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Wood properties of Japanese lilac (*Syringa reticulata*) that promoted selective use in prehistoric Hokkaido

Ryo Tsuchiya¹, Yutaka Tamai², Takanobu Sasaki² and Yuzou Sano^{2*} 

Abstract

It is known that in prehistoric Hokkaido, the wood of the Japanese lilac (*Syringa reticulata*) was used as structural material; for example, in pillars and rafters of dwellings. This suggests that Japanese lilac wood has useful properties, such as high strength and strong decay resistance. However, few studies have been conducted on the wood strength and decay resistance of this species. The present study was undertaken to evaluate the strength and decay resistance of Japanese lilac wood and reveal the factors responsible for its general use in prehistoric periods. The results of mechanical tests show that the strength of the wood, as quantified through several different indices, is above moderate. In particular, static modulus of elasticity and modulus of rupture of Japanese lilac wood were higher than those of other species commonly found in Hokkaido. Regarding decay resistance, the mass-loss rate was only 1.6% after incubation with *Trametes versicolor* for 60 days. We conclude that Japanese lilac is a suitable material for structural materials in which high bending strength is desired. In addition, its extremely high decay resistance makes it conducive to long-term use outdoors. Overall, the results of this study indicate that the extremely high decay resistance and excellent bending strength of Japanese lilac were the main reasons for its use in prehistoric periods.

Keywords *Syringa reticulata*, Japanese lilac, Mechanical properties, Decay resistance, Prehistoric period

Introduction

Japanese lilac (*Syringa reticulata*) is a deciduous hardwood tree native to East Asia. In Hokkaido, it grows in moist areas dominated by elm (*Ulmus davidiana* var. *japonica*) and ash (*Fraxinus mandshurica*) [1]. It has profuse white flowers and is mainly used as a roadside or ornamental tree, similar to the common garden lilac (*Syringa vulgaris*); however, unlike the common lilac, Japanese lilac can grow to over 10 m in height at maturity. As evidenced by the wood unearthed at archaeological sites in Hokkaido, Japanese lilac was also used in prehistoric periods to make

structural material and stakes. For example, excavations at the Yukanboshi C15 site (Chitose, Hokkaido, Japan) showed that Japanese lilac was used as material for pillars and rafters for pit houses [2]. The wood of this species is known in the traditions of the Ainu—the indigenous people of Hokkaido—to be strong and resistant to decay and thus was used for pillars and grave markers [3].

Wood properties are an important factor when considering the reasons for wood use during these periods. In particular, the results of excavation and traditional facts suggest that the Japanese lilac may have some useful properties, such as strength and decay resistance. However, there have been few empirical studies to confirm this. Therefore, this study was undertaken to evaluate the strength and decay resistance of Japanese lilac in the context of understanding building practices in prehistoric Hokkaido.

*Correspondence:

Yuzou Sano
pirika@agr.hokudai.ac.jp

¹ Graduate School of Agriculture, Hokkaido University, Sapporo 060-8589, Japan

² Research Faculty of Agriculture, Hokkaido University, Sapporo 060-8589, Japan

Methods

Mechanical test

Wood materials

Mechanical tests were performed using a specimen of Japanese lilac harvested from the Tomakomai Experimental Forest of Hokkaido University (height: 11.3 m, diameter at breast height: 21 cm). After felling, logs of 1 m in length were cut and transported to the laboratory. The logs were then sawn into 3-cm-thick lumbers and air-dried for one month.

Measurement method

Sixty-six small clear specimens with a cross section of 20 × 20 mm and a length of approximately 400 mm were cut from the air-dried lumbers, and their mechanical properties were tested. The air-dry density (WD) was measured for all specimens. Fifty-one specimens of the 66 were sawn exclusively from heartwood, while the remainders partly contained sapwood.

