# Study of Warty Layer by the Scanning Electron Microscopy. II.

## Occurrence of Warts in Vessel Members and Wood Fibers of Japanese Dicotyledonous Woods.*

By

**Jun OHTANI****

走査型電子顕微鏡によるイボ状層の研究 (第2報)

本邦産双子葉木本植物の道管要素と木部繊維における イボ状突起の存在*

大 谷 諄**

CONTENTS



## Introduction

The occurrence, origin and chemical nature of warts in gymnosperms tracheids have been studied by many authors (KOBAYASHI and UTSUMI 1951; LIESE 1951, 1956, 1957 a, 1963, 1965; HARADA 1953, 1955; FREY-WYSSLING et al. 1955, 1956; HARADA et al. 1958; WARDROP et al. 1959; CRONSHAW et al. 1961; WARDROP and DAVIES 1962; WARDROP 1964; CRONSHAW 1965; TSOUMIS 1965; CÔTÉ and DAY 1969; OHTANI and FUJIKAWA 1971; BAIRD et al. 1974 a, 1974 b; VERHOFF and KNIGGE 1976; TAKIYA et al. 1976). Although those of warts in dicotyledonous woods have also been studied, the number of species examined is rather limited (LIESE 1957 b, 1963, 1965; HARADA 1962, 1965; CÔTÉ and DAY 1962; SCHMID and

* Received 31 January 1979.

** Laboratory of Wood Physics, Dept. of Forest Products, Faculty of Agriculture, Hokkaido University.
北海道大学農学部林産学科木材理学教室

MACHADO 1964; SCHMID 1965; JAYME and AZZOLA 1966; SCURFIELD and SILVA 1970; SCURFIELD et al. 1970; GREAVES 1973; OHTANI and ISHIDA 1973, 1976 a, 1976 b; PARHAM and BAIRD 1974; MEYLAN and BUTTERFIELD 1974). Accordingly, observations on the occurrence of warts in a wide variety of dicotyledonous wood species have not yet been reported.

In connection with the observations on sculpturings of cell wall in Japanese dicotyledonous woods using scanning electron microscopy (SEM), the occurrence of warts in vessel members and wood fibers was examined in 221 species (121 genera, 52 families) of Japanese dicotyledonous woods using SEM and the results are presented in this paper.

## Materials and Methods

The names of the species (221 species, 121 genera, 52 families) examined in this study are listed in Table 1.

Wood samples were obtained from living trees and/or the wood collection of the Department of Forest Products, Hokkaido University. Small blocks were taken from the outer sapwoods of them. Longitudinal radial surfaces to be observed were obtained by cutting with new razor blades. Specimens were finished in the form of ca. 6 mm (l) × 6 mm (r) × 1 mm (t) and dried at room conditions. They were then stuck on the brass standard stubs with electrically conductive paste. The longitudinal radial surfaces were coated with carbon-gold in a high vacuum evaporation unit. Observations were made with a JSM-2 SEM at 15-25 kV.

In order to confirm the variation of warts occurrence in each species, observations were made across the annual rings in several specimens obtained from each of the 221 species.

## Results

In many of the species with warts, difference in the degree of warts occurrence was found not only between vessel members and wood fibers but also within the same cell type even within a species. Accordingly, warts occurrence in each cell type of vessel members and wood fibers in all the species examined is tabulated in Table 1. The marks used in the Table show three grades of warts occurrence classified on the basis of the difference in density of warts distribution on the entire inner surface within a cell, regardless of their shape and size. That is notified as follows; − : warts are not (or scarcely) present, + : warts are sparsely (or locally)present, ++ : warts are densely present. For instance, particular species indicated by three kinds of marks (−, +, ++) in the column of vessel member in the Table mean that the ones possess the vessel members in which warts are not, sparsely or densely present.

The species names used in the Table mostly follow OHWI (1972). In this paper, warts occurrence in parenchyma cells is not described, because it was very difficult to confirm accurately warts occurrence in many of the species examined due to cytoplasmic remnants existing in parenchyma cells. For convenience, the

**Table 1** Occurrence of warts in the species examined

| Botanical name | Warts occurrence | |
|---|---|---|
| | Vessel member | Wood fiber |
| Salicaceae | | |
| *Populus sieboldii* MIQUEL | — | — |
| *Populus maximowiczii* HENRY | — | — |
| *Populus nigra* LINN. var. *italica* MUENCHH. | — | — |
| *Salix bakko* KIMURA | — | — |
| *Salix kinuyanagi* KIMURA | — | — |
| *Salix sachalinensis* FR. SCHM. | — | — |
| Myricaceae | | |
| *Myrica rubra* SIEB. et ZUCC. | — | — |
| Juglandaceae | | |
| *Platycarya strobilacea* SIEB. et ZUCC. | — | — |
| *Pterocarya rhoifolia* SIEB. et ZUCC. | — | — |
| *Juglans ailanthifolia* CARR. | — | — |
| Betulaceae | | |
| *Carpinus tschonoskii* MAXIM. | — | — |
| *Carpinus laxiflora* (SIEB. et ZUCC.) BLUME | — | — |
| *Carpinus japonica* BLUME | — | — |
| *Carpinus cordata* BLUME | — | — |
| *Ostrya japonica* SARG. | — | — |
| *Corylus sieboldiana* BLUME | — | — |
| *Betula maximowicziana* REGEL | — | — |
| *Betula platyphylla* SUKATCHEV var. *japonica* (MIQ.) HARA | — | — |
| *Betula ermanii* CHAM. | — | — |
| *Betula grossa* SIEB. et ZUCC. | — | — |
| *Alnus firma* SIEB. et ZUCC. | — | — |
| *Alnus maximowiczii* CALLIER | — | — |
| *Alnus hirsuta* TURCZ. | — | — |
| *Alnus serrulatoides* CALLIER | — | — |
| *Alnus japonica* (THUNB.) STEUD. | — | — |
| Fagaceae | | |
| *Fagus crenata* BLUME | — + ++ | ++ |
| *Fagus japonica* MAXIM. | — + ++ | ++ |
| *Quercus acuta* THUNB. | + ++ | + ++ |
| *Quercus sessilifolia* BLUME | + ++ | + ++ |
| *Quercus gilva* BLUME | — + ++ | — + ++ |
| *Quercus myrsinaefolia* BLUME | + ++ | + ++ |
| *Quercus glauca* THUNB. | + ++ | — + ++ |
| *Quercus salicina* BLUME | + ++ | + ++ |
| *Quercus phillyraeoides* A. GRAY | — + ++ | — + |
| *Quercus mongolica* FISCHER | — | — |
| *Quercus crispula* BLUME | — | — |

**Table 1** (Continued) 2

| Botanical name | Warts occurrence | |
|---|---|---|
| | Vessel member | Wood fiber |
| *Quercus serrata* THUNB. | — | — |
| *Quercus dentata* THUNB. | — | — |
| *Quercus variabilis* BLUME | − + ++ | − + |
| *Quercus acutissima* CARRUTH. | − + ++ | − + |
| *Castanea crenata* SIEB. et ZUCC. | — | − + |
| *Castanopsis cuspidata* (THUNB.) SCHOTTKY | − + | + ++ |
| *Castanopsis cuspidata* (THUNB.) SCHOTTKY var. *sieboldii* (MAKINO) NAKAI | − + | + ++ |
| *Pasania glabra* (THUNB.) OERST. | + ++ | + ++ |
| Ulmaceae | | |
| *Ulmus davidiana* PLANCH. var. *japonica* (REHD.) NAKAI | — | — |
| *Ulmus laciniata* (TRAUTV.) MAYR | — | — |
| *Zelkova serrata* (THUNB.) MAKINO | — | — |
| *Celtis sinensis* PERS. var. *japonica* (PLANCH.) NAKAI | — | — |
| *Aphananthe aspera* (THUNB). PLANCH. | — | — |
| Moraceae | | |
| *Morus bombycis* KOIDZ. | — | — |
| *Broussonetia papyrifera* (LINN.) VENT. | — | — |
| *Ficus pumila* LINN. | — | — |
| *Ficus erecta* THUNBERG | — | — |
| *Ficus erecta* THUNBERG var. *yamadorii* MAKINO | — | — |
| Proteaceae | | |
| *Helicia cochinchinensis* LOUR. | — | − + |
| Trochodendraceae | | |
| *Trochodendron aralioides* SIEB. et ZUCC. | | + ++ |
| Cercidiphyllaceae | | |
| *Cercidiphyllum japonicum* SIEB. et ZUCC. | — | — |
| Berberidaceae | | |
| *Berberis thunbergii* DC. | — | — |
| *Nandina domestica* THUNB. | — | — |
| Magnoliaceae | | |
| *Michelia compressa* (MAXIM.) SARG. | — | — |
| *Magnolia obovata* THUNBERG | — | — |
| *Magnolia salicifolia* (SIEB. et ZUCC.) MAXIM. | — | — |
| *Magnolia kobus* DC. var. *borealis* SARG. | — | — |
| *Illicium religiosum* SIEB. et ZUCC. | — | + ++ |
| *Liriodendron tulipifera* L. | − + | ++ |
| Lauraceae | | |
| *Cinnamomum camphora* (LINN.) SIEBOLD | — | — |
| *Cinnamomum japonicum* SIEBOLD, ex NAKIA | — | — |

**Table 1** (Continued) 3

| Botanical name | Warts occurrence | |
|---|---|---|
| | Vessel member | Wood fiber |
| *Machilus thunbergii* SIEB. et ZUCC. | — | — |
| *Lindera erythrocarpa* MAKINO | — | — |
| *Lindera umbellata* THUNB. | — | — |
| *Parabenzoin praecox* (SIEB. et ZUCC.) NAKAI | — | — |
| *Neolitsea sericea* (BLUME) KOIDZ. | — | — |
| *Neolitsea aciculata* (BLUME) KOIDZ. | — | — |
| *Actinodaphne lancifolia* (SIEB. et ZUCC.) MEISN. | — | — |
| *Actinodaphne longifolia* (BLUME) NAKAI | — | — |
| Saxifragaceae | | |
| *Hydrangea petiolaris* SIEB. et ZUCC. | — | — |
| *Hydrangea paniculata* SIEBOLD | — | — |
| *Deutzia crenata* SIEB. et ZUCC. | — | — |
| Hamamelidaceae | | |
| *Hamamelis japonica* SIEB. et ZUCC. | — | — |
| *Distylium racemosum* SIEB. et ZUCC. | — | — |
| Rosaceae | | |
| *Prunus mume* SIEB. et ZUCC. | — | — |
| *Prunus persica* (LINN.) BATSCH. | — | — |
| *Prunus apetala* (SIEB. et ZUCC.) FRANCH. et SAVAT. | — | + ++ |
| *Prunus incisa* THUNB. | — | ++ |
| *Prunus pendula* MAXIM. forma *ascendens* (MAKINO) OHWI | — | − + |
| *Prunus jamasakura* SIEB., ex KOIDZ. | — | — |
| *Prunus sargentii* REHDER | — | — |
| *Prunus maximowiczii* RUPR. | — | − + |
| *Prunus spinulosa* SIEB. et ZUCC. | — | + ++ |
| *Prunus ssiori* Fr. SCHM. | — | ++ |
| *Prunus grayana* MAXIM. | — | ++ |
| *Prunus buergeriana* MIQ. | — | ++ |
| *Photinia glabra* (THUNB.) MAXIM. | — | — |
| *Eriobotrya japonica* (THUNB.) LINDL. | — | — |
| *Malus sieboldii* (REGEL) REHDER | — | — |
| *Pourthiaea villosa* (THUNB.) DECNE. var. *laevis* (THUNB.) STAPF | — | — |
| *Sorbus commixta* HEDL. | — | — |
| *Sorbus alnifolia* (SIEB. et ZUCC.) C. KOCH | — | — |
| *Sorbus japonica* (DECNE.) HEDL. | — | — |
| Leguminosae | | |
| *Albizia julibrissin* DURAZZ. | + ++ | — |
| *Acacia confusa* MERR. | ++ | — |
| *Gleditsia japonica* MIQ. | — | — |
| *Caesalpinia japonica* SIEB. et ZUCC. | + ++ | — |
| *Sophora japonica* LINN. | — | — |

