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Why *Phragmites australis* Canes Grown in Udono Reed Bed are the Best Materials for the Reeds of Japanese Wind Instrument 'Hichiriki'. A Structural and Biomechanical Study

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Hichiriki (Figure 1) is a double reed woodwind instrument in Japanese ancient imperial court music 'gagaku' since the 7th century and one of UNESCO Intangible Cultural Heritages. For more than 1,200 years, the best reeds for the hichiriki have been made only out of canes of *Phragmites australis* (*P. australis*) (common reed) harvested from "Udono" which is a limited reed bed of riverbanks near Kyoto along the Yodo River. This resembles that the best reed for clarinet, oboe, or bassoon is manufactured from a cane of *Arundo donax* (*A. donax*) (giant reed) which grows only in a few areas of the Var in France due to its very mild climate. Now, misgivings that environmental disruption in Udono causes ecocide of the *P. australis* for hichiriki reeds and may bring a catastrophic crisis to gagaku are expressed [1]. In this study, plant anatomy was examined for choice canes of *P. australis* grown in different reed beds in Japan as well as morphology, and the local indentation hardness and Young's modulus of tissues on the cross-sections of some representatives of hichiriki reeds were measured, searching why the canes from Udono's *P. australis* are the best materials for hichiriki reeds.

Specimens for light microscopy were prepared by cutting the sample cane pieces to transverse sections about 30 μm thick with a sliding microtome, followed by double staining with safranin and fast green FCF [2]. The hardness and Young's modulus of different parts on the cross-sectioned surfaces of four hichiriki reeds were measured with a Vickers indentation load of 5 mN using a nanoindentation system (Fischerscope, H100C-XYp).

Figure 2 shows light micrographs of the sections of the canes from different reed beds. *T* is the wall thickness measured from the image. The structure of the cane is indicated in Fig. 2(e). *P. australis* almost resembles *A. donax* in plant anatomical structure but not in outer shape and size of cells. This is the reason why *A. donax* cannot be used for hichiriki reeds. Figure 3 illustrates the hardness measurements of four hichiriki reeds. We conclude that the good canes for hichiriki reeds have an outer diameter of about 11 mm, a wall thickness of about 1 mm and comparatively homogeneous structure where harder materials, such as epidermis, hypodermis, sclerenchymatous cells, and vascular bundle sheaths with hard walls, are orderly deployed with softer materials such as parenchyma cells and vascular bundles. This structure has smaller differences of hardness and Young's modulus between the hard and soft materials in the reed, providing the best music performance. Hichiriki players say that it has become harder and harder to get good materials for reed, similar to the players of clarinet and oboe using *A. donax* reeds. However, they can be still found in Udono but be hardly found in other reed beds.

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[1] M. Schuring *et al*, 2013. Pipers **381** (2013)10.
[2] M. Kawasaki *et al*, Micros Res. Tech. (2015) in print.

Fig. 1. Hichiriki. Its length is about 180 mm.