We followed the measurement method of Teranishi et al. [4]. First, we evaluated the dynamic modulus of elasticity (E_d) and modulus of rigidity (G) of all the specimens using the longitudinal vibration method and the torsional tests [5]. All specimens were then subjected to static bending tests (span of bending: 280 mm) according to JIS Z 2101 [6]. The static modulus of elasticity (E_b), modulus of rupture (MOR), absorbed energy up to the maximum load during static bending (U_b) and Tetmajer's modulus (TM) were calculated [7]. The proportional limit was the point where the approximately straight line from 10 to 30% of the maximum load deviated from the load–deflection curve (point B in Fig. 1). TM was calculated as the ratio of the integration value of the load–deflection curves obtained from the bending tests up to the maximum load (area of OCD in Fig. 1) to the product of the maximum load and the deflection at the maximum load (area of OACD in Fig. 1).

After the bending tests, four test specimens were cut from undamaged sections. We then measured compressive strength parallel to the grain (CS), shear strength along the longitudinal–radial plane (SS), partial bearing strength (PBS), and Brinell's hardness (H) of these specimens based on JIS Z 2101 [6]. PBS was defined as the stress that develops when the specimen is compressed under a bearing plate to 1 mm (5% of the height of the specimen). The average moisture content of the test specimens was 12.2%.

Comparison with other species generally used in prehistoric Hokkaido

To characterize the mechanical properties of the Japanese lilac wood, the index values calculated from the

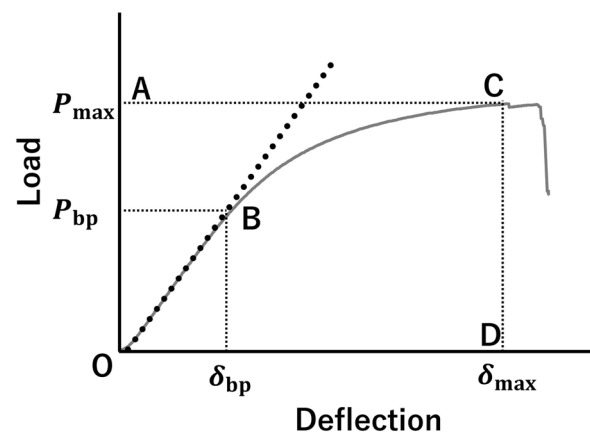


Fig. 1 An example of a load–deflection curve obtained from the bending test. P_{max} , maximum load; δ_{max} , maximum deflection; P_{bp} , proportional-limit load; δ_{bp} , proportional-limit deflection; **A** coordinate point (0, P_{max}); **B** coordinate point (δ_{bp} , P_{bp}); **C** coordinate point (δ_{max} , P_{max}); **D** coordinate point (δ_{max} , 0)

test described above were compared with those of other species or genera known to have been used as structural materials in prehistoric Hokkaido. The species or genera compared were selected based on two criteria. Firstly, the wood used as pillars, rafters, and stakes at two archaeological sites in Hokkaido: Yukanbosi C15 site and Bibi 8 site (Chitose, Hokkaido, Japan), as shown by the compilation of Itoh and Yamada [8]. Japanese lilac wood was excavated more frequently at these sites than at others. Secondly, from the species or genera, a smaller set was selected based on whether strength test data were available in two published studies [9, 10], in which mechanical tests were carried out using a method similar to that used in our study. The species and number of wood specimens used for this comparison are listed in Table 1.

Decay test

Materials

The specimens of Japanese lilac wood used in the decay test had been cut from the same trees (the same dried lumbers) from which the mechanical test specimens were obtained. For comparison, oak (*Quercus crispula*) and beech (*Fagus crenata*) were also tested. Oak was selected as a representative of wood having high resistance to decay [11], from tree species that were commonly used in prehistoric periods and during the Ainu culture. Beech, which has low resistance to decay, is specified by JIS Z 2101 [6] to be used as a control for decay tests. Oak and beech used for decay tests were grown in the Sapporo Experimental Forest of Hokkaido University.

