論　文（Original article）

Resin canals in “hiwada”, bark of hinoki (*Chamaecyparis obtusa*) as roofing material

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Abstract

"Hiwada” is a major roofing material of wooden cultural buildings in Japan, and can be harvested from outer bark of large-diameter trees of hinoki (*Chamaecyparis obtusa*) at roughly 10-year intervals. Hinoki is well known for having no normal resin canals in either xylem or phloem, but tangential bands of traumatic resin canals in the bark can be easily detected on the cross section of “hiwada” material. To clarify whether “hiwada” harvest is a stimulus to form traumatic resin canals in the phloem of hinoki, the distribution and the formation of resin canals were investigated on the occasion of the second “hiwada” harvest experiment at Kibune site in Kyoto in October 2011.

The first “hiwada” harvest in 2002 did not affect xylem and phloem production in subsequent years. Tangential bands of traumatic resin canals were scattered widely in the secondary phloem of most sample trees regardless of the debarking treatment, and their occurrence was not synchronous within the trees studied. After the second harvest in 2011 microscopic investigation confirmed that the debarking treatment did not induce traumatic resin canal formation.

The pathogenous stem canker fungus *Cistella japonica* was isolated from outer barks of some sample trees, but its presence was not related to the incidence of resin canals.

The injuries due to the samplings in October and December induced the formation of traumatic resin canals, consistent with previous studies, generally in the following year in the latest 2 growth rings of the phloem.

In conclusion, “hiwada” harvest dose not induce the formation of traumatic resin canals in the hinoki phloem. Although the cause is unfortunately entirely unknown, traumatic resin canal bands are common in the hinoki bark.

Keywords: phloem, debark, wood culture, anatomy, thin section, growth ring, *Cistella japonica*

1. Introduction

1.1 Supply of “hiwada” for cultural heritage wooden buildings in Japan

The importance of forest resources to maintain Japanese "wood culture" that places the origin on symbiosis in harmony with nature was discussed by Yamamoto (2005). He stated that “hiwada” is one of the roofing materials of cultural wooden buildings in Japan, that must be replaced every 30 to 40 years. "Hiwada” is a bark material that can be harvested from outer bark of large-diameter trees of hinoki (*Chamaecyparis obtusa*) over 70 years old at roughly 10-year intervals. There are about 700 wooden buildings roofed with “hiwada” designated as National Treasures and Important Cultural Properties in Japan. In order to replace the roofs at 35-year intervals roughly 3,500 m^2 of “hiwada” is required each year. For stable supply, it is necessary to secure constantly about 350,000 hinoki trees of over 70 years old as “hiwada” harvest trees. For numerous additional wooden buildings roofed with “hiwada” not designated as important cultural properties in Japan, the amount of “hiwada” necessary for their maintenance is estimated to be several times higher. However, in recent decades the supply of “hiwada” tends to decline by a serious decrease of forest owners who cooperate in the “hiwada” harvest for fear that it may inhibit the growth of hinoki trees and/or affect wood quality.

For this reason, a research group of Yamamoto set up 4

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experiment sites in university research forests to verify the influence of "hiwada" harvest on the growth rate and wood quality. As a result, all the inner bark and a part of the outer bark were still remaining in the debarked trees studied (Utsumi et al. 2006), and no obvious damage by "hiwada" harvest conducted in March 2002 were observed in the cambium nor in the inner bark (Koga and Utsumi 2005). "Hiwada" harvest did not obviously influence tree growth and wood quality (Yamamoto 2005, Saito et al. 2015). The "hiwada" tradition probably owes its sustainability to the fact that of outer bark harvests can be repeated without affecting the production of the high quality wood of hinoki (Koga and Utsumi 2005).

1.2 Anatomy and growth ring structure of bark in hinoki (*Chamaecyparis obtusa*)

According to the IAWA List of Microscopic Bark Features (Angyalossy et al. 2016), bark of trees has the following anatomical structure. Bark is partitioned by the innermost periderm, and is distinguished into "inner bark" on the inner side and "outer bark" on the outer side. In most tree species, cork cambium is active for a relatively short period, and a new periderm is sequentially formed in the inner phloem. In outer bark separated by the newly formed periderm, dead phloem tissue and periderm formed a layered structure.

Anatomical structure of the bark of hinoki was studied by Takamatsu (1928) and revealed to have a typical regular arrangement of "fiber - sieve cell - parenchyma cell - sieve cell". Miyoshi and Shimakura (1935) described that the cell wall thickness of the fiber bands were arranged from thick to thin inward, and then supposed that a tangential band of thick-walled fibers should be a growth ring boundary. The growth ring boundary situates between the last formed parenchyma cells and newly formed sieve cells reported by Itoh et al. (1968) for sugi (*Cryptomeria japonica*; Cupressaceae).

1.3 Traumatic resin canal formation in hinoki phloem

Yamanaka (1984) reported that healthy sugi and hinoki do not form axial resin canals in the phloem, but that traumatic canals are formed in response to insect damage or disease; trees damaged by the beetle sugikamikiri (*Semanotus japonicus*), form resin canals over 2 growth rings; areas of resin canals induced by resinous cankers (phathogen: *Monochaetia* spp.) are narrower than those caused by insect damage, and those due to shoe-string rot (phathogen: *Armillaria mellae*) spread widely forming annular and continuous bands that are concentrated in the lower stem where resin drainage is also massive. He suggested that the traumatic resin canals are formed in response to mechanical, biological or chemical stimuli.

Kuroda and Suzuki (1985) studied the formation of traumatic resin canals induced by "rooshi" resinous canker. Yamanaka (1989) and also Kuroda (1998) studied traumatic resin canal formation due to mechanical injury. Yamanaka (1989) assumed the youngest mature parenchyma cells preferentially develop traumatic resin canals. Kuroda (1998) clearly described that axial parenchyma that can redifferentiate must be younger than 2 years old.

1.4 Kinds of "hiwada" hinoki bark: "arakawa (rough bark)" and "kurokawa (black bark)"

"Hiwada" harvested for the first time from a trunk of hinoki is said not to be of a good quality and is called "arakawa (rough bark)". "Hiwada" harvested for the second or subsequent times is considered excellent, and is called "kurokawa (black bark)" (Utsumi et al. 2006).