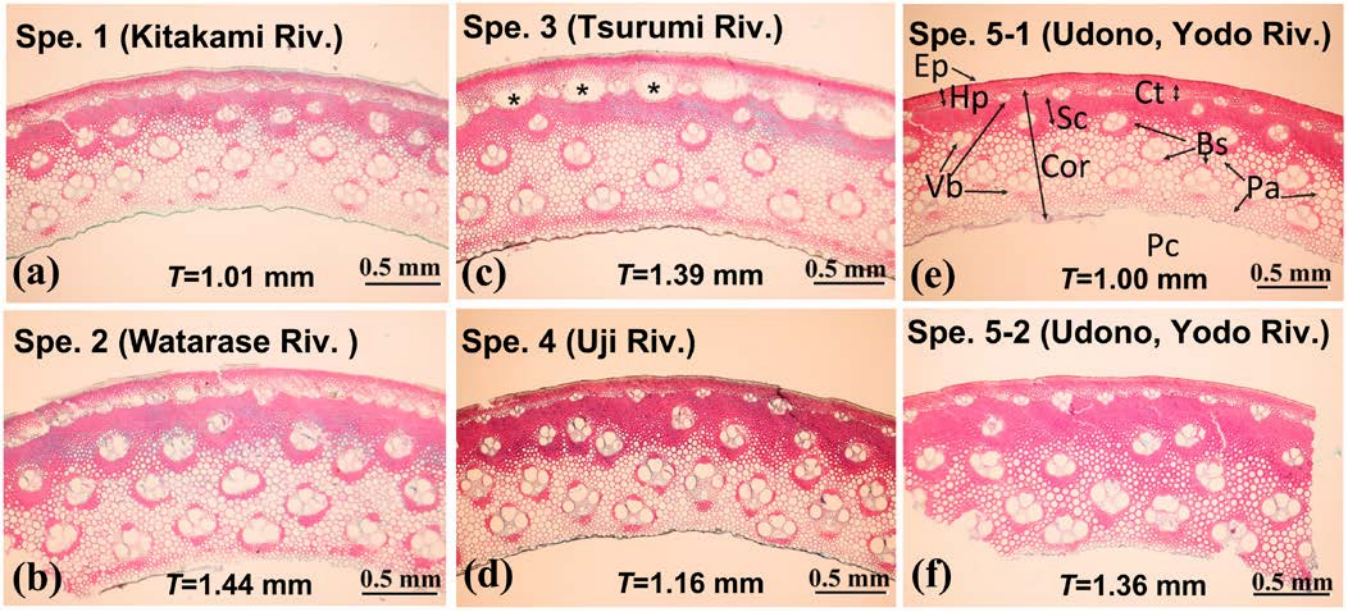

Fig. 2. Light micrographs of *P. australis* stems from different reed beds; Kitakami Riv. near Sendai, Watarase Riv. near Nikko, Turumi Riv. in Tokyo, Uji Rev. in Kyoto, and Udono. Ep: epidermis. Hp: hypodermis. Vb: vascular bundle. Bs: vascular bundle sheath. Cor: cortex. Pa: parenchyma cell. Ct: cells with thin cell wall. Sc: sclerenchymatous cells. Pc: pith cavity.

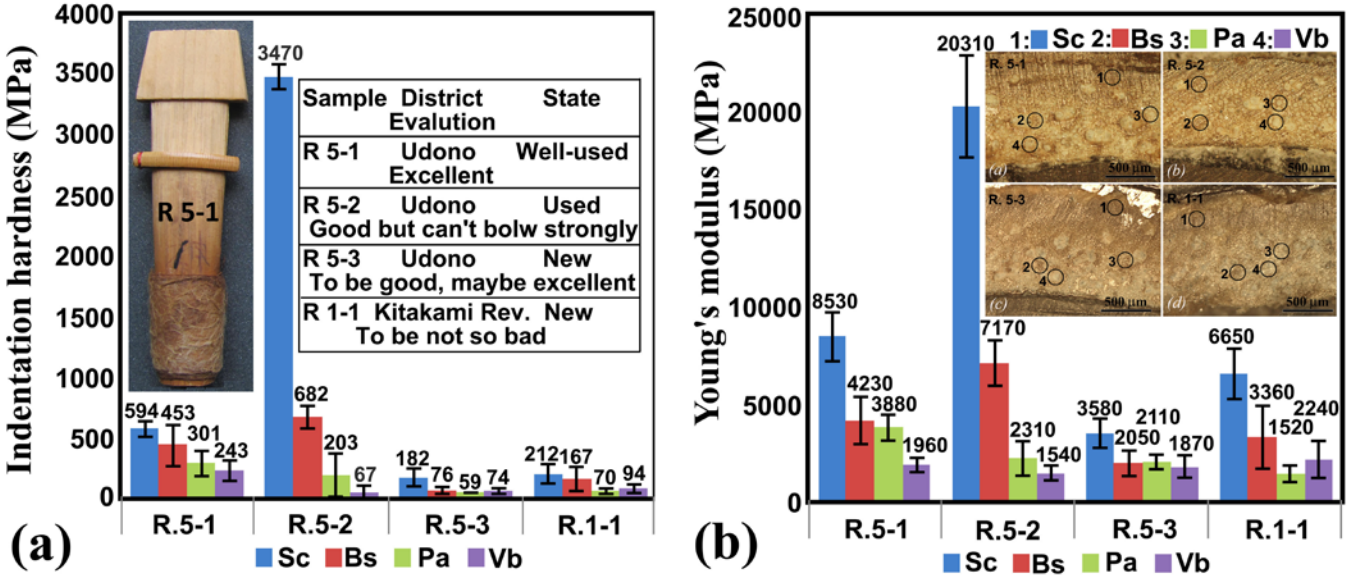

Fig. 3. Indentation hardness (a) and Young's modulus (b) of different parts (shown in the inset in b) in different hichiriki reeds (indicated in the inset in a). A photograph of reed (Rozetsu) R 5-1 is shown in a.

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