**Table 1** (Continued) 4

| Botanical name | Warts occurrence | |
|---|---|---|
| | Vessel member | Wood fiber |
| *Maackia amurensis* RUPR. et MAXIM. var. *buergeri* (MAXIM.) C. K. SCHN. | — | — |
| *Cladrastis platycarpa* (MAXIM.) MAKINO | — | — |
| *Euchresta japonica* HOOK. fil. | — | — |
| *Lespedeza bicolor* TURCZ. forma *acutifolia* MATSUM. | + ++ | — |
| *Caragana chamlagu* LAM. | — | — |
| *Pueraria lobata* (WILLD.) OHWI | — | — |
| *Wisteria floribunda* (WILLD.) DC. | — | — |
| *Millettia japonica* (SIEB. et ZUCC.) A. GRAY | — | — |
| *Robinia pseudo-acacia* LINN. | — | — |
| Rutaceae | | |
| *Zanthoxylum piperitum* (LINN.) DC. | — | — |
| *Zanthoxylum ailanthoides* SIEB. et ZUCC. | — | — |
| *Phellodendron amurense* RUPR. | — | — |
| Simaroubaceae | | |
| *Ailanthus altissima* SWINGLE | — | — |
| *Picrasma quassioides* (D. DON) BENN. | — | — |
| Meliaceae | | |
| *Melia azedarach* LINN. | — | — |
| *Cedrela sinensis* JUSS. | — | — |
| Euphorbiaceae | | |
| *Daphniphyllum macropodum* MIQ. | — | — |
| *Daphniphyllum teijsmannii* ZOLL. | — | — |
| *Mallotus japonicus* (THUNB.) MUELL. ARG. | — | — |
| *Aleurites cordata* R. Br. | ++ | — |
| *Sapium japonicum* (SIEB. et ZUCC.) PAX et HOFFM. | ++ | — |
| Buxaceae | | |
| *Buxus microphylla* SIEB. et ZUCC. var. *japonica* (MUELL. ARG.) REHD. et WILS. | — | — |
| Anacardiaceae | | |
| *Rhus succedanea* LINN. | — | — |
| *Rhus verniciflua* STOKES | — | — |
| *Rhus sylvestris* SIEB. et ZUCC. | — | — |
| *Rhus trichocarpa* MIQ. | — | — |
| *Rhus javanica* LINN. | — | — |
| Aquifoliaceae | | |
| *Ilex macropoda* MIQ. | — | − + |
| *Ilex micrococca* MAXIM. | — | − + ++ |
| *Ilex sugerokii* MAXIM. var. *longipedunculata* (MAXIM.) MAKINO | — | − + |
| *Ilex crenata* THUNB. | — | − + |
| *Ilex pedunculosa* MIQ. | — | − + |

**Table 1** (Continued) 5

| Botanical name | Warts occurrence | |
|---|---|---|
| | Vessel member | Wood fiber |
| *Ilex rotunda* THUNB. | — | − + |
| *Ilex integra* THUNB. | — | − + |
| *Ilex latifolia* THUNB. | — | − + |
| Celastraceae | | |
| *Celastrus orbiculatus* THUNB. | — | — |
| *Euonymus sieboldianus* BLUME | — | — |
| *Euonymus oxyphyllus* MIQ. | — | — |
| Staphyleaceae | | |
| *Euscaphis japonica* (THUNB.) KANITZ | — | + ++ |
| Aceraceae | | |
| *Acer sieboldianum* MIQ. | − + | — |
| *Acer japonicum* THUNB. | − + ++ | — |
| *Acer palmatum* THUNB. var. *palmatum* | − + | — |
| *Acer palmatum* THUNB. var. *matsumurae* (KOIDZ.) MAKINO | − + | — |
| *Acer mono* MAXIM. | − + | — |
| *Acer miyabei* MAXIM. | − + | — |
| *Acer distylum* SIEB. et ZUCC. | − + | — |
| *Acer ukurunduense* TRAUTV. et MEY. | − + | — |
| *Acer carpinifolium* SIEB. et ZUCC. | − + | — |
| *Acer crataegifolium* SIEB. et ZUCC. | − + | — |
| *Acer rufinerve* SIEB. et ZUCC. | − + | — |
| *Acer cissifolium* (SIEB. et ZUCC.) K. KOCH | − + | — |
| Hippocastanaceae | | |
| *Aesculus turbinata* BLUME | — | — |
| Sapindaceae | | |
| *Sapindus mukorossi* GAERTN. | — | — |
| Sabiaceae | | |
| *Meliosma rigida* SIEB. et ZUCC. | — | — |
| *Meliosma myriantha* SIEB. et ZUCC. | + ++ | − + |
| Rhamnaceae | | |
| *Zizyphus jujuba* MILL. var. *inermis* (BUNGE) REHD. | ++ | — |
| *Hovenia dulcis* THUNB. | — | — |
| Elaeocarpaceae | | |
| *Elaeocarpus japonicus* SIEB. et ZUCC. | — | — |
| Tiliaceae | | |
| *Tilia japonica* (MIQ.) SIMONKAI | — | — |
| Malvaceae | | |
| *Hibiscus syriacus* LINN. | — | — |
| Sterculiaceae | | |
| *Firmiana simplex* (LINN.) W. F. WIGHT | — | — |
| Theaceae | | |
| *Camellia japonica* LINN. | — | — |

**Table 1** (Continued) 6

| Botanical name | Warts occurrence | |
|---|---|---|
| | Vessel member | Wood fiber |
| *Camellia japonica* LINN. var. *hortensis* (MAKINO) MAKINO | — | — |
| *Stewartia monadelpha* SIEB. et ZUCC. | — | + ++ |
| *Ternstroemia gymnanthera* (WIGHT et ARN.) SPRAGUE | — | — |
| *Cleyera japonica* THUNB. (p. p., em. SIEB. et ZUCC.) | — | ++ |
| *Eurya japonica* THUNB. | ++ | ++ |
| Flacourtiaceae | | |
| *Idesia polycarpa* MAXIM. | — | — |
| Thymelaeaceae | | |
| *Daphne kiusiana* MIQUEL | — | — |
| *Daphne odora* THUNB. | — | — |
| *Daphne miyabeana* MAKINO | — | — |
| *Daphne pseudo-mezereum* A. GRAY. | — | — |
| *Daphne kamtschatica* MAXIM. var. *jezoensis* (MAXIM.) OHWI | — | — |
| Lythraceae | | |
| *Lagerstroemia subcostata* KOEHNE | ++ | — |
| *Lagerstroemia indica* LINN. | ++ | — |
| Araliaceae | | |
| *Aralia elata* (MIQ.) SEEMANN | — | — |
| *Dendropanax trifidus* (THUNB.) MAKINO | — | — |
| *Acanthopanax sciadophylloides* FRANCH. et SAVAT. | — | — |
| *Evodiopanax innovans* (SIEB. et ZUCC.) MAKAI | — | — |
| *Kalopanax pictus* (THUNB.) NAKAI | — | — |
| Cornaceae | | |
| *Cornus controversa* HEMSLEY | — | — |
| *Cornus brachypoda* C. A. MEY. | — | — |
| *Cornus kousa* BUERGER, ex HANCE | — | ++ |
| Clethraceae | | |
| *Clethra barbinervis* SIEB. et ZUCC. | + ++ | ++ |
| Ericaceae | | |
| *Pieris japonica* (THUNB.) D. DON | — | — |
| *Lyonia ovalifolia* (WALL.) DRUDE var. *elliptica* (SIEB. et ZUCC.) HAND. -MAZZ. | — | + ++ |
| *Enkianthus cernuus* (SIEB. et ZUCC.) MAKINO forma *rubens* (MAXIM.) OHWI | ++ | ++ |
| *Vaccinium bracteatum* THUNB. | — | — |
| Myrsinaceae | | |
| *Myrsine seguinii* LÉV. | — | — |
| Ebenaceae | | |
| *Diospyros morrisiana* HANCE | — | — |
| *Diospyros lotus* LINN. | — | — |

**Table 1** (Continued) 7

| Botanical name | Warts occurrence | |
|---|---|---|
| | Vessel member | Wood fiber |
| *Diospyros kaki* THUNB. | — | — |
| Symplocaceae | | |
| *Symplocos coreana* (LÉVEILLÉ) OHWI | + ++ | ++ |
| *Symplocos lancifolia* SIEB. et ZUCC. | — | — |
| *Symplocos theophrastaefolia* SIEB. et ZUCC. | — | — |
| *Symplocos glauca* (THUNB.) KOIDZ. | — | — |
| *Symplocos prunifolia* SIEB. et ZUCC. | — | — |
| Styracaceae | | |
| *Styrax japonica* SIEB. et ZUCC. | — | — |
| *Styrax obassia* SIEB. et ZUCC. | — | — |
| *Pterostyrax corymbosa* SIEB. et ZUCC. | — | — |
| Oleaceae | | |
| *Ligustrum japonicum* THUNB. | — | — |
| *Ligustrum obtusifolium* SIEB. et ZUCC. | — | — |
| *Osmanthus fragrans* var. *aurantiacus* MAKINO | — | — |
| *Osmanthus fragrans* LOUR. | — | — |
| *Osmanthus heterophyllus* (G. DON) P. S. GREEN | — | — |
| *Osmanthus fortunei* CARR. | — | — |
| *Syringa reticulata* (BLUME) HARA | — | — |
| *Fraxinus spaethiana* LINGELSH. | — | — |
| *Fraxinus mandshurica* RUPR. var. *japonica* MAXIM. | — | — |
| *Fraxinus japonica* BLUME | — | — |
| *Fraxinus lanuginosa* KOIDZ. | — | — |
| Verbenaceae | | |
| *Clerodendrum trichotomum* THUNB. | — | — |
| Scrophulariaceae | | |
| *Paulownia tomentosa* (THUNB.) STEUD. | — | — |
| Bignoniaceae | | |
| *Catalpa ovata* G. DON | — | — |
| Caprifoliaceae | | |
| *Sambucus sieboldiana* BLUME, ex GRAEBN. var. *miquelii* (NAKAI) HARA | — | — |
| *Viburnum dilatatum* THUNB. | — | — |
| *Viburnum awabuki* K. KOCH | — | — |

term "wood fiber" used in this paper includes the tracheid in certain species.