In 2009 T. Fujii found white dotted lines on the cross section of a "hiwada" bundle exhibited at the Technical Training Center for Preservation of Cultural Property Buildings, Kyoto City. The white were identified by hand lens as axial resin canals filled with solid resin arranged in continuous tangential bands (see Photo 3). As mentioned previously, normal resin canals are not formed in the healthy bark of hinoki, so that the resin canals observed in the "hiwada" bundle were considered to be of traumatic origin. But, they were so frequent and so constant in every piece that they seemed to be different from the traumatic resin canals caused by insect or disease damage reported by Yamanaka (1984). Therefore, considering that high quality "kurokawa (black bark)" is produced in bark 8-10 years after a previous "hiwada" harvest, Fujii hypothesized that those resin canals in "hiwada" were formed by the stimulation of the previous "hiwada" harvest, debarking. If "hiwada" harvest is a stimulus to induce traumatic resin canal formation, "arakawa (rough bark)" which is harvested for the first time from virgin bark should be free from such resin canals.

In this study, we aim to clarify whether "hiwada" harvest is a stimulus to form traumatic resin canals in the phloem of hinoki. Therefore, on the occasion of the second "hiwada" harvest experiment at the "hiwada" harvest experimental site at Kibune, Kyoto, the distribution and the formation of resin canals were investigated. Fresh samples of inner and outer barks were sampled subsequently from the harvesting time to the next year, and the formation of traumatic resin canals induced by the debarking for "hiwada" harvest and also by mechanical injuries were investigated. Furthermore, the possibility of a pathogenic induction of resin canals was tested by culturing bark fragments for the presence/absence of stem canker fungi.

2. Materials and methods

2.1 Sample trees

In 2002, Kinki Chugoku Regional Forest Office Bureau, Forestry Agency, has set up "hiwada" harvest experimental sites towards the stable supply of "hiwada". In the experimental site at Kibune, Kyoto (0.11 ha), twelve large-diameter hinoki trees were selected (Table 1). Six were debarked, and the remaining trees served as controls. The first "hiwada" harvest experiment was conducted in October 2002, and the 6 sample-trees and some other trees were debarked. On 14th March 2010, the sample trees were inspected. All trees were in good health, obvious changes since the previous investigation in 2006 were not detected, and new traces of insect damage were not observed on the trunks (Table 1).

On 14th March 2010, increment cores of about 10 cm depth were taken in 4 orthogonal directions of each sample tree at 40 cm above ground, and annual ring width were measured. The growth analysis before and after the "hiwada" harvest and also between the debarked (No.11-16) and control trees (No.1-6) were conducted.

2.2 Sampling of "hiwada" material on the occasion of the "hiwada" harvest

The second "hiwada" harvest experiment at the Kibune site was conducted in October 2011 in the framework of a workshop for fostering "motokawashi (master of "hiwada" harvest)", and most trees except the 6 control trees were debarked (Photo 1).

On this occasion, small pieces (about 5 cm^2) of "hiwada" material were sampled at breast height of most trees debarked at the site. "Kurokawa" samples were collected from "hiwada" strips harvested from the 6 debarked sample trees and 2 other debarked trees, and "arakawa" samples were from 18 trees which had never debarked. Resin canals were observed by a hand lens in cross section of these samples collected from "hiwada" materials, and also in microscopic sections of punched-out samples from control trees as described below. Small pieces were also collected from "arakawa" material of some trees recording the height position.

2.3 Sampling to observe resin canal formation induced by "hiwada" harvest experiment

Fresh sample blocks from outer bark to outer xylem were taken at breast height using a leather punch of 7 mm in diameter (Photo 2). The sampling dates were 11th October 2011 for the debarked trees (No. 11 to No.16), and 19th October for the control trees (No. 1 to No. 6). The leather punch was sterilized in 70 % ethanol just before the sampling.

To investigate the effect of the "hiwada" harvest experiment on the phloem, fresh samples were similarly collected on 8th December 2011 and 27th June 2012. Mutual effects of the injuries of the samplings were avoided by separating the sampling positions of 3 times (October, December and June) each other by about 40 to 50 cm in the lateral direction at the same height (Fig. 1).

The punched samples were immediately immersed in 2 % glutaraldehyde/phosphate buffer in bottles individually, and then dissected into small blocks in the laboratory. After the chemical fixation with glutaraldehyde in a refrigerator (4 °C), the small blocks were dehydrated with ethanol series, through propyleneoxide, and were embedded in epoxy resin (a mixture of Quetol 812 100 ml, DDSA 25 ml, MNA 75 ml and DMP-30 1.0 ml, A: B = 2: 8) by the usual procedure (Kushida 1974).

Thin cross sections (about 3 μm thick) were cut out from the resin embedded samples with a rotary microtome (Yamato RV-24) equipped with a glass knife. Then the thin sections were double stained with 0.5 % crystal violet aqueous solution and 1 % safranin in a 30 to 50 % ethanol solution on slide

Table 1. Results of the investigation in March 2010

Sample tree No	treatment	girth (cm) at dbh	girth 40cm agl	tree height (m)	Insect damage	tree vigor
11	debarked	164.0	181.3	23	no trace	good
12	debarked	191.6	217.5	24	no trace	good
13	debarked	203.9	235.2	29	no trace	good
14	debarked	181.8	202.3	28	no trace, but a dent due to scratches on the mountain side	good
15	debarked	201.7	227.1	27	no trace	good
16	debarked	164.1	181.7	29	a slight damage under bark at ground height	good
1	control	165.0	194.3	21	no trace	good
2	control	158.2	182.4	26	no trace	good
3	control	205.6	223.4	23	dent on trunk, damage caused by mining insect (old)	good
4	control	210.0	238.5	27	dent on trunk, insect pit	good
5	control	201.9	235.9	24	trace of insect damage	good
6	control	175.8	199.1	24	ant pathways (many)	good

Photo 1. 1a: Workshop for the second "hiwada" harvest experiment at the Kibune site. 1b: "Hiwada" harvest on a trunk.
Photo 2. Sampling with a leather punch (14 mm in diameter for pathogen detection) and a hole of a 7 mm leather punch.

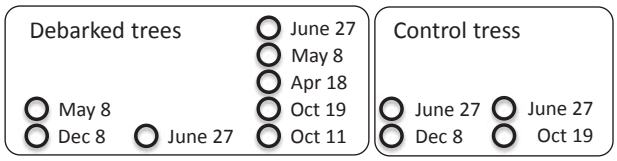

Fig. 1. Schematic diagram of sampling positions and collection dates

glasses, and mounted in Canada Balsam. Those sections were observed under an optical microscope, and digital microscopic images were recorded.

