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Water Distribution and Water Alleyway in the Living Stem of *Cryptomeria japonica**

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SUMMARY

In order to obtain fundamental knowledge on the heartwood formation, the water distribution in the living stem of *Cryptomeria japonica* (Taxodiaceae) and its seasonal variation were determined and the water (sap) flow in the stem was traced by marking with an acid fuchusine stain.

From the water distribution diagrams, it was reconfirmed that the wettest zone (moisture content around 250 percent) existed in the sapwood. This zone presumably shifted to the horizontal direction according to the season. Thus, from spring to summer, the wet zone was recognized in the inner sapwood, while from autumn to winter it was found in the outer sapwood.

Using the acid fuchusine staining method, the difference of sap flow phase in the living trunk was ascertained in terms of tree height. The presence of a characteristic water supply system, a water alleyway, was detected outside of the white zone within the region existing together with sapwood and heartwood. Then, in the upper region made up of sapwood only, water was supplied upward, through the whole stem. The alleyway tended to fulfil its function from spring to summer, but it showed reduced activity from autumn to winter.

Thus, it was pointed out that the water alleyway might be related to the intermediate wood and heartwood formations.

INTRODUCTION

Much information regarding water and its distribution in living trees has recently been reported from various viewpoint[1~10]. For example, Sasaki *et al.* studied the sap flow of pine seedlings by water soluble stain in connection with the early symptoms and recovery phenomena of pine wilt disease[9]. Miwa classified Japanese cedars (*C. japonica*) into three groups on the basis of water distribution patterns in the heartwood and discussed the classification in relationship to cytological structures[4,5]. Nobuchi *et al.* investigated the water distribution in the stem of the Japanese cedar (Sugi), focussing on the white zone and its seasonal change from the standpoint of elucidation of heartwood formation mechanism[6]. Their works were carried out in view of continuous, dynamic change with time. Under the present conditions, it is necessary to gather as much as fundamental information on water as possible, in order to discuss various physiological processes of woody plants and to make further clarifications.

In the present study, from this point of view, water distributions, its seasonal change and water (sap) circulation in the stem of living Sugi were determined for one and a half year. The dynamic

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* A part of this report was presented at the 35th Annual Meeting of the Japan Wood Research Society (1985) in Tokyo.

transition was discussed on the basis of the results, as a first step.

MATERIALS AND METHODS

Materials

Japanese cedars growing on the Kurai-yama Experimental Forest of Gifu University (Hagiwara-cho, Gifu Pref.), the Itonuki Training Forest of Gifu Agricultural High School (Itonuki-cho, Gifu Pref.), and the grounds of the Gifu Prefecture Forest Research Center (Mino-city, Gifu Pref.) were used for sample trees. Description of sample trees are given in Table 1.

Table 1. List of *Cryptomeria japonica* trees

Harvesting date	Harvesting place	Tree age	Tree height	Height of lowest branch	Experimental objective
9/19/83	Hagiwara (Gifu)	29	12.30m	m	moisture
12/ 9/83	Hagiwara (Gifu)	28	9.40	3.35	moisture
5/16/84	Hagiwara (Gifu)	32	13.85	7.50	moisture alleyway
7/end/84	Itonuki (Gifu)	18			alleyway
10/ 3/84	Hagiwara (Gifu)	32	12.90	8.65	moisture alleyway
10/ 3/84	Hagiwara (Gifu)	17	9.70	3.85	moisture alleyway
10/25/84	Itonuki (Gifu)	18	11.85		alleyway
12/14/84	Itonuki (Gifu)	18	12.60	6.20	moisture alleyway
1/25/85	Itonuki (Gifu)	15	12.10		alleyway
3/26/85	Mino (Gifu)	27	12.50	5.45	moisture alleyway

moisture : determination of moisture content,
alleyway : examination of water alleyway.

At the habitats, the sample was cut down and its total height, age, diameter at breast height and the lowest branch (H. L.) were measured. The boughs and twigs were removed from the trunk which was then cut off into 1.2 meter lenght. For prevention against water evaporation, the cut ends of logs were coated with paraffin, and then the logs were brought into the laboratory. Disks with 5 centimeters thickness were cut off from the log, for stem analysis and measurement of moisture content. The remaining logs were used for examination of the water alleyway with acid fuchusine tracer.

In this experiment, gross observation was used to determine the features of phloem, sapwood, white zone, heartwood and height at the vanishing point of heartwood (H. V.).

Methods

Stem analysis

For each Japanese cedar, stem analysis was undertaken in the usual way[11].

Measurement of moisture contents

Samples were cut off from the disk with a chisel, at each or every other annual ring, while determining the direction of cut off. For each sample, the wet and dry weights were determined, and the percent moisture content was calculated for a unit gram of dried sample (see Table 2).

Examination of alleyway

The log was soaked in *ca.* 0.5 percent acid fuchusine aqueous solution overnight. After removal, the treated log was longitudinally split with a wedge or swan transversely. Then, the fuchusine movement was observed and photographed (see Plate 1-8).

The samples sliced for observation by microscope were prepared from the ascending front of fuchusine. They were observed under a microscope (Olympus BHC) at 50 magnifications and photographed (see Plate 9, 10).

At breast height on the trunk of a growing Sugi tree, a hole was drilled. From there, 0.5 percent acid fuchusine aqueous solution was injected according to the essential absorption ability and kept for three months. The treated tree was cut down, the circulation of the stain was observed in the stem and photographed as mentioned above (see Plate 11).