Warts were found in vessel members and/or wood fibers in 66 species belonging to the following 18 families: Fagaceae, Proteaceae, Trochodendraceae, Magnoliaceae, Rosaceae, Leguminosae, Euphorbiaceae, Aquifoliaceae, Staphyleaceae, Aceraceae, Sabiaceae, Rhamnaceae, Theaceae, Lythraceae, Cornaceae, Clethraceae, Ericaceae, Symplocaceae.

## 1. Occurrence of warts in vessel members.

FAGACEAE

Warts varied remarkably in shape, size and density of distribution among vessel members in *Fagus crenata* and *F. japonica*. The detailed observations on morphological variation of warts in *F. crenata* have already been reported by the present author (OHTANI and ISHIDA 1973, 1976). Morphological variation of warts in *F. japonica* newly reported here was similar to that in *F. crenata*. In both species, warts were not present in the earlywood vessel members, while they were densely present in the latewood ones. Most of warts were hemispherical, conical or rod-like in shape. Size (diameter at the base) of the warts ranged from 50 to 700 nm. In general, large, well-developed warts in these species were bigger in height that in diameter, and some of them were very complicated in shape.

Of the 13 species examined belonging to *Quercus*, warts were found in nine species. Warts were found in all the vessel members in *Q. acuta*, *Q. sessilifolia* (Photos 1 and 2), *Q. myrsinaefolia*, *Q. glauca* and *Q. salicina*, and they were sparsely (Photo 1) or densely (Photo 2) distributed. They were more densely distributed in the smaller vessel members in diameter than in the larger ones, independently of their position within an annual ring. In *Q. gilva*, *Q. phillyraeoides*, *Q. variabilis* and *Q. acutissima*, they were present in some vessel members, but not in the others. In *Q. gilva* and *Q. phillyraeoides* (Photos 3 and 4), they were sparsely (Photo 3) or densely (Photo 4) present in the smaller vessel members, but not in the larger ones. In *Q. variabilis* and *Q. acutissima*, they were not or sparsely present in the early zone within an annual ring, while they were sparsely or densely present in the late zone. In the species in *Quercus*, the warts were, in general, hemispherical in shape and ranged from 50 to 500 nm in size.

In *Castanopsis cuspidata* and *C. cuspidata* var. *sieboldii*, warts were not present in the early zone, while they were not or sparsely present in the late zone. They were generally hemispherical in shape and ranged from 50 to 400 nm in size.

Warts were present in all the vessel members in *Pasania glabra*. They were more densely distributed in the smaller vessel members than in the larger ones, independently of their position within an annual ring. They were generally hemispherical in shape and ranged from 50 to 500 nm in size.

MAGNOLIACEAE

Of the six species examined, warts were found only in *Liriodendron tulipifera* (Photo 5). In this species, warts were sparsely present only in the vessel members of terminal zone (Photo 5), but not in the others. They were hemispherical or conical in shape and ranged from 50 to 500 nm in size.

LEGUMINOSAE

Of the 14 species examined, four revealed warts in all the vessel members, and in the remainder they were not or scarcely present. In *Albizia julibrissin* (Photo 6), branched and unbranched warts were found. They were more densely

distributed in the late zone within an annual ring than in the early zone. In *Acacia confusa* (Photo 7), unbranched warts were almost uniformly distributed, while branched ones were often aggregated or anastomosed in the localized region on the inner surface. In *Caesalpinia japonica* (Photo 8), warts varied remarkably in shape, size and density of distribution among vessel members. They varied irregularly within an annual ring. Especially, branched ones of various shape were found. In *Lespedeza bicolor* forma *acutifolia*, warts were sparsely or densely distributed. They were more densely distributed in the late zone within an annual ring than in the early zone. Branched ones were often observed in the former. In the four species, unbranched ones were hemispherical, conical or rod-like in shape. Branched ones appeared as various shape. The range of warts size could not be measured, because branched warts were often aggregated or anastomosed. The detailed observations on warts in the four species have already been reported elsewhere (OHTANI and ISHIDA 1976 b).

EUPHORBIACEAE

Of the five species examined, warts were found in *Aleurites cordata* and *Sapium japonicum* (Photo 9). They were densely distributed in all the vessel members in both species. They were, in general, hemispherical in shape and ranged from 50 to 600 nm in size.

ACERACEAE

Warts were not or present in each of all the species examined in *Acer*. Apart from the fact that warts were densely distributed in a few vessel members in *A. japonicum*, they were sparsely distributed in some vessel members in all the species examined (Photo 10). Vessel members with them occurred irregularly within an annual ring. They varied in the frequency of occurrence among the species. They were rarely found in *A. miyabei*, *A. distylum*, *A. carpinifolium* and *A. cissifolium*. They were always hemispherical in shape and ranged from 50 to 300 nm in size in all the species.

SABIACEAE

Warts were found in *Meliosma myriantha* (Photo 11), but not in *M. rigida* belonging to the same genus. Although warts were densely distributed in most of vessel members (Photo 11), they were sparsely distributed in the others. They varied irregularly in density of distribution within an annual ring. Shape and size of them in this species could not be confirmed accurately because they were always covered with amorphous substances in specimens examined.

RHAMNACEAE

Warts were densely distributed in all the vessel members in *Zizyphus jujuba* var. *inermis*. They were generally hemispherical in shape and ranged from 50 to 300 nm in size.

THEACEAE

Of the six species examined, warts were found only in *Eurya japonica* (Photo

12). They were densely distributed in all the vessel members. In many cases, however, they were not present in the region near the pit apertures (Photo 12). They were hemispherical or conical in shape and ranged from 50 to 500 nm in size.

LYTHRACEAE

Unbranched warts were always densely distributed in *Lagerstroemia subcostata* and *L. indica* (Photo 13). Branched ones were also occasionally found (Photo 14). Unbranched ones were hemispherical, conical or rod-like in shape. The range of warts size could not be measured, because warts were occasionally aggregated or anastomosed. Their occurrence in these species has already been reported by the present author (OHTANI and ISHIDA 1976).

CLETHRACEAE

Warts were present in all the vessel members in *Clethra barbinervis* (Photos 15 and 16). They were sparsely (Photo 15) or densely (Photo 16) distributed on the inner surface. They varied irregularly in density of distribution within an annual ring. They were always hemispherical in shape and ranged from 50 to 300 nm in size.

ERICACEAE

Of the four species examined, warts were present in only one species. Very small warts of 50–200 nm were always densely distributed in *Enkianthus cernuus* forma *rubens* (Photo 17). They were generally hemispherical in shape.

SYMPLOCACEAE

Of the five species examined belonging to *Symplocos*, warts were present only in *S. coreana* (Photos 18 and 19). They were sparsely distributed in the early zone within an annual ring (Photo 18), and sparsely or densely (Photo 19) in the late zone. They were hemispherical or conical in shape and ranged from 50 to 500 nm in size.

**2. Occurrence of warts in wood fibers.**

FAGACEAE

Warts were always densely distributed in *Fagus crenata* (Photo 20) and *F. japonica*. They were hemispherical, conical or rod-like in shape and ranged from 50 to 500 nm in size.

Of the 13 species examined belonging to *Quercus*, warts were found in nine species. Warts were present in all the wood fibers in *Q. acuta*, *Q. sessilifolia*, *Q. myrsinaefolia* and *Q. salicina*. They were sparsely (Photo 21) or densely (Photo 22) distributed. In *Q. gilva* and *Q. glauca*, they were not, sparsely or densely present. In *Q. phillyraeoides*, *Q. variabilis* and *Q. acutissima*, they were not or sparsely present. The warts in these species in *Quercus* were generally hemispherical in shape and ranged from 50 to 500 nm in size.

Warts were not or sparsely present in *Castanea crenata*. They were generally

hemispherical in shape and ranged from 50 to 500 nm in size.

Warts were present in all the wood fibers in *Castanopsis cuspidata* (Photo 23) and *C. cuspidata* var. *sieboldii*. They were sparsely (Photo 23) or densely distributed. They were generally hemispherical in shape and ranged from 50 to 400 nm in size.

In *Pasania glabra*, warts were present in all the wood fibers. They were sparsely or densely distributed. They were generally hemispherical in shape and ranged from 50 to 400 nm in size.

In these species in *Quercus*, *Castanea*, *Castanopsis* and *Pasania*, the warts varied irregularly in density of distribution within an annual ring.

PROTEACEAE

Warts were not or locally present on the inner surface in *Helicia cochinchinensis*. Wood fibers with warts occurred irregularly within an annual ring. They were always hemispherical in shape and ranged from 50 to 350 nm in size.

TROCHODENDRACEAE

Warts were always present in *Trochodendron aralioides*, a member of vesselless dicotyledons. They were more densely distributed in the earlywood within an annual ring than in the latewood. In the earlywood tracheids (Photo 24), warts of 50–600 nm were densely distributed and they were hemispherical, conical or rod-like in shape. Bigger warts were often concentrated at the tracheid corner (Photo 25). In the latewood fiber tracheids (Photo 26), warts of 50–300 nm were sparsely distributed and they were hemispherical or conical in shape.

MAGNOLIACEAE

Of the six species examined, only two revealed warts. In *Illicium religiosum*, warts were sparsely distributed in some wood fibers and densely in the others. They were always hemispherical in shape and ranged from 50 to 450 nm in size. They varied irregularly in density of distribution within an annual ring. In *Liriodendron tulipifera*, they were densely distributed in all the wood fibers. They were hemispherical or conical in shape and ranged from 50 to 500 nm in size.

ROSACEAE

Of the 19 species examined, the eight species belonging to *Prunus* possessed warts in wood fibers. However, the four species belonging to this genus possessed no warts. Warts were always densely distributed in *P. incisa*, *P. ssiori* (Photo 27), *P. grayana* and *P. buergeriana* (Photo 28). They were sparsely or densely distributed in *P. apetala* and *P. spinulosa*. They were not or sparsely present in *P. pendula* and *P. maximowiczii*. In *P. apetala*, *P. spinulosa*, *P. pendula* and *P. maximowiczii*, the warts varied irregularly in density of distribution within an annual ring. In all the species with warts in *Prunus*, they were always hemispherical in shape and ranged from 50 to 400 nm in size.

AQUIFOLIACEAE

In all the species in *Ilex* examined, warts were present in some wood fibers, but not in the others. They were not, sparsely or densely present in *Ilex micrococca* (Photo 29), while they were not or sparsely present in the remainder. Most of wood fibers possessed no warts in the latter. In all the species examined in *Ilex*, they were generally hemispherical in shape and ranged from 50 to 600 nm in size. They varied irregularly in density of distribution within an annual ring.