2.4 Isolation of pathogens of resinous stem canker

To detect pathogens of resinous stem canker, on 8th December 2011 two sample blocks from each sample tree were taken with a sterilized leather punch with 14 mm diameter (Photo 2), at a portion close to the sampling hole for microscopic observation. The sample blocks were individually placed into polyethylene bags with sealing fastener, and stored in a refrigerator for a few days until sent out to Tsukuba for a further experiment.

Each sample was dissected into three parts of "outer bark", "inner bark" and "sapwood". The surfaces of these samples were sterilized with 80 % ethanol and 0.1 % aqueous solution of Mercury Chloride ($HgCl_2$), and the samples were transplanted on a potato dextrose agar medium (PDA medium). The petri dishes were cultured in a 10 °C incubator for about 2 months, and the emerging fungi were identified.

2.5 Samples for resin canal formation induced by mechanical injuries

In order to investigate traumatic resin canal formation induced by mechanical injuries, fresh samples were taken from the debarked trees with a leather punch with 7 mm diameter on 19th October 2011 about 1-3 cm above the sampling hole of 11th October. Further samples were subsequently punched 2-3cm above the previous sampling hole on 18th April, 8th May, and 27th June 2012. Also from above the sampling holes of 8th December 2011 samples were punched on 8th May 2012 (Fig. 1).

For the control trees, samples were punched in the same way on 27th June 2012 from above each sampling hole of 19th October and 8th December 2011.

The sample blocks were fixed, embedded and sections as described above.

3. Results

3.1 Resin canals in "hiwada"

"Hiwada" traditionally assembled in 75 cm long bundles (Photo 3a) showed resin canals in white lines at the cross sections of all samples (Photo 3b). In outer bark, periderms were located at irregular radial intervals disrupting the regular cell arrangement (Photo 4). The regular cell layering of "sieve cells – flattened phloem parenchyma cells with colored substances lining the cell wall – phloem fibers" was well retained, and formed annual growth rings (Photo 5). Resin canals had large diameters and irregular shapes (Photo 5), and occurred at irregular radial intervals.

In samples of "kurokawa" and "arakawa", all the samples had resin canals regardless whether those sample trees have ever been debarked or not, and most had more than 2 bands of resin canals.

The occurrence of resin canals in the height direction in tree trunks were observed using samples cut from outer bark strips of "arakawa" material. Although the number of samples

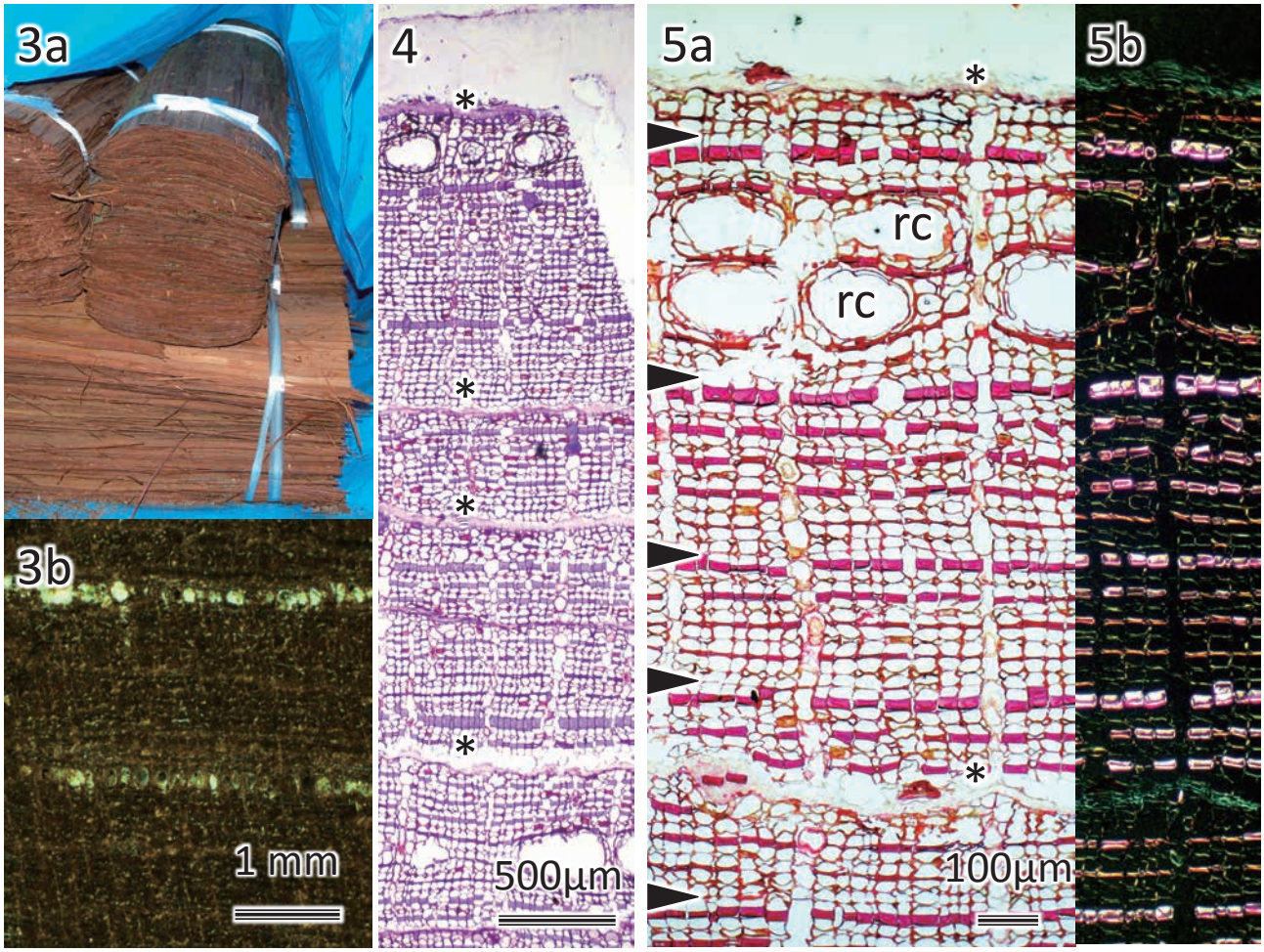

Photo 3. Overview of "hiwada" bundles. 3a: A bundle of "hiwada" material sized into about 75 cm long. 3b: A part of Photo 3a showing axial resin canals in tangential bands of white dotted lines on the edge.
Photo 4. Micrograph of outer bark in a control tree collected on 19th October 2011. *: periderm.
Photo 5. Micrograph of outer bark in a control tree collected on 19th October 2011. 5a: Ordinary micrograph. 5b: the same area in polarizing microscope highlighting fiber bands. Arrow head: growth ring boundary, *: periderm, rc: resin canal.

was limited, resin canals were observed in all samples with variation in the number of resin canal bands in each sample. And resin canal bands always occurred in all samples up to about 5 m above the ground.

