COMPARATIVE SUITABILITY OF LOCAL WOOD SPECIES FOR TOOL HANDLES

by

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Abstract

This study compares the results of tests on wooden tool handles made from 8 local and two imported species of hickory and ash, in terms of their breaking strength and stiffness. Of the 8 local timber species, white bakain was found to give best overall performance for tool handles. The effect of various factors such as orientation of growth rings in relation to the direction of loading in strength tests on handles and the mechanical properties of wood on the ultimate strength of the handle was also studied.

INTRODUCTION

A proper tool handle is one of the basic requirements for the safety and high productivity of forest workers. Several forest tools have wooden and metallic parts. Substantial amount of work has been done throughout the world to design tool handles which fulfill the ergonomical and physical requirements of the job. In the case of wooden handles, the choice of the species depends upon its strength and other desirable characteristics. It has been reported that besides strength and elasticity, other properties such as smoothness and the type of splintering that takes place during the failure of a handle are also important (Anon, 1967).

American hickory and European ash have proved to be the most suitable species for the manufacture of forest tool handles. Because of their high cost and non-availability in Pakistan, it was decided to conduct study to compare the suitability of 8 local wood species in relation to the imported timbers for forest tool handle manufacturing.

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MATERIAL AND METHODS

The local species investigated in this study were; white bakain (Ailanthus altissima), red bakain (Melia azederach), willow (Salix tetrasperma), chinar (Platanus orientalis), kikar (Acacia nilotica), shisham (Dalbergia sissoo), mulberry (Morus alba) and poplar (Populus spp.). The imported species used as control were; ash (Fraxinus excelsior) and hickory (Carya spp.). 20 handles of all species in the shape and size prescribed by the ILO were prepared for each of the three types of tools viz., small axe, large axe and sappie or pickaroon through one of the manufacturers in Sialkot.

The lengths of the handles were 76 cms, 80 cms and 103 cms respectively for the small axe with axe head weight of 1.325 kg and large axe with axe head weight of 2.040 kg and the sappie.

Two types of tests were carried out on the handles. There were prototype testing of handles in actual sizes for strength and laboratory tests of strength on wood samples cut from the wooden handles. In prototype tests, the breaking strength of the handles was determined by holding them in a specially prepared jig and applying the load with a puller jack. The maximum load that caused the failure was determined with the help of a strain gauge. Since the orientation of the annual growth rings in relation to the direction of loading in the strength tests of handles could have the effect on their ultimate strength, one half of the handles of each species and for each tool had the growth rings at right angles as compared to those in the other half in which growth rings were parallel to load direction. The handles were classified as (1) with annual rings running parallel, (2) at right angle and (3) at undefined angle to the direction of loading. The strength of the handle was determined in kgs of load causing breakage of the handle and the elasticity as deflection in cms of the handle with the maximum load.

All the handles were also graded on the basis of their smoothness and the type of failure during strength testing as 1, 2 and 3. Grade 1 of smoothness stood for very smooth, 2 for smooth and 3 for the rough surface, while in grades of failure 1 meant a very dangerous breakage with loose splinters, 2 a dangerous splintery failure and 3 a clear breakage without splinters.

RESULTS AND DISCUSSION

Laboratory test

Laboratory tests showed (Table 1) that hickory had the highest density and strength of all the tested species. Among the local woods, kikar proved to be the hardest of all, followed by mulberry, shisham, white bakain, chinar, red bakain, willow and poplar in the descending order. The modulus of rupture of red and white bakain, shisham, mulberry, chinar and kikar did not differ much from one another inspite of the variations in density. The modulus of elasticity and impact bending strength of all the local species, however, varied considerably from one another. The compressive strength in both parallel and perpendicular to the grain directions appeared to have a direct relationship with the densities of all wood species. It is also important to mention here that large variations were recorded in the laboratory tests on samples cut from the tool handles. This was due to the fact that variations in the grain direction could not be properly oriented in the test specimens according to the standard methods of testing wood when these were cut from the tool handles.