STAPHYLEACEAE

Warts were present in all the wood fibers in *Euscaphis japonica* (Photo 30). They were sparsely distributed in most of wood fibers and densely in some of the late zone within an annual ring. They were hemispherical or conical in shape and ranged from 50 to 600 nm in size.

SABIACEAE

Warts were not or locally present on the inner surface in *Meliosma myriantha*, while they were not present in *M. rigida*. They were generally hemispherical in shape and ranged from 50 to 500 nm in size. Wood fibers with warts occurred irregularly within an annual ring.

THEACEAE

Of the six species examined, three revealed warts. Warts were sparsely distributed in some wood fibers and densely in the others in *Stewartia monadelpha* (Photo 31). Their shape was always hemispherical. Although their size ranged from 50 to 300 nm, most of them were smaller than 200 nm. They varied irregularly in density of distribution within an annual ring.

Warts were densely distributed in all the wood fibers in *Cleyera japonica* (Photo 32). In many cases, however, they were not present in the region near the pit apertures. Their shape was hemispherical, conical or rod-like. Their size ranged from 50 to 800 nm and bigger warts of 500–800 nm were often observed (Photo 32).

Warts were densely distributed in all the wood fibers in *Eurya japonica* (Photo 33). As in vessel members, however, they were not present in the region near the pit apertures. They were hemispherical or conical in shape and ranged from 50 to 700 nm in size.

CORNACEAE

Warts were present in *Cornus kousa*, but not in *C. controversa* and *C. brachypoda* belonging to the same genus. They were always densely distributed in *C. kousa*. They were hemispherical, conical or rod-like in shape and ranged from 50 to 400 nm in size.

CLETHRACEAE

Warts were always densely distributed in *Clethra barbinervis* (Photo 35). Their shape was always hemispherical. Although their size ranged from 50 to 350 nm,

most of them were smaller than 200 nm (Photo 35).

ERICACEAE

Warts were found in two of the four species examined. In *Lyonia ovalifolia* var. *elliptica*, warts were sparsely distributed in some wood fibers and densely in the others. They were generally hemispherical in shape and ranged from 50 to 300 nm in size.

In *Enkianthus cernuus* forma *rubens*, small warts were densely distributed in all the wood fibers, as in all the vessel members. They were generally hemispherical in shape and ranged from 50 to 200 nm in size.

SYMPLOCACEAE

Of the five species examined in *Symplocos*, only one revealed warts. Warts were always densely distributed in *Symplocos coreana* (Photo 36). They were hemispherical or conical in shape. Their size ranged from 50 to 800 nm and many of them were bigger than 500 nm.

## Discussion and Conclusions

The present SEM observation on warts occurrence in vessel members and wood fibers of Japanese dicotyledonous woods revealed shape, size and density of distribution of warts in many species which have not yet been reported and also confirmed the known information in several species already reported.

In the present SEM observation, however, the obscure granular structure covered with amorphous substances was found in the following species: *Cinnamomum camphora*, *C. japonicum*, *Machilus thunbergii*, *Lindera erythrocarpa*, *L. umbellata*, *Parabenzoin praecox*, *Neolitsea sericea*, *N. aciculata*, *Actinodaphne lancifolia*, *A. longifolia* —(Lauraceae), *Mallotus japonicus*— (Euphorbiaceae), *Meliosma rigida* —(Sabiaceae), *Myrsine seguinii*— (Myrsinaceae). The granular structure was similar to that in *Fagus grandifolia* and *Platanus occidentalis* reported by PARHAM and BAIRD (1974). Such a structure might be a characteristic of the species described above. Although it resembled incipient warts, it was difficult to decide whether the structure was warts or not. Further examination would be required to confirm such a structure in these species. For convenience, the species with this kind of structure are regarded as the ones without warts in Table 1.

As shown in Table 1, warts were found in vessel members and/or wood fibers in 66 species (30 genera, 18 families) of the 221 (121, 52) examined. That is, the species with warts were fewer in number than those without warts. On the contrary, the former is more than the latter in gymnosperms investigated by HARADA (1953), HARADA et al. (1958) and LIESE (1965). It can be considered, therefore, that the species with warts in Japanese dicotyledonous woods are restricted in the frequency of their occurrence compared with that in gymnosperms.

It is well known that the presence or absence of warts in softwoods tracheids is consistent within the same genus except *Pinus* (HARADA 1953; HARADA et al. 1958; LIESE 1965). That the presence or absence of warts is consistent within

the same genus was also confirmed in many of genera examined in the present observation. However, the species with and without warts were found in certain several genera. As shown in Table 1, such examples were recognized in *Quercus, Prunus, Meliosma, Cornus* and *Symplocos.* The difference of warts occurrence among the species within each of these genera brings us to interesting problem from point of view of wood taxonomy. In this connection, PARAMESWARAN and LIESE (1977) have reported that there is no recognizable correlation between the occurrence of warts and the taxonomic grouping of bamboos and that warts appear restricted and more irregularly developed within the genera and species of the monocots than in dicots.

Although 20 of the 66 species with warts possessed warts in both vessel members and wood fibers, the remainder possessed warts only in vessel members (in 21 species) or in wood fibers (in 25 species). This fact indicates that warts occurrence in many species is variable between different cell types even within the same species. Moreover, of the 41 species having warts in vessel members, 21 species possessed vessel members with and without warts. Of the 44 species having warts in wood fibers, 18 species possessed wood fibers with and without warts. This fact indicates that warts occurrence in many species varies even in the same cell type within the same species. These evidences suggest that variation of warts occurrence within the same species in dicotyledonous woods is more remarkable compared with that in softwoods (OHTANI and FUJIKAWA 1971).

Density of warts distribution in vessel members within an annual ring was about constant in the nine species, but not in the 32 species. In the latter case, variation of that showed different patterns among the species. Density of warts distribution varied in association with the position of vessel members within an annual ring in the following species: *Fagus crenata, F. japonica, Quercus variabilis, Q. acutissima, Castanopsis cuspidata, C. cuspidata* var. *sieboldii, Liriodendorn tulipifera, Albizia julibrissin, Lespedeza bicolor* forma *acutifolia, Symplocos coreana.* In these species, warts were more densely distributed in late zone within an annual ring than in the early zone. On the other hand, density of warts distribution varied in association with the diameter of vessel members independently of their position within an annual ring in the following species: *Quercus acuta, Q. sessilifolia, Q. gilva, Q. myrsinaefolia, Q. glauca, Q. salicina, Q. phillyraeoides, Pasania glabra.* In these species, warts were more densely distributed in the smaller vessel members than in the larger ones. In the others except the 18 species described above, warts varied irregularly in density of distribution within an annual ring independently of the diameter of vessel members and their position within an annual ring. Density of warts distribution in wood fibers within an annual ring was about constant in the 13 species, but not in the 31 species. In latter case, warts varied irregularly in density of distribution within an annual ring in all the species except *Trochodendron aralioides.* They were more densely distributed in the earlywood tracheids than in the latewood fiber tracheids in *T. aralioides.*

The size (diameter at the base) of warts in vessel members and wood fibers

varied not only among the species but also within a species. The size of the warts in vessel members examined ranged from 50 to 700 nm. Their size lay between 50 and 500 nm in many species. Only small warts of 50–200 nm were found in *Enkianthus cernuus* forma *rubens*. Warts bigger than 500 nm were often found in *Fagus crenata* and *F. japonica*, but numerous smaller ones were also present. The size of the warts in wood fibers examined ranged from 50 to 800 nm. Their size lay between 50 to 500 nm in many species. These values are the same as those in the vessel members. Only small warts of 50–200 nm were present in *Enkianthus cernuus* froma *rubens*. Most of warts in *Stewartia monadelpha* and *Clethra barbinervis* were smaller than 200 nm. On the other hand, warts bigger than 500 nm were often found in *Cleyera japonica*, *Eurya japonica* and *Symplocos coreana*. These values in vessel members and wood fibers fall within the range reported in softwoods tracheids (LIESE 1965; OHTANI and FUJIKAWA 1971).

The shape of the warts in vessel members examined can be divided into two main types: unbranched and branched. Unbranched warts were found in all of the species with warts. Unbranched ones observed were hemispherical, conical, rod-like etc. in shape. Although many species revealed hemispherical (and conical) ones, certain species did hemispherical, conical and rod-like ones. Some of the warts in *Fagus* examined were very complicated in shape as already reported by several authors (HARADA 1962, 1965; LIESE 1965; OHTANI and ISHIDA 1973; PARHAM and BAIRD 1974). Such warts were not found in the other species. Branched warts were restricted in the six species with vestured pits, though unbranched ones were also present in these species. The author's opinion with regard to the resemblance between the branched warts and pit vestures has already been described elsewhere (OHTANI and ISHIDA 1976 b). Branched warts were not found in wood fibers examined. The unbranched ones observed in wood fibers were hemispherical, conical and rod-like in shape. Generally, many species possessed hemispherical (and conical) ones.

As described above, shape, size and density of distribution of warts in vessel members and wood fibers are extremely variable between the species. Morphological variation of warts within the same species was consistent in several specimens from different trees more than one in all of many species which could be collected. Consequently, morphological variation of warts within an annual ring in each species is considered to be a characteristic of the species. As in the softwood tracheids reported in the previous paper (OHTANI and FUJIKAWA 1971), shape, size and density of distribution of warts in vessel members and wood fibers can be helpful for wood identification in dicotyledonous woods.

Vessel members with warts were found in 41 species, 20 genera, 12 families. Wood fibers with warts were found in 44 species, 21 genera, 13 families. That is, the frequency of warts occurrence in vessel members of the species examined differed little from that in wood fibers. As a whole, remarkable morphological difference of warts between in vessel members and in wood fibers was not recognized, with exception of the fact that branched warts were present in vessel members in certain

species but not in wood fibers. Although no definite conclusion can be described as yet from only these results of the limited species examined, it is assumed that the occurrence of warts is not necessarily associated with cell types (conducting and supporting cells).