The dimensions of specimens were approximately 20 mm × 20 mm × 20 mm. Japanese lilac and oak specimens

Table 1 Woody species referred for comparison with Japanese lilac and the number of specimens tested in the previous studies

Name of species (common name)	Number of test trees	Number of specimens	Reference
<i>Fraxinus lanuginosa</i> (Japanese ash)	5	22	Muto and Koizumi [9]
<i>Phellodendron amurense</i> (Amur cork tree)	1	2	Koizumi et al. [10]
<i>Kalopanax pictus</i> (Castor aralia)	1	3	Koizumi et al. [10]
<i>Ulmus davidiana</i> var. <i>japonica</i> (elm)	6	27	Koizumi et al. [10]
<i>Acer mono</i> (maple)	1	6	Koizumi et al. [10]
<i>Salix hultenii</i> var. <i>angustifolia</i> (willow)	1	4	Koizumi et al. [10]
<i>Tilia japonica</i> (lime tree)	1	6	Koizumi et al. [10]
<i>Sorbus commixta</i> (mountain ash)	1	11	Koizumi et al. [10]
<i>Alnus japonica</i> (alder)	2	20	Koizumi et al. [10]

were obtained from heartwood, whereas beech specimens were taken from sapwood. After cutting, specimens of Japanese lilac and oak were dried at 40 °C for 2 days in an oven, and beech specimens were air-dried at room temperature with a fan on a bench until the weight stops decreasing. Although these procedures differed from JIS Z 2101 [6], we adopted such milder conditions to minimize the formation of checks in specimens. The size, average annual ring width, and mass of each specimen were measured, and all specimens were then sterilized using ethylene oxide gas.

Preparation of test fungus

Before starting the test, the test fungus (*Trametes versicolor*, NBRC 30343) was cultured in two steps: preculture and main culture. Pre-culture was performed in the liquid medium (4% glucose, 1.5% malt extract, 0.3% peptone) with occasional stirring for 2 weeks. The mycelial culture was then inoculated into the culture bottle containing quartz sand liquid medium (1.5% malt extract) and incubated for 2 weeks.

Evaluation of decay resistance

Three specimens of each species were placed in each culture bottle so that one of the transverse sections of each specimen was in contact with the quartz sands. Three specimens of each species were placed in culture bottles without fungi in order to determine mass loss without decay. The test was conducted at 25 °C for 60 days.

At the end of the test, the mycelia on the wood specimens were scraped off and dried at 30 °C for 1 day with airflow, followed by 2 days at 60 °C. Subsequently, the mass was measured. The mass-loss and corrected mass-loss rates of the wood specimens were calculated for each species following the JIS Z 2101 (Eqs. 1 and 2) [6]. The decay resistance ratio was also determined based on JIS Z 2101 (Eq. 3) [6]:

$$\Delta m = \frac{m_1 - m_2}{m_1} \times 100 \quad (1)$$

Δm : mass-loss rate, m_1 : mass before the test, m_2 : mass after the test.

$$\Delta m_c = \Delta \overline{m}_d - \Delta \overline{m}_o \quad (2)$$

Δm_c : corrected mass-loss rate, $\Delta \overline{m}_d$: average mass-loss of the specimens with decay treatment, $\Delta \overline{m}_o$: average mass-loss of the specimens without decay treatment.

$$\Delta R_D = \frac{100 - \Delta m_{sc}}{100 - \Delta m_{bc}} \quad (3)$$

ΔR_D : decay resistance ratio, Δm_{sc} : corrected mass-loss rate of Japanese lilac or oak, Δm_{bc} : corrected mass-loss rate of beech.