The results of the laboratory tests are therefore, in general, lower than they should have been, had the samples been completely defect free. The average strength properties of a number of wood species are also described in one of the previous publications of the Pakistan Forest Institute,Peshawar (Siddiqui, et. al., 1986).

Since the results of modulus of rupture, modulus of elasticity and impact bending strength, in general, determine the suitability of a species for tool handles, the following species were found to be suitable for handle manufacturing based on their laboratory tests in the descending order of suitability:

1. White bakain
2. Mulberry
3. Kikar
4. Red bakain
5. Shisham

Table.1: Physical and mechanical properties of different wood species used for axe handles at 12% m.c.

Properties		Species				
		W.Bakain	Red Bakain	Pak.Willow	Chinar	Kikar
Air dry density. (g/c.c.)	$\bar{X}$	0.681	0.570	0.514	0.670	0.768
	S.D.	0.055	0.070	0.029	0.024	0.042
Modulus of rupture	$\bar{X}$	118	96	76	101	108

Table.1(contd): Physical and mechanical properties of different wood species used for axe-handles at 12% m.c.

(N/sq.mm)	S.S.	5.68	10	11.96	9.79	10.00
Modulus of elasticity	$\bar{X}$	9408	8271	5737	6274	9257
(N/sq.mm)	S.D.	600	822	883	837	1408
Max. comp. parallel	$\bar{X}$	42	36	32	47	63
to grain. (N/sq.mm)	S.D.	4.07	6.47	3.43	4.35	6.66
Comp.parallel to	$\bar{X}$	30	28	24	37	47
grain at E.L.(N/sq.mm)	S.D.	2.89	2.94	1.95	3.03	5.09
Impact bending	$\bar{X}$	30	42	10	26	28
(m-N)	S.D.	6.01	17	3.96	3.98	9.01
Cleavage (N/mm).	$\bar{X}$	29	28	21	30	28
	S.D.	4.50	3.66	2.20	6.10	4.32
Tension perpendi-	$\bar{X}$	3.68	2.94	2.25	3.02	2.94
cular to grain(N/sq.mm)	S.D.	0.61	0.67	0.0	0.44	0.65
Hardness Side	$\bar{X}$	6886	4864	3505	6671	8885
	S.D.	750	1069	380	491	1314
End	$\bar{X}$	7801	6433	4855	7059	9287
	S.D.	553	1657	390	669	1118

Properties		Species				
		Shisham	Mulberry	Poplar	Hickory	Ash
Air dry density	$\bar{X}$	0.749	0.688	0.388	0.826	0.657
(g/c.c.)	S.D.	0.038	0.030	0.024	0.061	0.067
Modulus of rupture.	$\bar{X}$	119	114	61	221	119
(N/sq.mm)	S.D.	9.48	13.98	9.29	10.88	13.70
Modulus of elesticity	$\bar{X}$	8829	9070	5239	15730	8470
(N/sq.mm)	S.D.	461	471	502	3001	461
Max. comp. parallel	$\bar{X}$	63	56	37	75	53
to grain. (N/sq.mm).	S.D.	7.42	3.31	2.16	8.99	7.53

Table.1(contd): Physical and mechanical properties of different wood species used for axe-handles at 12% m.c.

Comp.parallel to grain at E.L.(N/sq.mm)	$\bar{X}$	48	43	27	52	41
	S.D.	5.74	4.00	1.08	5.82	6.05
Impact bending (m-N)	$\bar{X}$	23	38	15	70	31
	S.D.	6.28	12.26	3.00	15.11	7.07
Cleavage (N/mm)	$\bar{X}$	29	32	18	37	30
	S.D.	1.81	3.10	1.49	3.56	2.93
Tension Perpendicular to grain(N/sq.mm)	$\bar{X}$	2.78	2.71	2.25	5.20	3.31
	S.D.	0.39	0.41	0.316	0.49	0.44
Hardness (N). Side	$\bar{X}$	7532	7889	2410	8848	6424
	S.D.	654	678	432	579	352
End	$\bar{X}$	7825	8140	4071	9055	7952
	S.D.	834	581	412	611	624

Prototype testing of handles

Although clear instructions were given to the manufacturers of the handles, for using only defect-free wood, it appeared that they had not properly understood the requirements. In several cases, handles were delivered with visible knots and therefore, had to be discarded. For that reason, some treatments had less than 10 replications.