3.2 Effect of the first "hiwada" harvest on resin canal formation

Photo 6 illustrates a bark of hinoki collected on 8th December 2011. Growth rings of secondary phloem were visible especially clearly under a polarizing microscope. Axial resin canals in tangential bands were found also in inner bark, and were similar in anatomical features to those in the outer bark as illustrated in Photo 4. Within a growth ring, each of phloem elements arranged regularly in a tangential layer, where phloem parenchyma cells had somewhat swelled in cross section, and also fiber bands showed gradual decrease in the diameter and in the cell wall thickness inward (Photo 7).

In the inner bark of samples collected in October and December, 2011 and June, 2012, resin canals in tangential bands were found in all the debarked trees, and number and location of those resin canals were different among samples within individual trees and also among the sample trees. The ratio of resin canal incidence in individual growth rings observed in the samples collected three times is summarized in Fig. 2, and varied by year. In the growth ring of 2002, it seems to be slightly higher than before and after, and also obviously higher than the control. Here, the growth ring of 2002 was the youngest growth ring upon the first debarking treatment and therefore resin canals are supposed to had been induced by the "hiwada" harvest in 2002 autumn.

The effect of the second "hiwada" harvest was analyzed using the samples collected on 27th June 2012, when newly developed phloem was obvious and resin canals formed in response to the harvest was expected to be detectable. The ratio

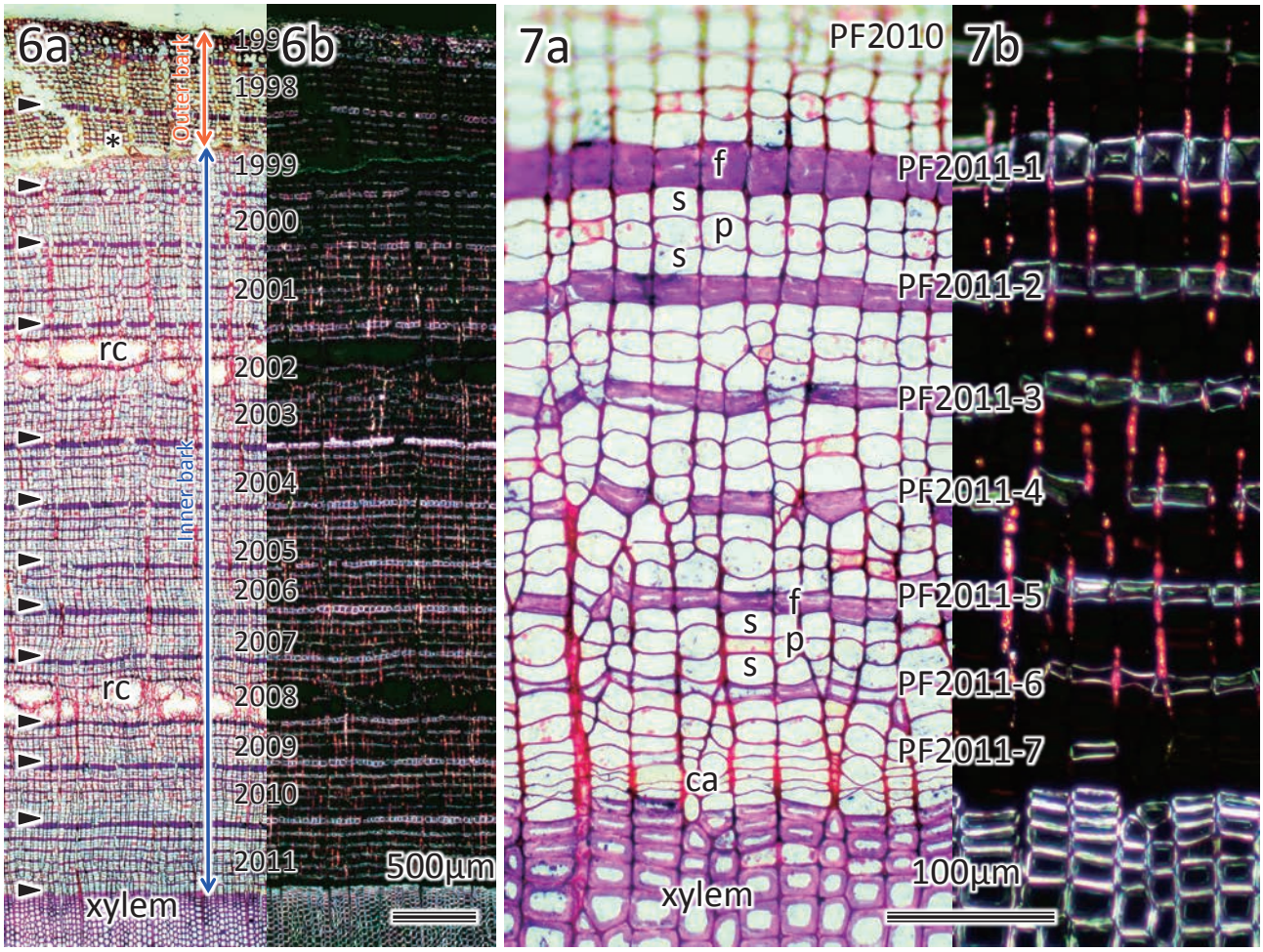

Photo 6. Micrographs of hinoki bark in a debarked tree collected on 8th December 2011. 6a: ordinary optical micrograph, 6b: polarizing micrograph of the same area as 6a. arrow head: growth ring boundary, *: periderm, rc: resin canal, 4 digit number: formation year.

Photo 7. A part adjacent to cambial zone in Photo 6. Regular cell arrangement of phloem elements is clear. 7a: ordinary optical micrograph, 7b: polarizing micrograph of the same area as 7a. f: phloem fiber, s: sieve cell, p: phloem parenchyma cell, ca: cambial zone, PF2011-1 etc.: phloem fiber band formed in 2011 and the order of formation.

of sample trees with resin canal incidence in the growth rings of 2010 and 2011was added in Fig. 2. It was a little lower than that of total of the three subsequent sampling dates, because some resin canals were already formed in the samples collected in October and December but not in the sample of June.