**Acknowledgement** The author wishes to thank Prof. Dr. Shigeo ISHIDA for valuable comments on the manuscript.

## References

1) BAIRD, W. M., PARHAM, R. A. and JOHNSON, M. A.: Development and composition of the warty layer in balsam fir. I. Development. Wood and Fiber, **6**, 114–125 (1974 a).
2) BAIRD, W. M., JOHNSON, M. A. and PARHAM, R. A.: Development and composition of the warty layer in balsam fir. II. Composition. Wood and Fiber, **6**, 211–222 (1974 b).
3) CÔTÉ, W. A. Jr. and DAY, A. C.: Vestured pits — Fine structure and apparent relationship with warts. Tappi, **45**, 906–910 (1962).
4) CÔTÉ, W. A. Jr. and DAY, A. C.: Wood ultrastructure of the southern yellow pines. SUNY College of Forestry Technical Publication, No. 95, Syracuse, New York (1969).
5) CRONSHAW, J., DAVIES, G. W. and WARDROP, A. B.: A note on the wart structure of conifer tracheids. Holzforsch., **15–3**, 75–78 (1961).
6) CRONSHAW, J.: The formation of the wart structure in tracheids of *Pinus radiata*. Protoplasma, **60**, 233–242 (1965).
7) FREY-WYSSLING. A., MÜHLETHALER, K. and BOSSHARD, H. H.: Das Elektronenmikroskop im Dienste der Bestimmung von Pinusarten. Holz Roh- Werkstoff, **13**, 245–249 (1955).
8) FREY-WYSSLING, A., MÜHLETHALER, K. and BOSSHARD, H. H.: Nachtrg zu: Das Elektronenmikroskop im Dienste der Bestimmung von Pinusarten. Holz Roh- Werkstoff, **14**, 161–162 (1956).
9) GREAVES, H.: Comparative morphology of selected sapwood species using the scanning electron microscope. Holzforsch., **27–3**, 80–88 (1973).
10) HARADA, H.: Electron-microscopic investigation on the wart-like (particle) structure of conifer tracheids. J. Japan For. Soc. **35**, 393–396 (1953).
11) HARADA, H.: Electron-microscopic investigation on the wart-like structure of conifer tracheids. II. J. Japan Wood Res. Soc., **1**, 85–89 (1955).
12) HARADA, H., MIYAZAKI, Y. and WAKASHIMA, T.: Electronmicroscopic investigation on the cell wall structure of wood. Bull. For. Exp. Sta., Meguro, **104**, 1–115 (1958).
13) HARADA, H.: Electron microscopy of ultrathin sections of beech wood (*Fagus crenata* BLUME). J. Japan Wood Res. Soc., **8–6**, 252–258 (1962).
14) HARADA, H.: Ultrastructure of angiosperm vessels and ray parenchyma. in "Cellular ultrastructure of woody plants." CÔTE, W. A. Jr., ed., Syracuse Univ. Press. N. Y., 235–249 (1965).
15) JAYME, G. and AZZOLA, K.: Zur chemischen Resistenz der Warzenschicht von Holzfasern. Holzforsch., **20–3**, 101–103 (1966).
16) KOBAYASHI, K. and UTSUMI, N.: See LIESE (1965).
17) LIESE, W.: Demonstration elektronenmikroskopischer Aufnahmen von Nadelholztüpfeln. Ber. Deut. Botan. Ges., **64**, 31–32 (1951).
18) LIESE, W.: Zur systematischen Bedeutung der submikroskopischen Warzenstruktur bei der Gattung Pinus L. Holz Roh- Werkstoff, **14**, 417–424 (1956).
19) LIESE, W.: Beitrag zur Warzenstruktur der Koniferentracheiden unter besonderer Berücksichtigung der Cupressaceae. Ber. Deut. Botan. Ges. **70**, 21–30 (1957 a).

20) LIESE, W.: Zur Struktur der Tertiärwand bei den Laubhölzern. Naturwiss., **44**, 240–241 (1957 b).

21) LIESE, W.: Tertiary wall and warty layer in wood cells. J. Polymer Sci., Part C, **2**, 213–219 (1963).

22) LIESE, W.: The warty layer. in "Cellular ultrastructure of woody plants." CÔTÉ, W. A. Jr., ed., Syracuse Univ. Press. N. Y. 251–269 (1965).

23) MEYLAN, B. A. and BUTTERFIELD, B. G.: Occurrence of vestured pits in the vessels and fibers of New Zealand woods. New Zealand J. Bot. **12**, 3–18 (1974).

24) OHTANI, J. and FUJIKAWA, S.: Study of warty layer by the scanning electron microscopy. I. The variation of warts on the tracheid wall within an annual ring of coniferous woods. J. Japan Wood Res. Soc., **17-3**, 89–95 (1971).

25) OHTANI, J. and ISHIDA, S.: An observation the sculptures of the vessel wall of *Fagus crenata* BL. using scanning electron microscopy. Res. Bull. College Exp. For., Hokkaido Univ., **30-1**, 125–144 (1973).

26) OHTANI, J. and ISHIDA, S.: An observation on perforation plate differentiation in *Fagus crenata* BL., using scanning electron microscopy. Res. Bull. College Exp. For., Hokkaido Univ., **33-1**, 115–126 (1976 a).

27) OHTANI, J. and ISHIDA, S.: Study on the pit of wood cells using scanning electron microscopy. Report 5. Vestured pits in Japanese dicotyledonous woods. Res. Bull. College Exp. For., Hokkaido Univ., **33-2**, 407–436 (1976 b).

28) OHWI, J.: Flora of Japan (in Japanese). Revised Ed. Shibundo, Tokyo (1972).

29) PARAMESWARAN, N. and LIESE, W.: Occurrence of warts in bamboo species. Wood Sci. Technol., **11**, 313–318 (1977).

30) PARHAM, R. A. and BAIRD, W. M.: Warts in the evolution of angiosperm wood. Wood Sci. Technol., **8**, 1–10 (1974).

31) SCHMID, R. and MACHADO, R. D.: Zur Entstehung und Feinstruktur skulpturierter Hoftüpfel bei Leguminosen. Planta **60**, 612–626 (1964).

32) SCHMID, R.: The fine structure of pits in hardwoods. in "Cellular ultrastructure of woody plants." CÔTÉ, W. A. Jr., ed., Syracuse Univ. Press. N. Y. 291–304 (1965).

33) SCURFIELD, G. and SILVA, S. R.: The vestured pits of *Eucalyptus regnans* F. MUELL.: a study using scanning electron microscopy. Bot. J. Linn. Soc. **63-4**, 313–320 (1970).

34) SCURFIELD, G., SILVA, S. R. and INGLE, H. D.: Vessel wall structure; an investigation using scanning electron microscopy. Aust. J. Bot., **18-3**, 301–312 (1970).

35) TAKIYA, K., HARADA, H. and SAIKI, H.: The formation of the warts structure in conifer tracheids. Bull. Kyoto Univ. For., **48**, 187–191 (1976).

36) TSOUMIS, G.: Electron microscopic observations relate the warty layer to extractives in wood. Tappi, **48-8**, 451–455 (1965).

37) VERHOFF, S. and KNIGGE, W.: Untersuchungen über Größe, Anzahl und Verteilung der Warzen auf der Radialwand der Tracheiden der Tanne (*Abies alba* M.). Holz Roh-Werkstoff, **34**, 175–180 (1976).

38) WARDROP, A. B., LIESE, W. and DAVIES, G. W.: The nature of the wart structure in conifer tracheids. Holzforsch. **13**, 115–120 (1959).

39) WARDROP, A. B. and DAVIES, G. W.: Wart structure of gymnosperm tracheids. Nature. **194**, 497–498 (1962).

40) WARDROP, A. B.: The structure and formation of the cell wall in xylem. in "The formation of wood in forest trees." Zimmermann, M. H., ed., Academic Press., N. Y., 87–134 (1964).

## 要　　約

本邦産双子葉木本植物 (52 科, 121 属, 221 種) の道管要素と木部繊維におけるイボ状突起の存否およびそれらの形態が走査型電子顕微鏡により観察された。得られた結果を要約すれば次のとおりである。

**1.** 調査樹種の道管要素と木部繊維におけるイボ状突起の出現についての観察結果は, Table 1 に示されている。イボ状突起が存在する樹種の多くでは, イボ状突起は同一樹種内の道管要素と木部繊維間のみならず同じ種類の細胞間でもその出現状態が異なる場合が観察された。したがって, 道管要素と木部繊維のイボ状突起の出現状態は, 一細胞内でのそれらの分布密度をもとにして次の三つに区別され Table 1 に記入されている。すなわち, i. イボ状突起が全く, または, 殆んど存在しない (−)。 ii. イボ状突起が散在的か, または, 局部的に存在する (+)。 iii. イボ状突起が密に存在する (++)。

**2.** 調査された 221 樹種 (121 属, 52 科) のうち, 66 樹種 (30 属, 18 科) にイボ状突起が存在することがみとめられた。このことは, 本邦産双子葉木本植物におけるイボ状突起が存在する樹種の出現割合は針葉樹材におけるそれにくらべて著しく少ないことを示している。

**3.** イボ状突起が存在するか否かは多くの属では一定していることが認められた。しかしコナラ属, サクラ属, アワブキ属, ミズキ属, ハイノキ属では, イボ状突起が存在する樹種と存在しない樹種が認められた。

**4.** 道管要素にイボ状突起が存在する樹種は 41 樹種であった。それらの樹種の道管要素におけるイボ状突起の分布密度は, 9 樹種では年輪内でほぼ一定していたが, 32 樹種では著しく変動した。後者の場合, ブナ, イヌブナ, アベマキ, クヌギ, ツブラジイ, スダジイ, ユリノキ, ネムノキ, ヤマハギ, タンナサワフタギでは, 年輪の内方におけるよりも外方における方がイボ状突起はより密に存在する傾向が認められた。一方, アカガシ, ツクバネガシ, イチイガシ, シラカシ, アラカシ, ウラジロガシ, ウバメガシ, シリブカガシでは, イボ状突起は年輪内の道管要素の位置には無関係に径の小さな道管要素における方が大きな道管要素におけるよりも密に存在する傾向が認められた。しかし, 上記以外の 14 樹種では, イボ状突起の分布密度は年輪内で上記のような規則性は認められず変動した。木部繊維にイボ状突起が存在する樹種は 44 樹種であった。それらの樹種の木部繊維におけるイボ状突起の分布密度は, 13 樹種では年輪内でほぼ一定していたが, 残りの 31 樹種ではヤマグルマを除き不規則に変動した。ヤマグルマでは, イボ状突起は早材の仮道管では密に存在していたが, 晩材の繊維状仮道管では散在していた。

**5.** 道管要素のイボ状突起の大きさ (基部の直径) は 50～700 nm であったが, 大部分の樹種では 50～500 nm であった。ベニドウダンの道管要素では, 50～200 nm の小さなイボ状突起のみが存在した。一方, ブナ, イヌブナの道管要素では, 500 nm 以上の大きなものがしば

しば観察された。木部繊維のイボ状突起の大きさは50～800 nmであったが，大部分の樹種では，道管要素の場合と同様50～500 nmであった。しかし，ベニドウダンの木部繊維では，50～200 nmの小さなもののみが存在した。また，ヒメシャラとリョウブの木部繊維では，大部分は200 nm以下のものであった。一方，サカキ，ヒサカキ，タンナサワフタギの木部繊維では，500 nm以上の大きなイボ状突起がしばしば観察された。

**6.** 道管要素におけるイボ状突起の形は，枝分れしているものと枝分れしていないものが観察された。枝分れしているものは，ネムノキ，ソーシジュ，ジャケツイバラ，ヤマハギ，シマサルスベリ，サルスベリの道管要素に認められた。これらの樹種はベスチャード壁孔を有する。枝分れしていないイボ状突起の形は，半球状，円錐状，棒状などであった。多くの樹種の道管要素では，半球状，円錐状のもののみが観察された。木部繊維には，枝分れしているイボ状突起は認められなかった。木部繊維におけるそれらの形は，半球状，円錐状，棒状であったが，道管要素における場合と同様，多くの樹種では半球状，円錐状であった。