The results of the tests with small axes, large axes and sappies are given in Tables 2, 3 and 4 respectively. The tests were carried out to find out the difference in the strength properties of handles with annual rings parallel and perpendicular to the direction of application of load. In those cases where enough samples were not available, their number was increased by using those samples with annual rings running at an undefined angle to the direction of loading. On the basis of the results the Pakistani timbers with acceptable strength for different types of handles were classified as follows:

for small axes:	Mulberry and Kikar
for big axes:	Kikar
for sappies:	White Bakain

Similarly, the timbers with the best elasticity were:

for small axes:	Mulberry and White Bakain
for big axes:	Pak.Willow
for sappies:	White bakain

The timbers were classified on the basis of their splintering ability in the following manner:

for small axes:	Poplar and White Bakain
for big axes:	White Bakain
for sappies:	Poplar

The order of timbers in terms of smoothness of their surfaces is given below:

for small axes:	Kikar and others
for big axes:	Kikar
for sappies:	Kikar and Mulberry

The above comparative analysis of the results of timber species in the prototype tests showed that the ranking of different timbers for 3 different tools was not always the same. The reasons might be found in the length of tools. The size of the handles is important in the sense that smaller-sized pieces could easily be selected from woody material which has the uniform strength and physical characteristics. As the size of the handle increases, it becomes difficult to avoid the defects like knots and irregular grains especially in timbers like shisham and kikar. Both shisham and kikar woods have in general higher strength properties as compared to white bakain but as a tool handle, failed to perform better than the latter. For short handles, therefore, kikar and mulberry performed well as far as their strength and elasticity are concerned (Table 2) and while white bakain and mulberry proved to be better for sappies handles in this regard (Table 4).

Local timbers like white and red bakain and mulberry have in general less defects than the other hardwood species of this study. They normally have straight grains which add to their performance as a tool handle. Of the imported species, hickory gave a comparatively good performance in the prototype tests. The performance of hickory as a tool handle in comparison to the local species has however, not been of the same order as was determined from the laboratory tests. In laboratory tests on small samples, the strength of hickory wood was found to be significantly higher than that of all other species.

The influence of annual ring orientation on ergonomical and mechanical properties of tool handles was variable in different timber species. The application of load parallel to the direction of the annual rings caused a less dangerous splintering in 75% of the species. On the other hand 65% and 56% of the species had lower resistance to rupture and lower elasticity respectively. It may be mentioned here that in most cases, it is difficult to have a specimen handle in which the annual rings are exactly either parallel or perpendicular to the direction of application of load. The type of splintering in fact depends upon the grain direction in relation to the long axis of the handle rather than on the orientation of the annual rings. In the case of fast growing species, it is, however, especially recommended to have the growth rings running parallel to the direction of application of load in a tool handle.

Considering weight, smoothness, elasticity, strength and splintering, white bakain proved to be the overall best species for tool handles in this study. Kikar had on the average higher strength properties, but its poor elasticity, heaviness and splintery failures makes it a less suitable choice for handles. White bakain was also found to take a smooth finish which is another requirement for a handle. It is, however, believed that the finishing of most species can be improved by superior workmanship.

White bakain is slightly more expensive than kikar. However, inspite of higher cost, it should be used for the manufacture of tool handles on the basis of its performance reported here. In the case of kikar, large variation in the strength of handles made of this wood was recorded. This was probably due to variations in the grain direction of this wood. Properly selected straight-grained kikar would therefore be the least expensive suitable species for tool handles (Table 5). Mulberry, which is also an expensive wood, may also be considered as a good substitute for white bakain.