Results and discussion

Mechanical test

The results of the tests are shown in Table 2, and the literature values for comparison are summarized in Table s1. Among the woody species tested and referred in this study, Japanese lilac had the highest E_b value. The E_d and MOR values of Japanese lilac were the fourth highest, followed by Japanese ash, Amur cork tree, and maple. E_d and E_b are indexes of resistance to deformation, and MOR is an index of strength under bending loads. Since E_d , MOR and E_b values of Japanese lilac were similar to, or slightly lower than, those of Japanese ash, Amur cork tree, and maple, which are considered high-strength species in Hokkaido [9], it is possible to state that Japanese lilac has higher values for these indexes. However, the TM value of Japanese lilac was the lowest among all species compared. In terms of PBS and H , Japanese lilac ranks the third lowest, followed by willow and lime trees. TM is an index of tenacity (resistance to buckling) under bending loads, and low tenacity is more likely to cause brittle fracture. The other mechanical properties of

Table 2 Mechanical test results (average and standard deviation)

WD (g/cm ³)	G (MPa)	E _d (GPa)	E _b (GPa)	MOR (MPa)	U _b (N·m)	TM	CS (MPa)	SS (MPa)	PBS (MPa)	H (MPa)
0.62 ± 0.03	1027.6 ± 71.6	13.3 ± 1.0	10.9 ± 0.8	92.7 ± 8.6	14.4 ± 4.1	0.614 ± 0.050	43.3 ± 4.1	10.0 ± 1.6	11.7 ± 1.6	13.0 ± 2.0

WD air-dry density, G modulus of rigidity, E_d dynamic modulus of elasticity, E_b static modulus of elasticity, MOR modulus of rupture, U_b absorbed energy up to the maximum load in static bending, TM Tetmajer's modulus, CS compressive strength parallel to the grain, SS shear strength concerning the longitudinal-radial plane, PBS partial bearing strength, H Brinell's hardness