In inner bark of the control trees, resin canals were also frequently found (Fig. 2) consistent with the results on “hiwada” materials previously mentioned. Furthermore, in some growth ring years such as 1996 and 2005, the ratio was apparently higher than those in the debarked trees.

In the samples collected in October, the cambial zone was still active in some samples, as there were more than several layers of wall-thickening cells with flat shape and thin walls both in phloem and xylem, and several layers of xylem tracheids were still developing secondary walls (Photos 8a & 8b). In some other samples (Photos 8c & 8d), the cambium was nearly dormant, but the latest latewood tracheids in xylem had thin secondary walls and were still continuing cell wall thickening. Comparing the cambial zones in October (Photos 8c & 8d) to those in December (Photos 8e & 8f), it is apparent that the latest phloem fibers were also in the wall thickening stage in October. The rest trees were already inactive as the dormant stage.

In December, the cambial zones were completely dormant in all samples (Photos 8e, 8f & 9). In the debarked trees, resin canals in the growth ring of 2010, the second youngest growth ring upon the second “hiwada” harvest, were found in 2 out of 6 sample trees, but not in the other 4 trees. All samples did not have resin canals in the growth ring of 2011, the youngest growth ring upon the treatment. Also, the resin canals in the 2010 annual ring were also observed in the control trees which had not been subjected to the debarking treatment.

In the samples of 27th June in the next growing season, no resin canals were formed in the growth ring of 2011 in the

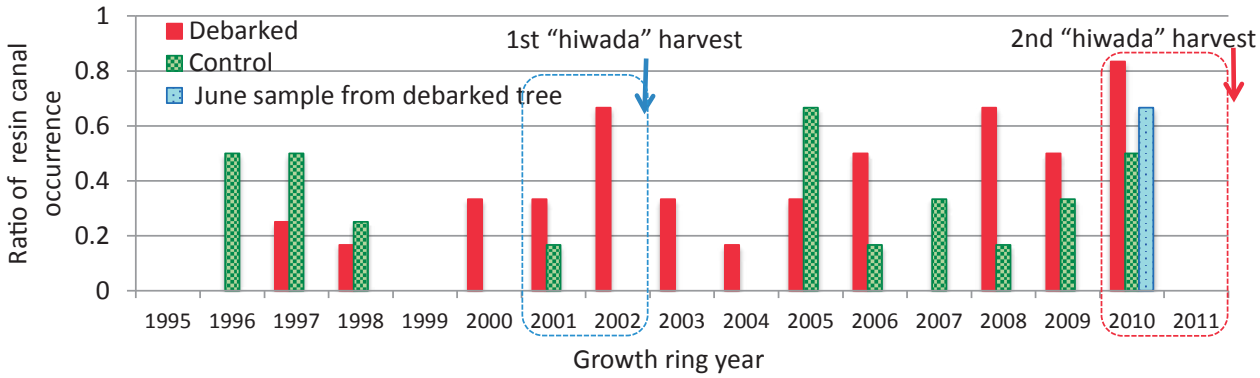

Fig. 2. Ratio of sample trees with resin canals in growth ring of each year to total sample trees. Broken lines indicate the youngest 2 growth rings at the "hiwada" harvest.

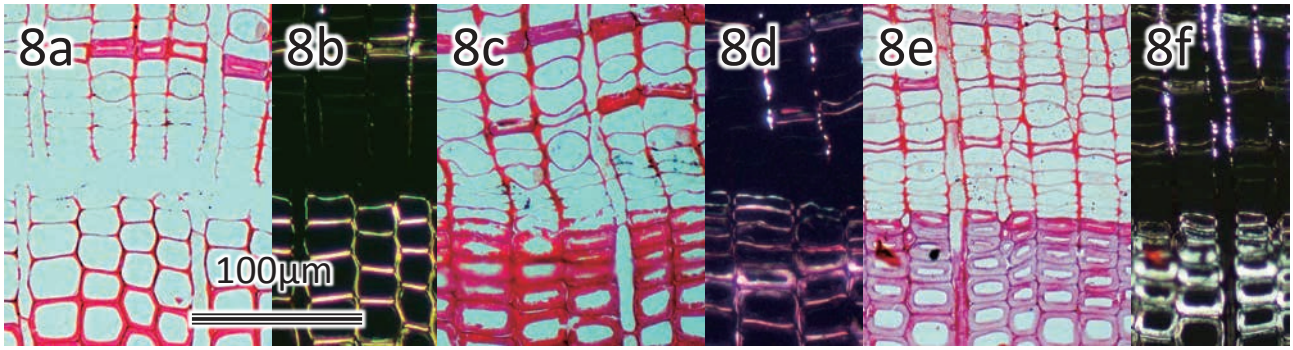

Photo 8. Micrographs of cambial zones in debarked trees collected on 11th October 2011 (8a & 8c) and in a debarked tree collected on 8th December 2011 (8e). 8b, 8d and 8f: polarizing micrograph of the same part of 8a, 8c and 8e, respectively.

debarked trees (Photo 10). In the growth ring of 2010, resin canals were found in 3 control trees which did not have resin canals in the sample of December.

3.3 Effect of mechanical injury on resin canal formation

A symptom of traumatic resin canal formation in response to the injury caused by leather punch sampling in October was first observed in the samples collected 8 days later in the growth ring of 2010 in some trees (3 of 6 trees; No.11, No.13, No.14) as expanding phloem parenchyma cells (Photo 11). These trees (No.11 and No.13) were already almost in cambial dormancy at the time of the injury. Other trees (No.12 and No.15) had a relatively wide cambial zone in October. The condition of trees No.14 and No.16 were unknown because of accidental lack of cambial zone in the samples.

Injuries in October frequently induced traumatic resin canal formation in both or one of the latest 2 growth rings in the next spring, but the responses to the injuries were not uniform among the sample trees, and some trees did not develop any traumatic resin canals in response to the injury. The ratio of trees which developed traumatic resin canals in the growth rings of 2010 and 2011 individually is summarized in Fig. 3. Traumatic resin canals present in those growth rings in the samples collected at the time of injury time were not counted for the response to injuries, but included in the total.

Injuries in December also frequently but not always induced traumatic resin canals in the following year similarly to that given in October (Fig. 3).

Injuries in April and May given on the debarked trees induced typical traumatic resin canals in both growth rings of 2010 and 2011 in all trees without exceptions.