On the basis of above discussion of results of this study, the wood species are ranked below as far as their suitability for tool handles is concerned:

1. White Bakain
2. Mulberry
3. Kikar
4. Red Bakain
5. Shisham

Poplar and chinar are not considered suitable for handle manufacturing. In practical prototype strength tests of tool handles carried out by Kraft in Kalam in 1986 with few specimens of almost all species as in the present study, the suitability ranking was found to be as follows:

1. White Bakain
2. Shisham
3. Mulberry
4. Chinar
5. Poplar
6. Pak.Willow

Thus white bakain was found to be the most suitable for tool handles in both studies.

Table 2: Mechanical, Physical and ergonomical properties of wooden handles for small axes

Species		Grain	No.of samples	Weight (gr)	Smooth-ness	Deflec-tion(cm)	Rupture (Kg)	Splint-ering
White bakain	$\bar{X}$	1.2	9	463.33	1.0	16.0	101.78	1.22
	SD	0.67		25.50	0.0	3.74	11.62	0.44
	$\bar{X}$	2.0	10	464.00	1.0	17.4	99.00	1.30
	SD	0.0		32.04	0.0	5.23	19.03	0.48
Red bakain	$\bar{X}$	1.2	10	391.00	2.0	16.7	76.7	2.10
	SD	0.42		31.07	0.0	5.60	18.98	0.88
	$\bar{X}$	2.5	10	420.00	2.0	10.2	87.7	1.70
	SD	0.53		61.64	0.0	4.42	15.59	0.82
Willow	$\bar{X}$	1.6	10	337.00	2.2	19.7	64.1	2.30
	SD	0.97		28.30	0.42	7.23	11.03	0.82
	$\bar{X}$	2.1	10	340.00	2.0	13.5	59.0	2.20
	SD	0.32		30.55	0.0	6.24	20.44	0.92
Chinar	$\bar{X}$	1.7	10	454.00	1.3	10.8	64.4	1.60
	SD	0.48		17.13	0.48	3.12	15.61	0.70
	$\bar{X}$	2.8	10	461.00	1.0	15.2	80.4	1.90
	SD	0.42	10	19.12	0.0	7.39	13.38	0.88
Kikar	$\bar{X}$	1.7	10	548.00	1.0	14.3	134.0	1.80
	SD	0.82		43.67	0.0	4.22	41.65	0.92
	$\bar{X}$	3.0	10	534.00	1.0	14.5	120.2	2.20
	SD	0.0		38.93	0.0	2.64	28.28	0.92

Table 2.(contd): Mechanical, Physical and ergonomical properties of wooden handles for small axes

Shisham								
	X̄	1.0	10	493.00	1.0	12.1	86.5	1.80
	SD	0.0		29.83	0.0	3.73	20.74	0.7
	X̄	2.0	10	506.00	1.0	14.0	100.2	2.30
	SD	0.0		20.11	0.0	4.55	23.63	0.48
Mulberry								
	X̄	1.4	10	465.00	1.0	17.3	130.3	2.60
	SD	0.52		29.15	0.0	4.47	25.07	0.70
	X̄	2.4	10	472.00	1.0	16.2	124.1	1.60
	SD	0.52		26.16	0.0	4.29	28.53	0.70
Poplar								
	X̄	1.0	10	262.50	1.0	11.9	39.2	1.10
	SD	0.0		20.31	0.0	4.91	9.31	0.32
	X̄	2.0		285.00	1.0	13.7	45.4	1.40
	SD	0.0		15.81	0.0	4.97	10.49	0.70

Table 3: Mechanical, physical and ergonomical properties of wooden handles for big axes.

Species		Grain	No.of samples	Weight (gr)	Smoothness	Deflection(cm)	Rupture (kg)	Splintering
White bakain	X̄	1.0	10	504.50	2.0	17.0	86.4	1.50
	SD	0.00		31.22	0.0	2.36	13.67	0.85
	X̄	2.0	9	496.10	2.0	14.67	94.78	1.56
	SD	0.0		14.09	0.0	2.00	8.97	0.88
Red bakain	X̄	1.44	9	464.40	2.0	13.22	7.56	1.56
	SD	0.53		49.27	0.0	5.70	16.99	0.73
	X̄	2.50	10	459.00	2.0	16.30	91.60	1.80
	SD	0.53		46.06	0.0	4.52	15.82	0.92
Willow								
	X̄	1.00	10	374.00	2.0	19.0	67.80	2.60
	SD	0.0		61.86	0.0	5.35	13.52	0.52
	X̄	2.50	·10	337.00	2.0	20.7	67.80	2.60
	SD	0.53		34.66	0.0	4.90	6.20	0.70

Table 3.(contd): Mechanical, physical and ergonomical properties of wooden handles for big axes.