**7.** 上述のように，道管要素と木部繊維におけるイボ状突起の形，大きさおよび分布密度は，樹種間で異なることが認められた。同一樹種内でのイボ状突起の形態変動の仕方は，樹種固有の特徴であると考えられる。したがって，道管要素と木部繊維のイボ状突起の形，大きさおよび分布密度は，樹種識別の一つの指標となり得ると考えられる。

**8.** 本研究では，イボ状突起が存在する道管要素は41樹種 (20属，12科) に，また，それらが存在する木部繊維は44樹種 (21属，13科) にそれぞれ認められた。枝分れしているイボ状突起が6樹種の道管要素に認められたが，木部繊維にはそれらが認められなかったことを除いて，道管要素のイボ状突起と木部繊維のそれらとの間に形態上の著しい相違は認められなかった。これらの観察結果から判断すれば，双子葉木本植物におけるイボ状突起の出現の傾向は細胞の種類と必ずしも関係していないことが推定される。

## Explanation of photographs

**Photos 1-19 show warts on the inner surface of vessel members viewed from the lumen side.**

**Photo 1.** *Quercus sessilifolia* BLUME Warts sparsely distributed on the inner surface of a vessel member.

**Photo 2.** *Quercus sessilifolia* BLUME Warts densely distributed on the inner surface of a vessel member.

**Photo 3.** *Quercus phillyraeoides* A. GRAY Warts sparsely distributed on the inner surface of a vessel member.

**Photo 4.** *Quercus phillyraeoides* A. GRAY Warts densely distributed on the inner surface of a vessel member.

**Photo 5.** *Liriodendron tulipifera* L. Warts sparsely distributed on the inner surface of a vessel member in the terminal zone.

**Photo 6.** *Albizia julibrissin* DURAZZ. Branched and unbranched warts on the inner surface of a vessel member.

**Photo 7.** *Acacia confusa* MERR. Branched and unbranched warts on the inner surface of a vessel member. Branched warts are irregularly distributed and are anastomosed.

**Photo 8.** *Caesalpinia japonica* SIEB. et ZUCC. Branched and unbranched warts on the inner surface of a vessel member.

**Photo 9.** *Sapium japonicum* (SIEB. et ZUCC.) PAX et HOFFM. Warts densely distributed on the inner surface of a vessel member.

**Photo 10.** *Acer palmatum* THUNB. var. *matsumurae* (KOIDZ.) MAKINO Warts sparsely distributed on the inner surface of a vessel member.

**Photo 11.** *Meliosma myriantha* SIEB. et ZUCC. Warts densely distributed on the inner surface of a vessel member. Warts are covered with amorphous substances.

**Photo 12.** *Eurya japonica* THUNB. Warts densely distributed on the inner surface except the region near the pit apertures of a vessel member.

**Photo 13.** *Lagerstroemia indica* LINN. Warts densely distributed on the inner surface of a vessel member.

**Photo 14.** *Lagerstroemia subcostata* KOEHNE Branched and unbranched warts densely distributed on the inner surface of a vessel member.

**Photo 15.** *Clethra barbinervis* SIEB. et ZUCC. Warts sparsely distributed on the inner surface of a vessel member.

**Photo 16.** *Clethra barbinervis* SIEB. et ZUCC. Warts densely distributed on the inner surface of a vessel member. Warty layer is removed at the bottom in this photo.

**Photo 17.** *Enkianthus cernuus* (SIEB. et ZUCC.) MAKINO forma *rubens* (MAXIM.) OHWI Warts densely distributed on the inner surface of a vessel member.

**Photo 18.** *Symplocos coreana* (LÉVEILLÉ) OHWI Warts sparsely distributed on the inner surface of a vessel member.

**Photo 19.** *Symplocos coreana* (LÉVEILLÉ) OHWI Warts densely distributed on the inner surface of a vessel member.

**Photos 20–36 show warts on the inner surface of wood fibers viewed from the lumen side.**

**Photo 20.** *Fagus crenata* BLUME Warts densely distributed on the inner surface of a wood fiber.

**Photo 21.** *Quercus acuta* THUNB. Warts sparsely distributed on the inner surface of a wood fiber.

**Photo 22.** *Quercus sessilifolia* BLUME Warts densely distributed on the inner surface of a wood fiber.

**Photo 23.** *Castanopsis cuspidata* (THUNB.) SCHOTTKY Warts sparsely distributed on the inner surface of a wood fiber.

**Photo 24.** *Trochodendron aralioides* SIEB. et ZUCC. Warts densely distributed on the inner surface of an earlywood tracheid.

**Photo 25.** *Trochodendron aralioides* SIEB. et ZUCC. Bigger warts concentrated at the cell corner of an earlywood tracheid.

**Photo 26.** *Trochodendron aralioides* SIEB. et ZUCC. Warts sparsely distributed on the inner surface of a latewood fiber tracheid.

**Photo 27.** *Prunus ssiori* Fr. SCHM. Warts densely distributed on the inner surface of a wood fiber.

**Photo 28.** *Prunus buergeriana* MIQ. Warts densely distributed on the inner surface and trabecula of a wood fiber.

**Photo 29.** *Ilex micrococca* MAXIM. Warts sparsely distributed on the inner surface of a wood fiber.

**Photo 30.** *Euscaphis japonica* (THUNB.) KANITZ Warts sparsely distributed on the inner surface of a wood fiber.

**Photo 31.** *Stewartia monadelpa* SIEB. et ZUCC. Warts sparsely distributed on the inner surface of a wood fiber.

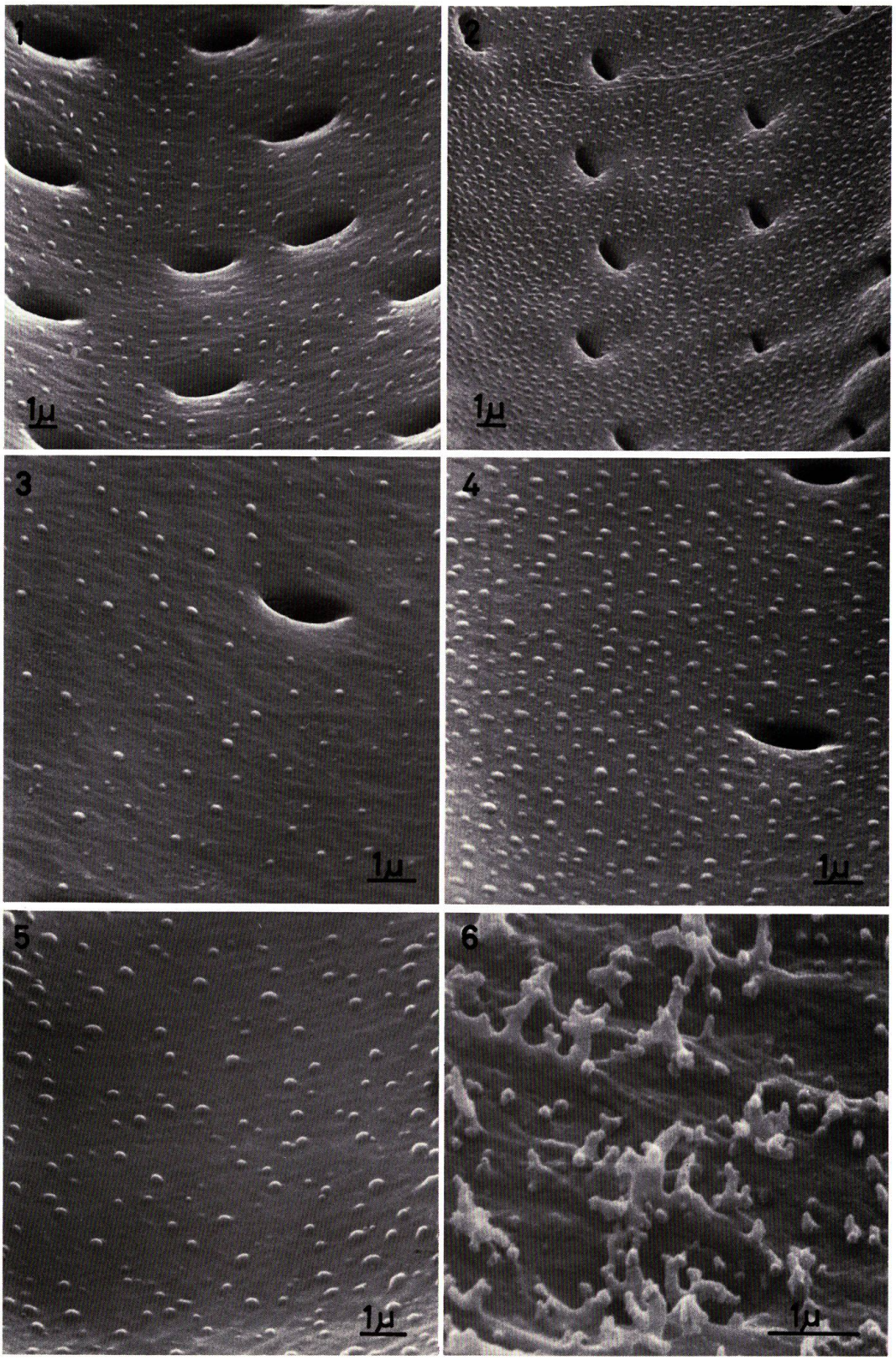
**Photo 32.** *Cleyera japonica* THUNB. (p. p., em. SIEB. et ZUCC.) Warts densely distributed on the inner surface of a wood fiber.