3.4 Isolation of pathogens of resinous stem canker

In the samples used in this study, only a few fungi were isolated both from debarked and control trees. They were *Cistella japonica*, *Cladosporium* sp., *Penicilllim* sp., *Phomopsis* sp. and unidentified fungi. But excepting *C. japonica*, these fungi are not considered to stimulate the formation of resin canals in the bark.

3.5 Analysis of xylem growth in the "hiwada" harvest trees

There is no significant difference in average growth ring width before and after the first "hiwada" harvest, and also between debarked and control trees (Fig. 4). Those of the debarked trees look to be slightly higher in the years after

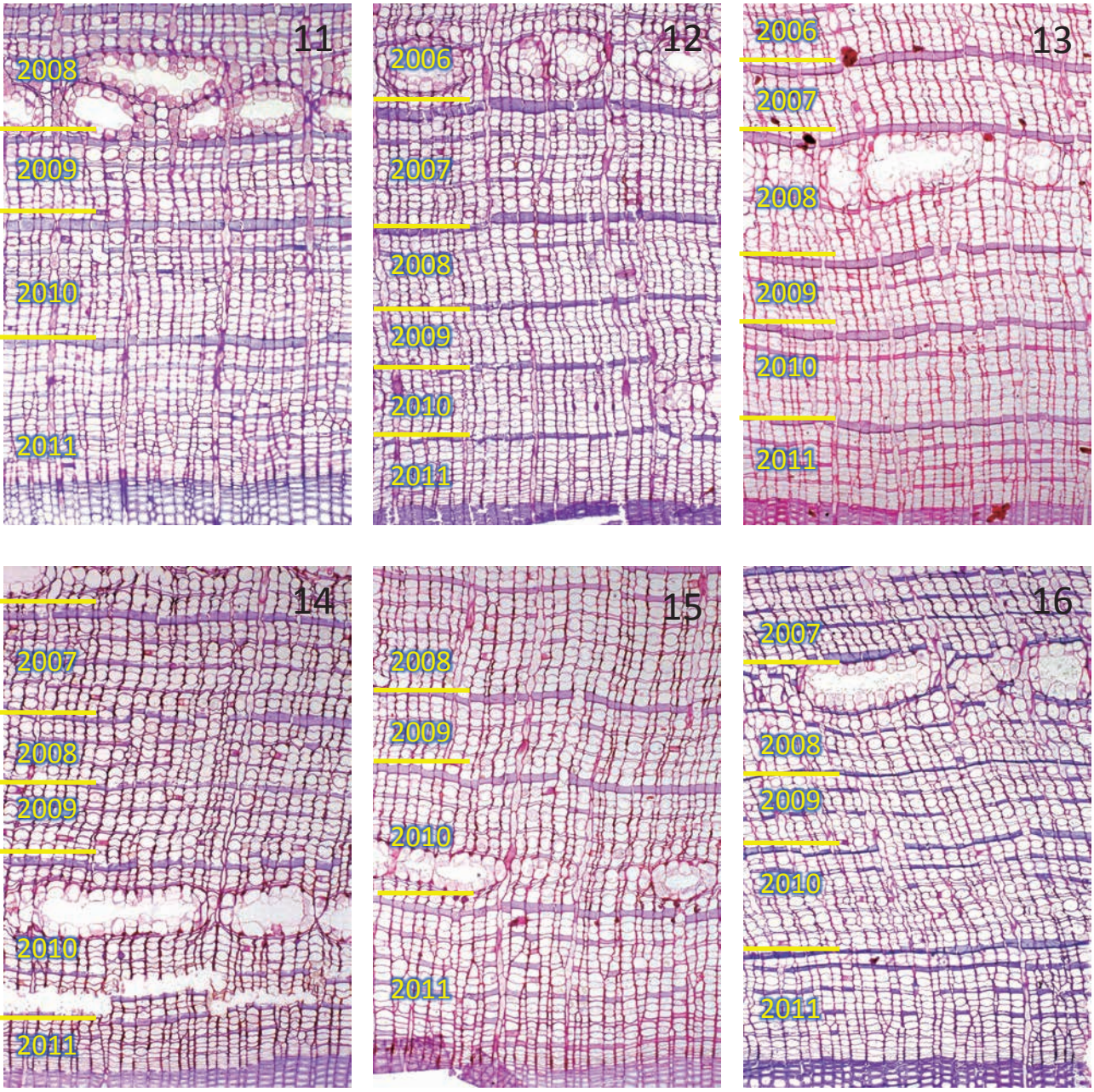

Photo 9. Micrographs of inner bark of debarked trees on 8th December 2011. Digits imposed are formation year of each growth ring and the sample tree number.

the experiment year. But, slightly wider growth ring width are shown also in a few years before the experiment, on which the debark treatment can not have been a causal factor. Furthermore the control trees show a similar tendency.

4. Discussion

We found that resin canals in the secondary phloem of hinoki had a large diameter and irregular shape and occurred at irregular radial intervals in tangential bands (Photos 4, 5 & 6) as reported for traumatic resin canals induced by mechanical injury and tree diseases by Yamanaka (1984), Kuroda and Suzuki (1985), and Kuroda (1998). In this sense, the resin canals in the secondary phloem of hinoki resemble to axial resin canals in the xylem of *Shorea* spp. (Dipterocarpaceae) as described by Ogata et al. (2008) as "*axial resin canals in more or less continuous concentric bands*" not in regular intervals and "*often irregular in size and shape, resembling traumatic canals*"

"Kurokawa" samples were harvested from the sample trees debarked firstly in autumn of 2002, so that the phloem in "kurokawa" samples should be influenced by the debarking treatment. Assuming that the debarking treatment stimulates to form traumatic resin canals, it is a natural consequence that traumatic resin canals exist in the all "kurokawa" samples. Incidentally, even in "arakawa" samples, that were not affected