Chinar								
	$\bar{X}$	1.0	10	476.00	2.0	9.0	49.0	2.00
	SD	0.0		18.38	0.0	2.40	9.19	0.82
	$\bar{X}$	2.0	10	483.00	2.0	14.0	69.0	2.10
	SD	0.0		25.41	0.0	4.62	16.02	0.88
Kikar								
	$\bar{X}$	2.0	8	556.25	1.0	13.75	104.75	2.40
	SD	0.07		29.25	0.0	1.91	26.63	0.92
	$\bar{X}$	2.0	8	566.25	1.0	15.00	121.8	2.25
	SD	0.0		35.83	0.0	3.66	36.44	0.71
Shisham								
	$\bar{X}$	1.60	10	527.00	2.0	11.10	72.90	1.40
	SD	0.97		18.29	0.0	3.60	14.27	0.70
	$\bar{X}$	2.0	10	515.00	2.0	12.0	76.30	1.80
	SD	0.0		15.09	0.0	3.56	19.01	0.79
Mulberry								
	$\bar{X}$	1.0	10	457.00	1.0	14.3	82.80	1.80
	SD	0.0		20.71	0.0	3.77	17.81	0.63
	$\bar{X}$	2.0	10	466.00	2.0	14.0	87.80	2.40
	SD	0.0		23.31.	0.0	4.58	16.59	0.84
Poplar								
	$\bar{X}$	1.2	10	315.00	1.9	17.9	66.30	2.30
	SD	0.63		10.80	0.32	5.43	16.71	0.82
	$\bar{X}$	2.1	10	340.00	1.1	19.0	74.10	2.60
	SD	0.32		47.80	0.32	4.37	10.93	0.70
Hickory								
	$\bar{X}$	1.0	10	666.00	1.0	17.70	168.90	0.70
	SD	0.0		44.52	0.0	3.16	18.81	0.67

Table 4: Mechanical, physical and ergonomical properties of wooden handles for sappies

Species		Grain	No.of samples	Weight (gr)	Smooth-ness	Deflec-tion (cm)	Rupture (kg)	Splint-ering
W.Bakain								
	$\bar{X}$	1.0	10	1,045.00	2.0	26.2	157.7	2.0
	SD	0.0		55.03	0.00	6.78	27.70	0.94
	$\bar{X}$	2.0	10	1,017.00	2.0	23.8	157.6	2.0
	SD	0.0		35.29	0.0	6.88	44.61	0.94

Table 4.(contd): Mechanical, physical and ergonomical properties of wooden handles for sappies