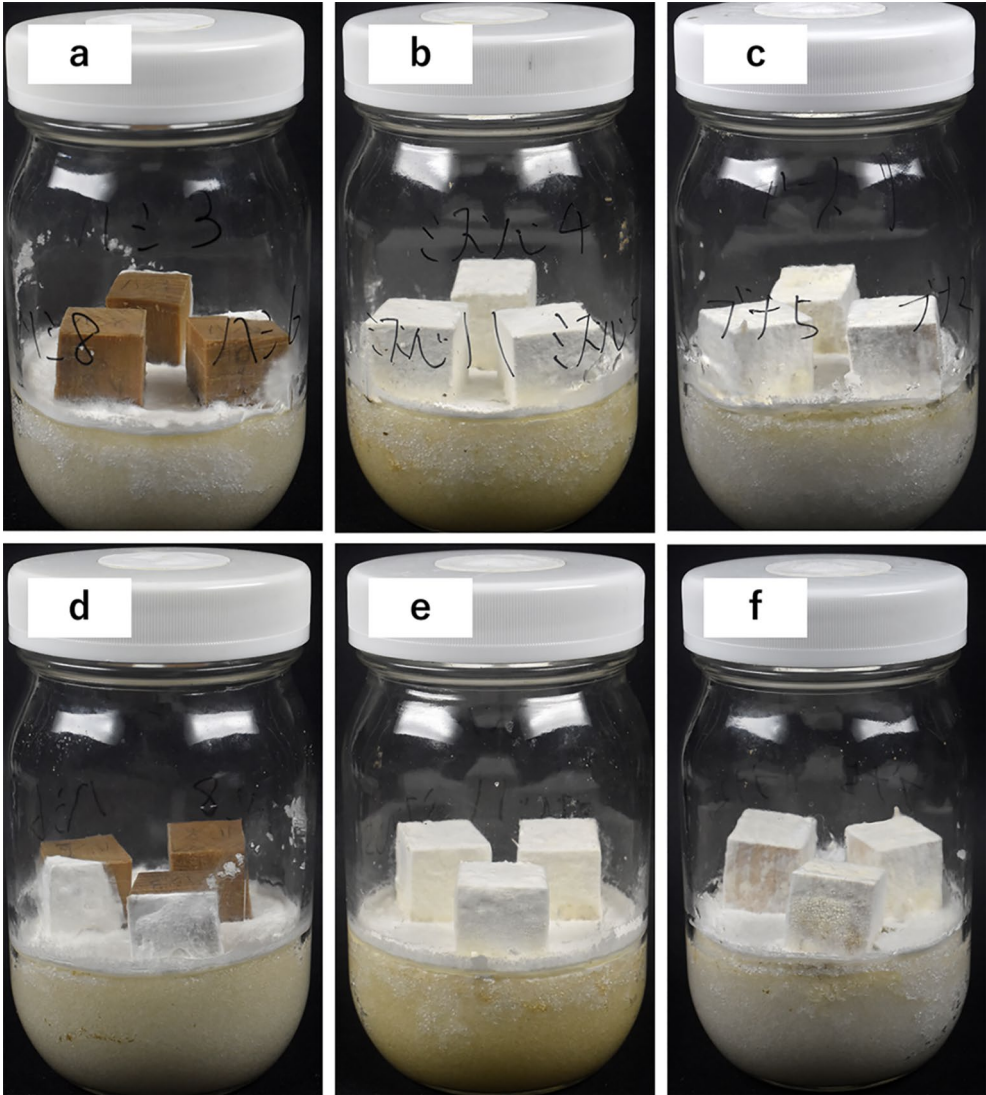


Fig. 2 Specimens at the end of the decay test. **a** Specimens of Japanese lilac; **b** specimens of oak; **c** specimens of beech; **d** opposite side of 2-a; **e** opposite side of 2-b; **f** opposite side of 2-c

Japanese lilac were found to be moderate. In summary, the wood of Japanese lilac was found to have high resistance to deformation and breakage under bending loads, although brittle fracture was more likely to occur in this

species compared to others, which were commonly used for building pit houses in prehistoric Hokkaido.

Decay test

The specimens of each species at the end of the test are shown in Fig. 2. The surfaces of the oak and beech

Table 3 Results of decay tests

Species (common name)	Corrected mass loss rate (%) ^{*1}	Decay resistance ratio	Number of specimens
Japanese lilac	1.6 ± 1.2	1.24	18
Oak	13.2 ± 1.2	1.09	9
Beech	20.6 ± 3.5	–	9

^{*1} average and standard deviation

specimens were completely covered with mycelia, whereas those of the Japanese lilac specimens were barely covered with mycelia. Some Japanese lilac specimens were also covered to some degree with mycelia (e.g., the left and middle specimens in Fig. 2-d). However, the specimens that were partly covered with mycelia had been mistakenly extracted from the region including the boundary between sapwood and heartwood. Mycelia were almost completely absent from the heartwood regions of all the specimens.

The mass-loss rates of Japanese lilac, oak, and beech were 1.6, 13.2, and 20.6%, respectively (Table 3). The results showed that Japanese lilac had much higher decay resistance than did oak, which is regarded as a highly decay-resistant species in the Japanese Agricultural Standards (JAS 1083) [12], like Japanese cedar (*Cryptomeria japonica*), Japanese cypress (*Chamaecyparis obtusa*) and chestnut (*Castanea crenata*). Therefore, heartwood of Japanese lilac, which had a much lower mass-loss rate than did the oak specimens, can be considered to have extremely high decay resistance.

Merits in using Japanese lilac for structural materials

Mechanical tests showed that the bending strength of Japanese lilac was particularly high among species that are commonly distributed in Hokkaido. In prehistoric periods, Japanese lilac was frequently used for pillars and rafters. These structural materials, especially rafters, need to support heavy bending loads; therefore, the Japanese lilac is highly suitable in this context.

Compared to oak heartwood, Japanese lilac heartwood has an extremely high decay resistance. Oak is a highly decay-resistant species that was used in prehistoric periods. The fact that Japanese lilac is much more resistant to decay than oak clearly indicates that Japanese lilac was a highly desirable species among those available in prehistoric periods. The Ainu people recognized these qualities of lilac wood, as reflected in the saying ‘it will turn to stone’ [13]. In an era without preservatives, high decay resistance was a very important property of long-lasting structural materials exposed to weather or soil. This remarkable property of

Japanese lilac is most likely the reason why the wood was selected for structural materials.

