linear term Yellow Teak, Red cedar, North Indian rose timber, Lebbeck, Java plum, Margosa, Eucalyptus, Teak, Mango and Sal timber over the Impact strength is significant at the 0.05 % level of confidence.The following conclusions have been drawn on the basis of physical and mechanical properties to make the different component of agriculture implements and tools. The timber of yellow teak, teak was found suitable for making Yoke. The timber of North Indian rose timber and Sal was found suitable for making Plankar, pulley and bearing block.

REFERENCES

1. **Antwi-Boasiako C. 2016.** Strength properties and calorific values of sawdust-briquettes as wood-residue energy generation source from tropical hardwoods of different densities *Biomass & Bioenergy,***85:** 144-152.
2. **Awan A.R., Chughtai M.I., Ashraf M.Y., Mahmood, K., Rizwan, M., Akhtar, M., Siddiqui, M.T. and Khan, R.A. 2012.** Comparison for physical and mechanical properties of *Eucalyptus camaldulensisdehn* with conventional timbers. *Pak.,***44** (6): 2067-2070, 2012.
3. **Bali B.I. and Singh K.R. 1983.** A Note on the physical and mechanical properties of *tectona grandis* (Teak) from Gorakhpur division of Uttar Pradesh". *J. Timb. Assoc. (India).***24** (1): 25-34.
4. **Bhat, K.M. 1995**. A note on the heartwood proportion and wood density of 8-year-old teak. *Indian Forester***121**(6): 514–517.
5. **Bhatt, S., Dutt, B., Meena, K.R. and Ahmed, T. 2015.** Studies on tensile strength property of commercial timber species of Solan district, Himachal Pradesh. *International Journal of Farm Sciences,* **5** (3): 119-123
6. **Hanns, C.H. and Pfisterer, J. 2013.** "Mechanical properties of green wood and their relevance for tree risk assessment". *Arboriculture & Urban Forestry,***39** (5): 218–225.
7. **Izekor, D.N., Fuwape, J.A. and Oluyege, A.O. 2010. "**Effects of density on variations in the mechanical properties of plantation grown Tectona grandis wood". *Archives of Applied Sci. Res*., **2**(6) 113-120.
8. **Izekor D.N. and Fuwape J.A. 2010. "**Variations in mechanical properties among trees of the same different age classes of teak wood". *J. of Applied Sci. Res.,***6** (4), 562 – 567.
9. **Jamala, G.Y., Olubunmi, S.O., Mada, D.A. and Abraham, P. 2013**. "Physical and mechanical properties of selected wood species in tropical rainforest ecosystem, Ondo State, Nigeria." *IOSR J. Agril. And Vet. Sci.,***5** (3) pp 29-33.
10. **Josue J. 2004**. Some wood properties of Xylia xylocarpa planted in Sabah. *Sepilok Bulletin* **1**: 1-15.
11. **Joycharat, N., Thammavong, S., Limsuwan, S., Homlaead, S., Voravuthikunchai, S.P., Yingyongnarongkul, B.E., Dej-Adisai, S. and Subhadhirasakul, S. 2013.** "Antibacterial substances from Albizia myriophylla wood against cariogenic streptococcus mutans". *Archives of Pharmacal Research,* **36** (6):

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723–730.

12. **Karthikeyan, D. Veeraragavathatham, D. Karpagam and Ayisha Firdo, 2009**. "Traditional tools in agricultural practices." *Ind. J. of Traditional Knowledge*, **8** (2) 212-217.
13. **Kishan Kumar. V.S., Sharma C.M. and Sachin Gupta, 2015.** "Compression and flexural properties of finger jointed mango wood sections." *Maderas. CienciaTechnologia*., **17** (1): 151 – 160.
14. **Khazaei, J. 2008.** Water Absorption Characteristics of three wood varieties. *CercetariAgronomice in Moldova*., **151**(2):5-16.
15. **Krishna G. Saxena and Nehal A. Farooquee 1996.** Conservation and utilization of medicinal plants in high hills of the central Himalayas. *Environmental.*
16. **Lal, P. 2011** Clonal agroforestry plantations in India, *Indian J. Ecol.,* 38 (Special Issue), 6-10 conservation. **23**:75-80.
17. **Sapari, M.Z., Jamaludin Kasin, Wan Mohd Nazri, Wan Abdul Rahman and Abdul Hamid Saleh, 2012.** Bending strength properties of finger jointed Off-cut Yellow Meranti (Shorea spp.) wood. *J. Chem. Chem. Eng*., **l 6**: 997-1002.
18. **Sanyal, S.N., Bali, B.I., Singh, K.R. and Sharma, B.D. 1987**. A note on the physical and mechanical properties of plantation-grown Tectona grandis (teak) from Tanjavur district, Tamil Nadu. *Journal of the Timber Development Association of India,***33** (4): 15–22
19. **Sharmin, A., Ashaduzzaman, M. and Shamsuzzaman, M. 2015**. Variations of the physical and mechanical wood properties of Swietenia macrophylla in Mixed and Monoculture plantations. *Int. Res. J. Eng. & Tech.,***02** (05) 692-697.
20. **Shanavas, A. and Kumar, B.M. 2006.** Physical and mechanical properties of three agroforestry tree species from Kerala, India". *Journal of Tropical Agriculture,***44** (1-2): 23-30.

1. **ASTM D256, 1992.** Standard test methods for determining impact strength the Izod pendulum impact.
2. **ASTM D1037, 1999**. Standard test methods for evaluating properties of timber-base fiber and particle panel materials
3. **ISI (Indian Standards Institution) 1986**. Indian standards method of testing small clear specimens of timber**.**
4. **ISI: 1708**, *Bureau of Indian Standards* (BIS), New Delhi. **36**, 6-10.

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ABBREVIATIONS

ASTM: American Society for Testing and Materials

ISI: Indian Standards Institution

BIS: Bureau of Indian Standards

APPENDIX

Table (A-1): ANOVA table for the effect of different types of timber on Hardness

Test of between –Subject Effects						
Dependent Variable: Hardness						
Source	**Df**	**Sum of Square**	**Mean Square**	**F value**	**R squared**	**Sig**
Replication	4	16.36	4.09	1.23	0.999	
Treat	9	78.36	8.70	2.62		**
Error	36	119.3	3.31			
Total	49	214.06				
Critical difference at 5 %	2.33					
Table value of $F_{0.05}$(4,36)	3.89					
Coefficient of variance	1.32					

Table A-2: ANOVA table for the effect of different types of timber on Impact strength

Test of between –Subject Effects						
Dependent Variable: Impact strength						
Source	**Df**	**Sum of Square**	**Mean Square**	**F value**	**R squared**	**Sig**
Replication	4	69.99	17.49	0.33	0.99	
Treat	9	132.13	1468.17	27.5		**
Error	36	1923.46	53.43			
Total	49	15206.9				
Critical difference at 5 %	9.37					
Table value of $F_{0.05}$(4,36)	3.89					
Coefficient of variance	25.71					