Red Bakain	$\bar{X}$	1.6	10	879.00	2.0	23.0	123.0	1.8
	SD	0.97		86.34	0.0	6.83	33.78	0.92
	$\bar{X}$	2.0	10	913.00	2.0	18.4	110.2	2.1
	SD	0.0		52.29	0.0	6.64	26.95	0.88
Willow	$\bar{X}$	1.2	10	742.00	2.0	17.7	84.0	1.6
	SD	0.63		54.73	0.0	5.21	16.70	0.97
	$\bar{X}$	2.1	10	734.00	2.0	19.0	86.6	2.1
	SD	0.32		71.21	0.0	5.56	16.20	0.88
Chinar	$\bar{X}$	1.0	8	1,008.75	2.0	21.13	103.25	1.75
	SD	0.0		32.27	0.0	6.83	25.50	0.46
	$\bar{X}$	2.0	9	985.56	2.0	20.33	119.56	1.78
	SD	0.0		56.59	0.0	7.00	32.97	0.97
Kikar	$\bar{X}$	1.4	10	1,129.0	1.0	12.80	106.40	2.40
	SD	0.84		62.80	0.0	6.25	44.06	0.84
	$\bar{X}$	2.4	10	1,160.0	1.0	12.20	112.60	2.50
	SD	0.52		71.93	0.0	3.05	20.41	0.85
Shisham	$\bar{X}$	1.0	10	1,024.0	2.0	16.80	120.10	2.50
	SD	0.0		57.77	0.0	3.46	14.62	0.85
	$\bar{X}$	2.0	9	1,113.33	2.0	15.33	122.33	1.56
	SD	0.0		42.13	0.0	3.00	22.29	0.88
Mulberry	$\bar{X}$	1.6	10	1,030.0	1.0	22.60	152.90	1.90
	SD	0.97		45.22	0.0	6.42	24.82	0.88
	$\bar{X}$	2.0	10	1,017.0	1.0	20.70	152.70	2.0
	SD	0.0		39.45	0.0	8.15	34.36	0.94
Poplar	$\bar{X}$	1.0	10	613.0	3.0	21.20	64.10	1.2
	SD	0.0		90.56	0.0	5.69	23.08	0.63
	$\bar{X}$	2.0	10	581.0	3.0	15.4	68.90	1.8
	SD	0.0		57.24	0.0	5.95	20.51	1.03

Table 4.(contd): Mechanical, physical and ergonomical properties of wooden handles for sappies

Ash								
	$\bar{X}$	1.7	10	915.0	1.0	19.60	122.80	2.2
	SD	0.67		75.02	0.0	5.95	20.51	1.03
	$\bar{X}$	1.0	4	860.0	1.0	17.00	116.0	1.5
	SD	0.0		43.20	0.0	2.94	6.00	1.00
	$\bar{X}$	2.0	5	954.0	1.0	22.00	127.8	2.6
	SD	0.0		78.61	0.0	3.67	16.15	0.89

Table 5: Price list of handles from Chouhan Sports Engineers Sialkot (Pakistan) (1 US $ = 21.6 Pak. Rs.)

Species	Small felling axe Pak. Rs. per handle	Big felling axe Pak. Rs. per handle	Sappie or pickaroon Pak. Rs. per handle
White bakain	70	75	100
Red bakain	70	75	100
Pak.Willow	75	85	120
Chinar	70	80	120
Kikar	65	70	100
Shisham	80	90	125
Mulberry	75	80	115
Poplar	50	60	90

CONCLUSION

From the above, it may be concluded that though the overall strength in bending of wood determines the strength of a tool handle made from it, still, great reductions are caused in the strength of the latter due to variations in the grain direction, local weaknesses in the wood material and the presence of knots large or small. This was quite evident from the results of the laboratory tests and the prototype testing of the handles. It was seen that handles made out of very strong woods failed at considerably lower loads due either to variations in grain direction or the presence of a certain localized defect. Some of the woods proved to be better than the others for small sized handles but as the size was increased, their performance was decreased. It is thus very essential that in addition to using a strong timber for manufacture of tool handles great care should also be taken in the actual selection of the material. Only specially selected material with straight grains should be used for this purpose.

REFERENCES

1. Ahmed, S.S. & M. Ayaz (1970). Identification of some of the common commercial timbers of Pakistan. Bulletin No.1 FPRD, PFI, Pakistan.

2. Anonymous. (1967). Handbook on basic logging instructor course. Logging Training Project. Govt. of India/FAO, Dehra Dun/India

3. Anonymous. (1970). Selection and maintenance of logging tools. An illustrated training manual for foresters, loggers, foremen and workers. International Labour Office, Geneva, 1970.

4. Kraft, T. (1986) Practical test of forest tool handles made out of local species. A technical report of the Pakistan Swiss Project Kalam, Pakistan.

5. Siddiqui, K. M., M. Ayaz & I. Mahmood (1986) Properties and use of Pakistan Timbers. Technical Bulletin of the FPRD, PFI, Pakistan.