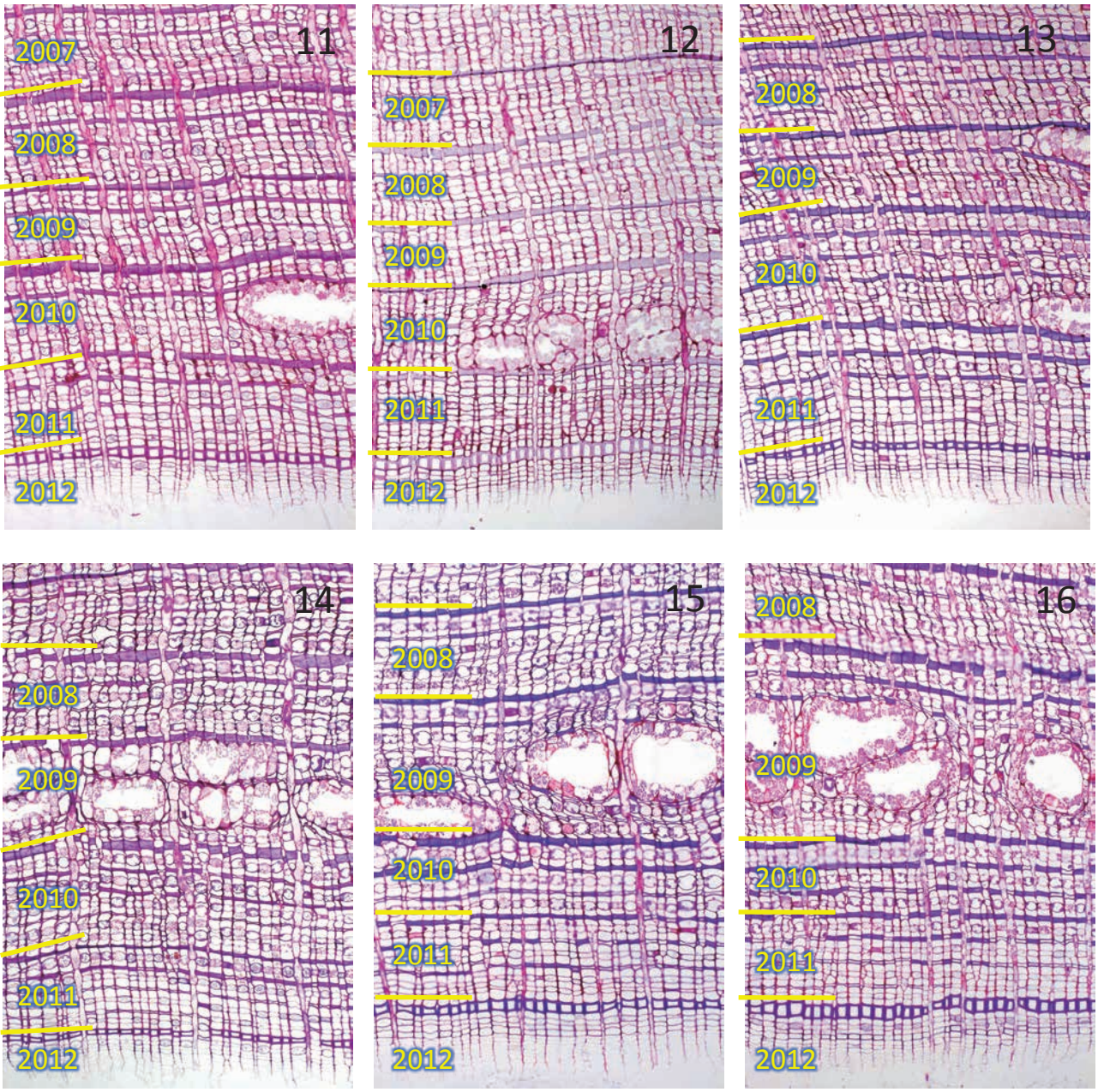

Photo 10. Micrographs of inner bark of debarked trees on 27th June 2012. Digits imposed are formation year of each growth ring and the sample tree number.

by "hiwada" harvest in 2002, resin canals were present and probably extending along the tree height without exception. As already clearly shown in a table of Miyoshi and Shimakura (1935) as a result of the measurement on over 200 hinoki trees collected all over Japan, traumatic resin canals are common and distributed throughout the whole stem bark of hinoki trees.

In the inner bark, tangential bands of resin canals were occurred at irregular radial intervals similarly to the outer bark in the secondary phloem of most sample trees regardless of the debarking treatment, and their occurrence varied among the trees studied (Fig. 2). They were not restricted to the growth rings of 2001, 2002 and 2010, contrary to the prediction that the resin canals are induced within the youngest 2 growth rings by the stimulation of debarking treatment according to Yamanaka (1989) and Kuroda (1998). Utsumi et al. (2006), who conducted analyses of the bark 4 years after a debarking treatment, simply reported only that resin canals were present in both debarked and control trees, and canals were absent in the first growth ring after the debarking treatment, but did not described in detail.

As shown in the results of the investigation of 2010 (Table 1), most sample trees were healthy without any signs of disease or insect attack. As cautioned by Kuroda (2000), traumatic resin canals may be formed in superficially healthy

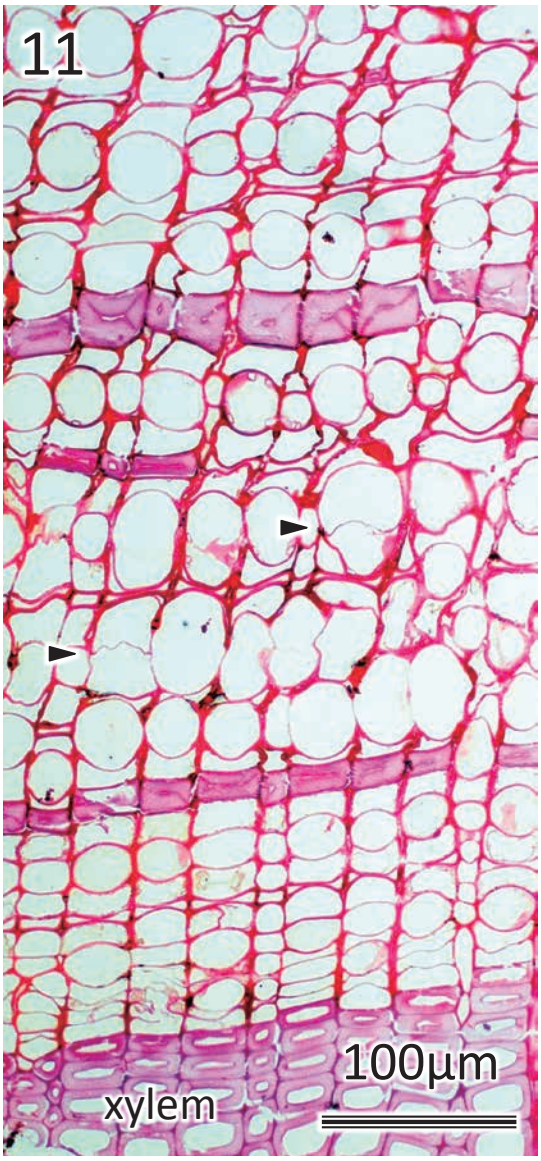

Photo 11. Expansion and periclinal divisions of phloem axial parenchyma in the growth ring of 2010 were observed in the samples collected from just above the mechanical injury of 11th October on 19th October, 8 days after the injury. Arrow head: periclinal division in expanded axial parenchyma cells.

trees due to latent morbidity even if they do not obviously develop resinous stem canker. But, the pathogen of resinous stem canker *Cistella japonica* was not isolated from the inner bark at all and only in a limited number of samples from the outer bark in this study. The potential morbidity of resinous stem canker can therefore not be the factor responsible for the resin canals in this study.