Conclusions

The Japanese lilac has high resistance to deformation and breakage under bending loads, and its heartwood has extremely high decay resistance. By quantifying these properties, we have shown why this species would be selected as the preferred structural material in pre-historic periods in Hokkaido.

Abbreviations

CS	Compressive strength parallel to the grain
E_d	Dynamic modulus of elasticity
E_b	Static modulus of elasticity
G	Modulus of rigidity
H	Brinell's hardness
MOR	Modulus of rupture
PBS	Partial bearing strength
SS	Shear strength concerning the longitudinal-radial plane
TM	Tetmajer's modulus
U_b	Absorbed energy up to the maximum load in static bending
WD	Air-dry density

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s10086-025-02201-4>.

Additional file 1

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Author contributions

RT and YS designed the study. RT performed experimental works and analyzed the data under instructions by YT and TS. RT wrote a draft and YS modified it. All the authors read and approved the final manuscript.

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Availability of data and materials

The raw data can be obtained from the corresponding author on reasonable request.

Declarations

Competing interests

The authors declare that they have no competing interests.

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References

- Ohno K (1989) (4) Shisseirin Shitchirin. In: Miyawaki A (ed) Vegetation of Japan Hokkaido. Shibundo, Tokyo, pp 180–181 **(in Japanese)**
- Hokkaido Archaeological Operations Center (2002) Chitose Yukanboshi C15 iseki (3) hokkaidoodanjidoshado (Chitose-Yubari) maizobunkazai hakkutsuchosahokokusho. Research Report of Hokkaido Archaeological Operations Center 146 **(in Japanese)**
- Sarashina G, Sarashina H (2020) kotan seibutsuki jumoku zasso hen [translated to “The Ethnobotany of Kotan”]. Seidosha, Tokyo, pp 58–59 **(in Japanese)**
- Teranishi M, Koizumi A, Hirai T (2008) Evaluation of quality indexes of bending performance and hardness for hardwoods. *J Wood Sci* 54:423–428
- Koizumi A, Takata K, Yamashita K, Nakada R (2003) Anatomical characteristics and mechanical properties of *Larix sibirica* grown in south-central Siberia. *IAWA J* 24:355–370
- Japanese Industrial Standards (2009) Methods of test for woods, JIS Z 2101. Japanese Standards Association, Tokyo **(in Japanese)**
- Kijidani Y, Kitahara R (2005) Effect of basic wood properties on strength and stiffness in bending of *Cryptomeria japonica* timbers. *J Soc Mater Sci* 54:377–380 **(in Japanese with English summary)**
- Itoh T, Yamada M (2012) Archaeological wood in Japan database of tree species used for excavated wooden artifacts. Kaiseisha, Otsu **(in Japanese)**
- Muto G, Koizumi A (2007) Mechanical properties of aodamo (*Fraxinus lanuginosa*), white ash (*Fraxinus americana*), and sugar maple (*Acer saccharum*) as baseball bats. *Res Bull Hokkaido Univ For* 64(2):113–122 **(in Japanese with English summary)**
- Koizumi A, Teranishi M, Hirai T (2007) Shrinkage and mechanical properties of wood sampled from the trees planted in Hokkaido University. *Res Bull Hokkaido Univ For* 64(2):91–104 **(in Japanese with English summary)**
- Matsuoka S, Shoji Y (1960) Studies on natural durability of woods (the first report) relative durability of woods tested according to Japanese industrial standard. *Bull FFPRI* 123:137–152 **(in Japanese)**
- Japanese Agricultural Standard (2019) Sawn Lumber, JAS 1083. Ministry of Agriculture, Forestry and Fisheries of Japan, Tokyo **(in Japanese)**
- Fukuoka I (1995) Hashidoi (dosunara) In: Ainu shokubutsushi. Sofukan, Urayasu, p 127 **(in Japanese)**

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