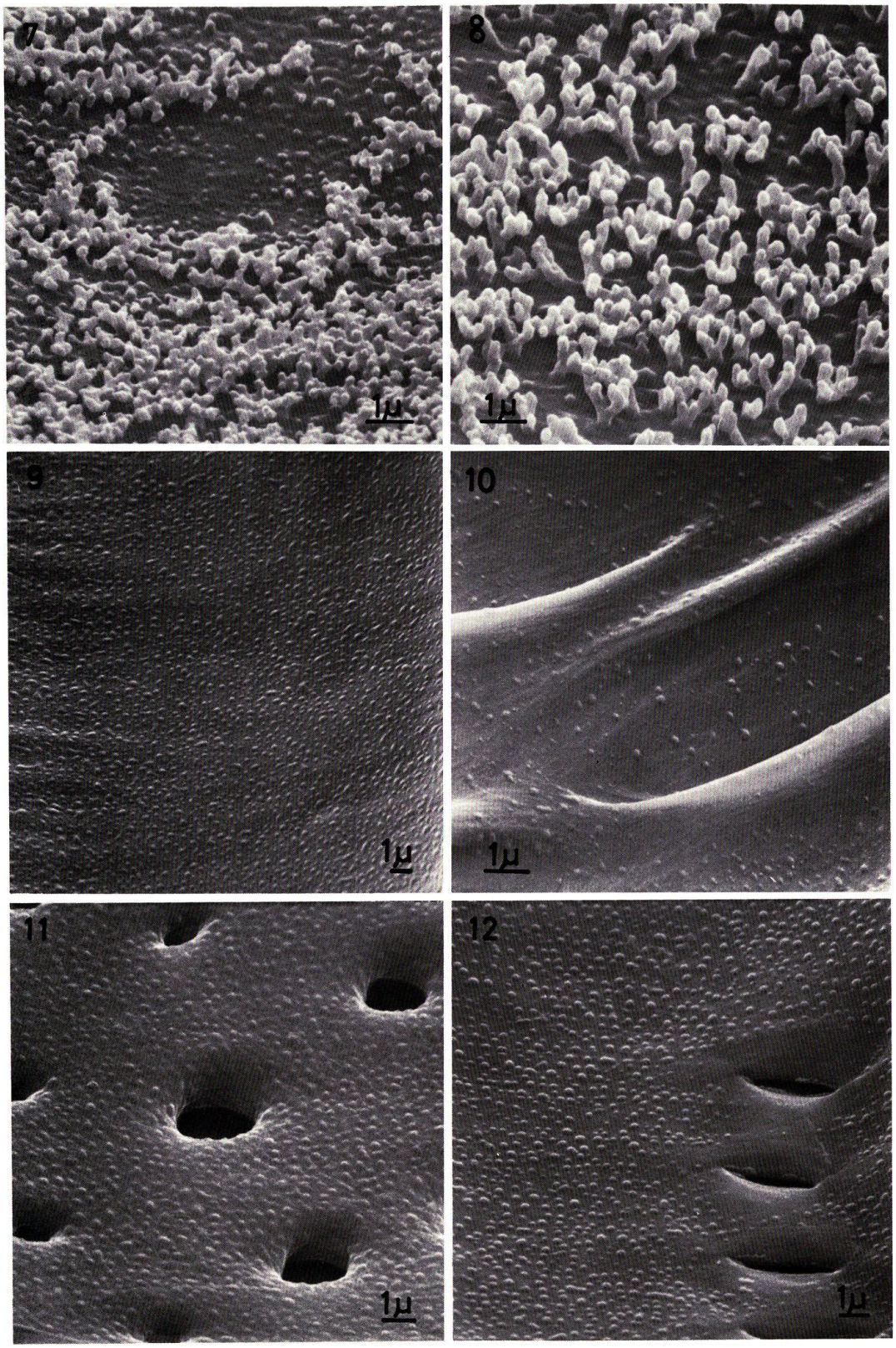
**Photo 33.** *Eurya japonica* THUNB. Warts densely distributed on the inner surface of a wood fiber.

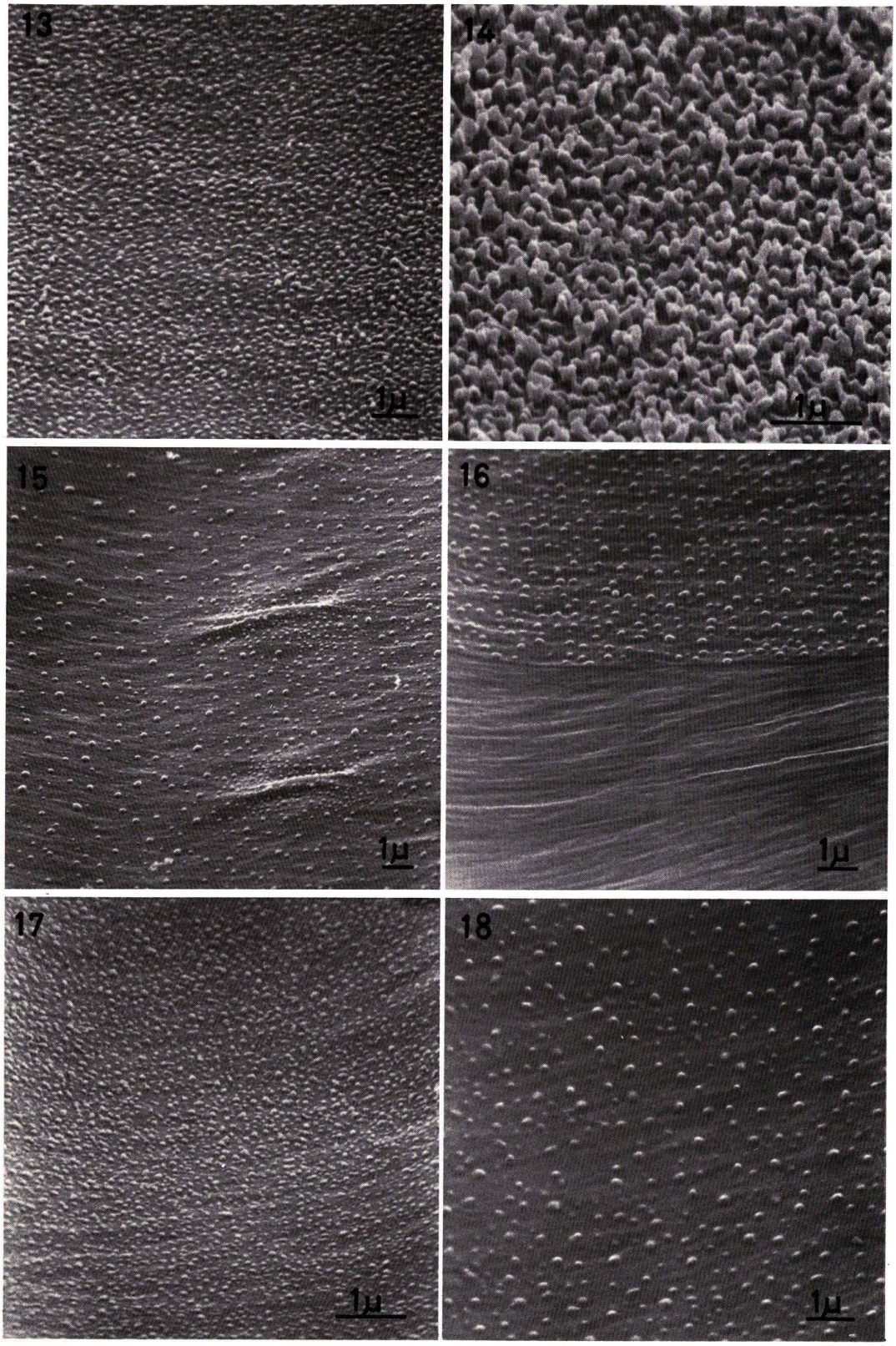
**Photo 34.** *Cornus kousa* BUERGER, ex HANCE Warts densely distributed on the inner surface of a wood fiber.

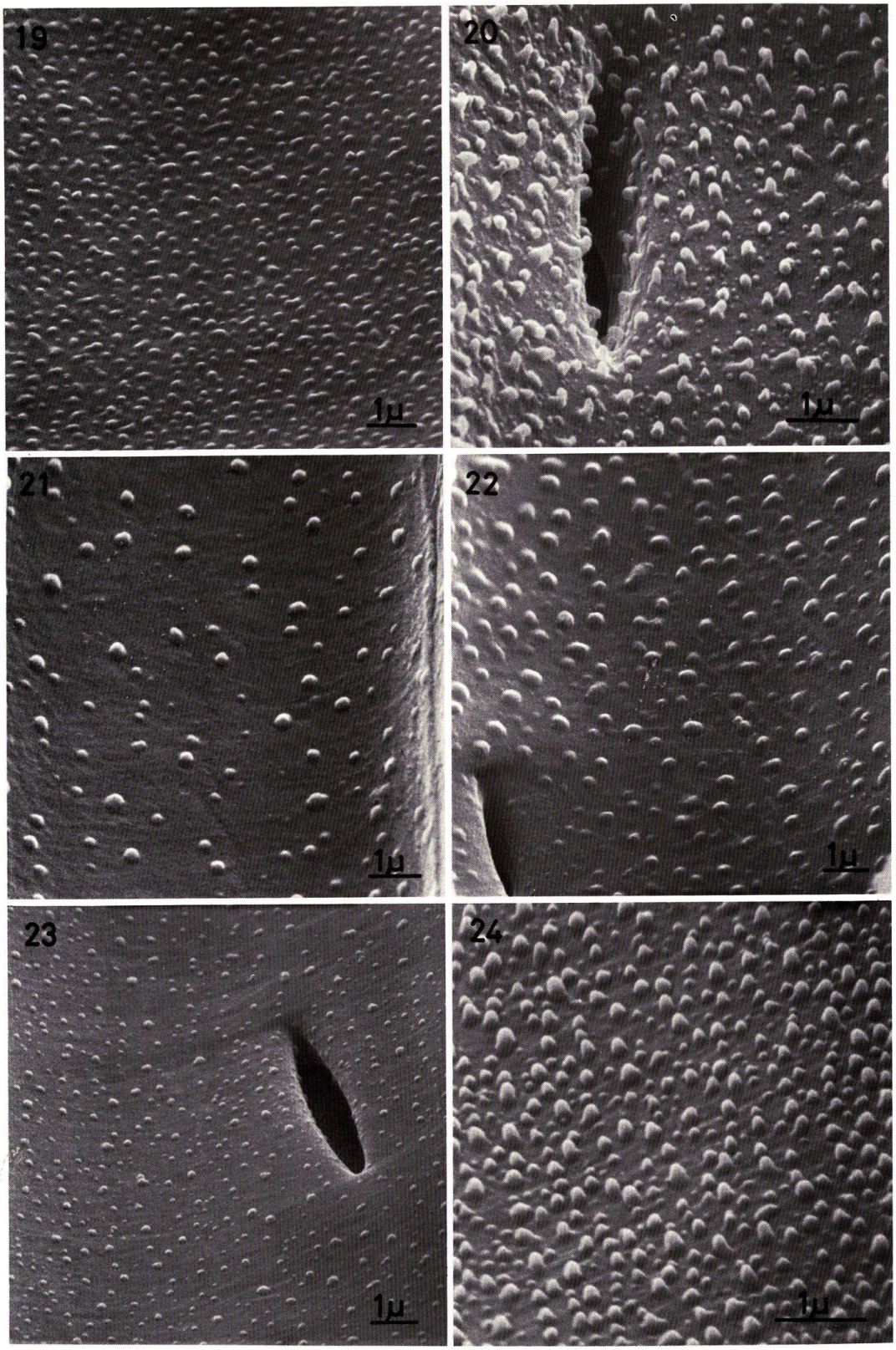
**Photo 35.** *Clethra barbinervis* SIEB. et ZUCC. Warts densely distributed on the inner surface of a wood fiber.