In the both debarked and control trees in this study, resin canals were not formed in the growth ring of 2011, the youngest growth ring at the debarking treatment (Fig. 2 & Photo 10). Mechanical injuries applied on the same day as the debarking treatment induced traumatic resin canal formation

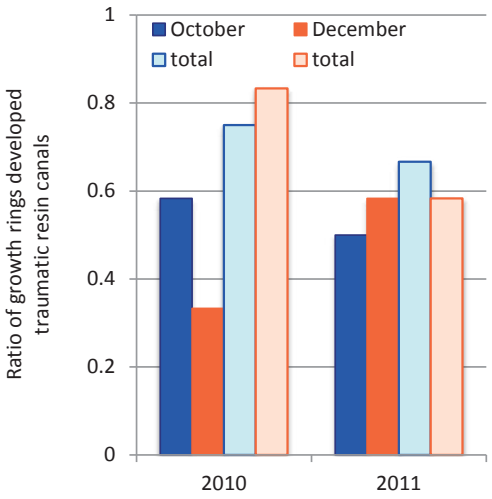

Fig. 3. Ratio of sample trees that developed traumatic resin canals in growth rings of 2010 and 2011, respectively, induced by injuries in October and December. total: including resin canals already present at the time of injury.

in the growth rings of 2010 and 2011 (Fig. 3), and 8 days later phloem parenchyma cells started to periclinal cell division in some trees which were already almost in cambial dormancy (Photo 11). These results suggest that the ability of the growth ring of 2011 to develop traumatic resin canals is assumed high, so that the sample trees could develop traumatic resin canals if the debarking treatment was a certain stimulation to induce resin canals. But they did not. As a result, any causes of the formation of the common resin canals are still unknown.

Therefore, it is reasonable to conclude that the traditional "hiwada" harvest at descending to and during the cambium dormancy does not induce the formation of resin canals in the debarked trees. "Hiwada" harvest does not inhibit the production of high quality wood in hinoki trees agreeing with the results of Koga and Utsumi (2005), Utsumi et al. (2006) and Saito et al. (2015), and does not seem to increase the risk of tree diseases. As has been declared by Yamamoto and his research group, the sustainable traditionally-inherited "hiwada" harvest does greatly contribute to the Japanese wood culture by the supply of the traditional roofing material without affecting the production of high quality wood of hinoki trees.

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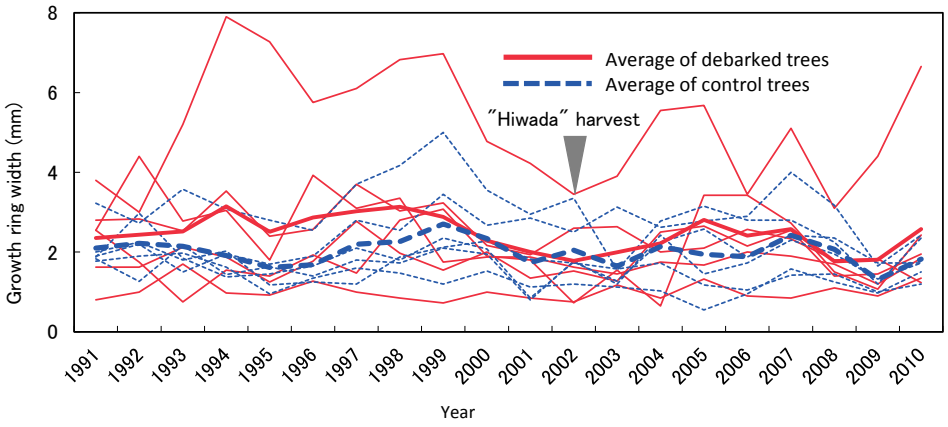

Fig. 4. Annual xylem growth ring width in average of 4 directions, and the average of each of debarked and control trees, before and after the first "hiwada" harvest experiment in autumn of 2002.

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「桧皮」、屋根葺き材としてのヒノキ (*Chamaecyparis obtusa*) の樹皮における樹脂道

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要旨

「桧皮」は、文化財木造建造物の主要な屋根葺き材で、ヒノキの大径木から約 10 年間隔で採取可能とされる樹皮である。林野庁近畿中国森林管理局が 2002 年秋と 2011 年 10 月の 2 度、桧皮採取を実施した試験地で、高齢ヒノキ（剥皮木：6 本、対照木：6 本）を供試木とし、剥皮前後の樹皮における樹脂道形成を顕微鏡観察した。内樹皮と外樹皮の両方に、剥皮処理の有無に関わらず、接線方向に配列した樹脂道の帯が不規則な間隔で存在し、それらの形成年は供試木間で同調していなかった。桧皮採取時に最新 2 年の師部年輪は、外的傷害によって翌年には樹脂道を形成したことから、傷害樹脂道を発達させる能力を十分に備えていたことが明らかである。しかし、桧皮採取のみでは、これらの年輪に、剥皮木でも樹脂道が形成されない供試木があり、対照木でも樹脂道が形成された供試木があった。従って、桧皮採取のための剥皮処理によって傷害樹脂道の形成が誘引されるものではないことは明らかである。さらに、供試木における樹脂道の形成要因がヒノキ漏脂病の病原菌ではないことが病理学的に示唆された。ヒノキは正常樹脂道を木部にも師部にも持たない樹種とされているが、桧皮には樹脂道が多く含まれている。ヒノキの樹皮の樹脂道は顕微形態的には傷害樹脂道であるが、三好・島倉 (1935) の結果が示唆するように、その存在は普遍的であって、その形成は桧皮採取に起因するものではない。

キーワード：師部、剥皮、木の文化、顕微鏡観察、薄切片、年輪、*Cistella japonica*

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