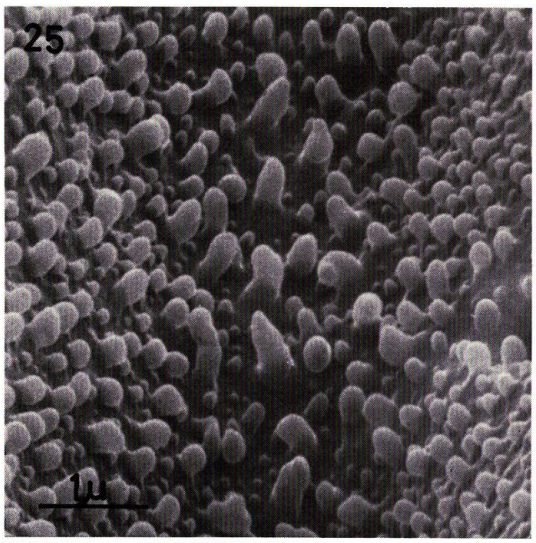
**Photo 36.** *Symplocos coreana* (LÉVEILLÉ) OHWI Warts densely distributed on the inner surface of a wood fiber.

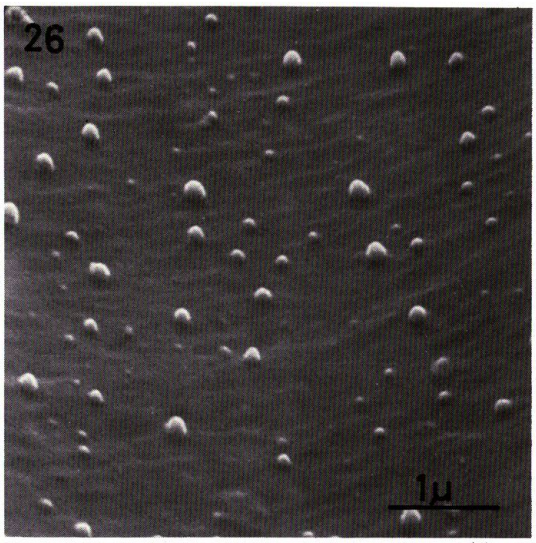

1
1μ
2
1μ
3
1μ
4
1μ
5
1μ
6
1μ

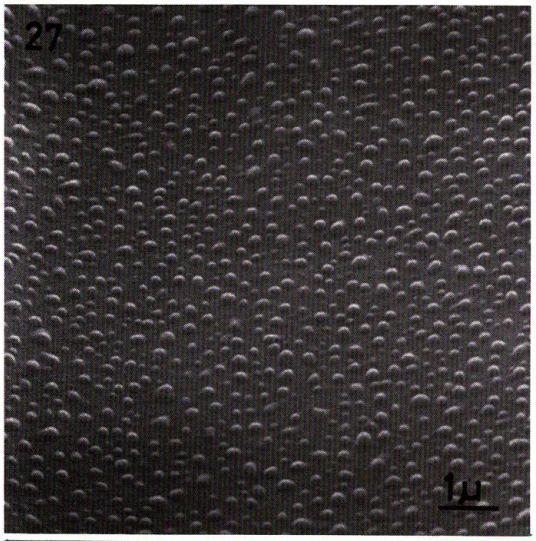

7
1μ
8
1μ
9
1μ
10
1μ
11
1μ
12
1μ

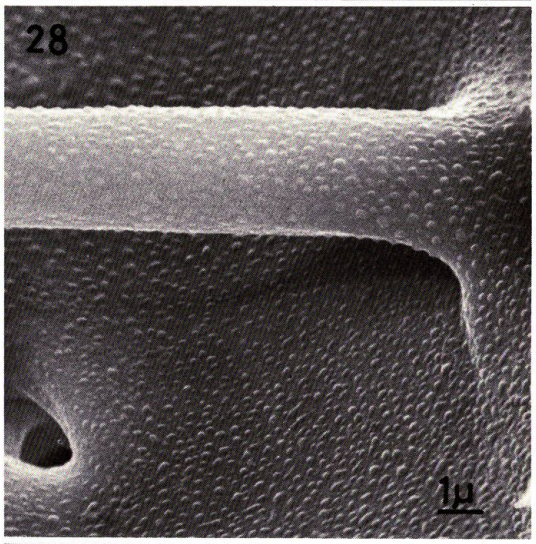

13
1μ
14
1μ
15
1μ
16
1μ
17
1μ
18
1μ

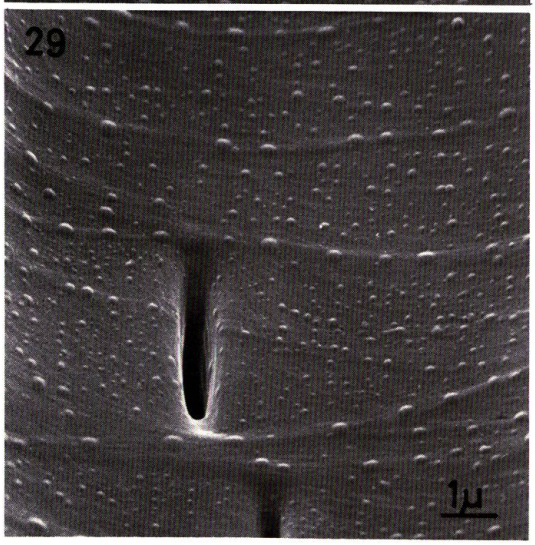

19
1μ
20
1μ
21
1μ
22
1μ
23
1μ
24
1μ

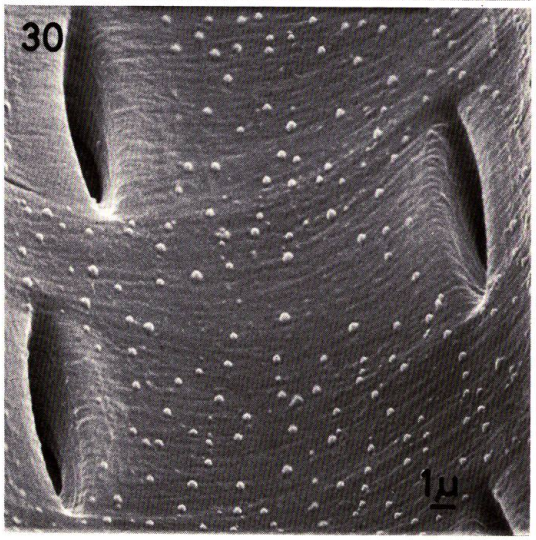

25
1μ

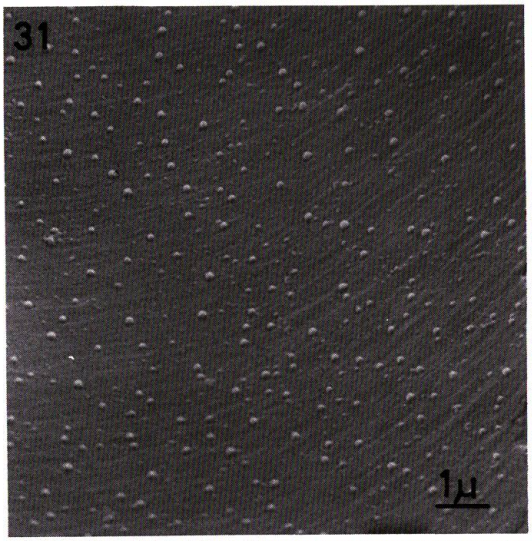

26
1μ


27
1μ

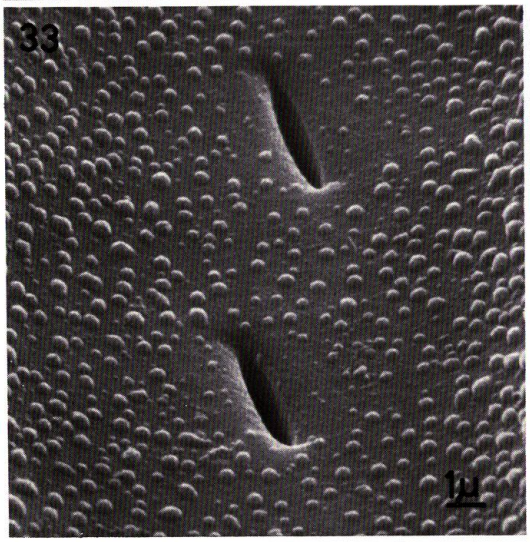

28
1μ

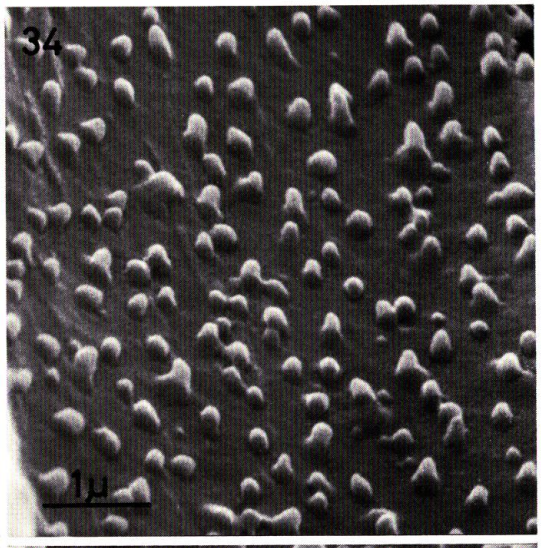

29
1μ

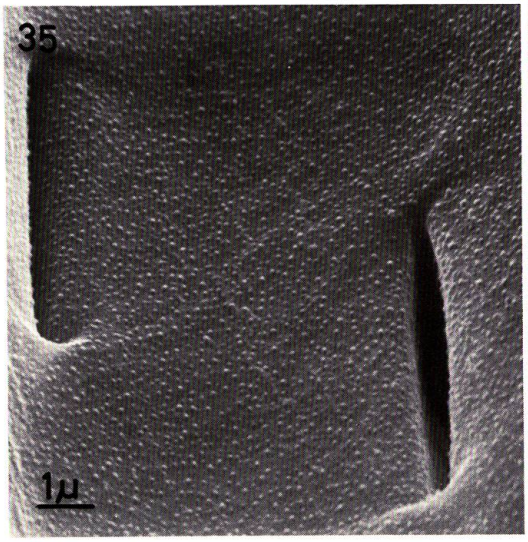

30
1μ

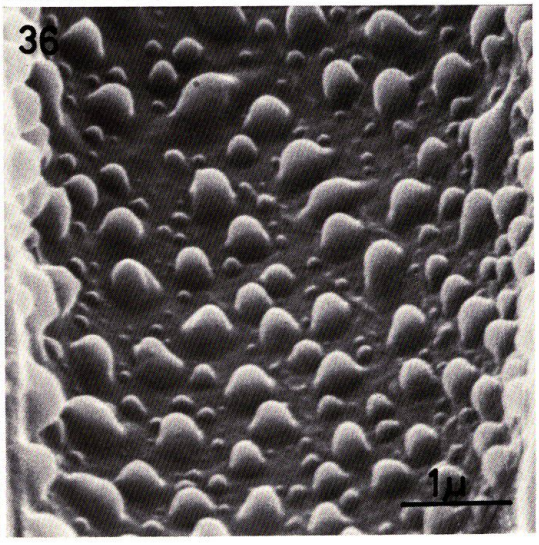

31
1μ


32
1μ


33
1μ


34
1μ


35
1μ


36
1μ