RESULTS AND DISCUSSION

Samples

The gathering of Sugi trees was carried out at three habitats from season to season. As many as possible sliced samples were obtained in horizontal and vertical directions. The concrete object of this investigation was to determine water distribution in the living stem of the Japanese cedar and to assess the seasonal variation. Another object was to determine water (sap) circulation in the living stem of Sugi by acid fuchusine staining method. Then, Sasaki *et al.* revealed that acid fuchusine tracing method was available for the diagnostic purpose of elucidation of the sap flow in pine seedlings infected with pine wilt disease[9].

Water distribution and its seasonal variation

The firsthand results as to water distribution and its seasonal variation in the living stem of Japanese cedars are summarized inTable 2. The moisture contents in the stem were classified into 6 divisions according to the water holding grades, as shown in Fig. 1, 2.

In the radial direction, the moisture content of sapwood was higher than that of phloem irrespective of tree height or season. Both contents decreased toward the tree top. Closer investigation showed that the moisture content of sapwood varied considerably in the horizontal direction. The inner sapwood presumably became more damp than the other parts from spring to summer. On the other hand, the outer sapwood was more damp from autumn to winter (Table 3). Also, it was revealed that the entire white zone was too dry in May, whereas the outside became wet in December. Then, in the following spring, this area became dry again and attained the inner white zone.

In the longitudinal direction, the changing trend in moisture contents differed in terms of zones (*i. e.,* phloem, outer sapwood, inner sapwood and heartwood) as expected. The phloem content varied in the crown part, especially with the height of the lowest branch and the vanishing point of heartwood, whereas others did not vary remarkably. As the white zone did not occupy a few spheres which were formed in the same year, the sampling was carried out according to the naked eye. The latitude of the white zone was fluctuated little, and its seasonal change was few, unlike other zones.

Water alleyway

Kondo explained briefly that the water conducting tissue was indispensable for many physiological phenomena of tree, as show an intelligible diagram[3]. Concerning the conducting tissue, it was known that the tracheid serves to supply water to the crown in a coniferous tree, but its position was not specified in sapwood zone. There has been a divergence of opinion on this point. Therefore, the characterization was expected for the elucidation of many physiological problems.

In the living stem of Sugi harvested in May, the acid fuchusine was absorbed and rose remarkably in the inner sapwood which was between the outside of the white zone and the inside of the most damped zone of sapwood as mentioned above (Plate 1). On the other hand, the phase of fuchusine development in the dried log differed from that in the fresh one (Plate 2). This characteristic pathway of water (sap) ascending, designated as "water alleyway," was limited to a few summer woods in the

Table 2. Moisture content of *Cryptomeria japonica* tree trunks
Tree (1) [harvesting date : 9/19/83]

Position		Fresh weight	Dry weight	Moisture* content	Notes
I (0.05m)					
A	phloem	5.50 g	1.70 g	224%	
B	29(years old)	8.00	2.70	196	
C	27—28	9.50	3.00	217	
D	24—26	10.50	3.10	239	
E	21—23	12.50	3.90	221	
F	18—20	12.00	4.00	200	
G	16—17	6.50	3.00	117	
H	14—15	9.00	5.20	73	white zone
I	12—13	5.00	2.30	117	
J	10—11	5.00	2.00	150	
K	8— 9	5.00	2.20	127	
L	6— 7	5.50	2.50	120	
M	4— 5	5.00	2.80	79	
N	2— 3	3.50	1.80	94	
O	1	1.50	0.90	67	
II (1.00m)					
A	phloem	8.00	2.90	176	
B	29	10.80	3.90	177	
C	27—28	6.50	2.10	210	
D	24—26	14.50	5.30	174	
E	21—23	9.90	4.10	141	
F	18—20	6.30	3.30	91	white zone
G	16—17	5.90	2.30	157	
H	14—15	6.50	2.70	141	
I	12—13	7.90	3.50	126	
J	10—11	2.00	1.00	100	
K	7— 9	1.50	0.80	88	
III (2.00m)					
A	phloem	5.00	2.30	117	
B	29	5.00	1.80	178	
C	27—28	6.50	2.20	195	
D	24—26	5.00	1.70	194	
E	21—23	5.00	1.55	287	
F	18—20	7.00	2.30	204	
G	16—17	5.00	3.10	61	white zone
H	14—15	5.00	2.90	72	
I	12—13	6.00	4.40	36	
J	9—11	5.00	2.50	100	
IV (3.00m)					
A	phloem	13.00	5.00	160	
B	29	21.50	7.50	187	
C	27—28	6.00	2.00	200	
D	24—26	8.50	2.70	215	
E	21—23	8.50	3.00	183	
F	18—20	5.50	3.40	62	white zone
G	16—17	4.50	2.60	73	
H	13—15	5.50	3.00	83	
V (4.00m)					
A	phloem	5.00	2.00	150	
B	29	5.00	1.80	178	
C	27—28	5.00	1.60	213	
D	24—26	5.00	1.60	213	
E	21—23	5.00	1.90	163	
F	18—20	5.00	2.90	72	white zone

Position		Fresh weight	Dry weight	Moisture* content	Notes
G	16—17	4.50 g	2.10 g	114%	
H	14—15	5.00	2.20	127	
VI(5.00m)					
A	phloem	6.10	2.40	154	
B	29	6.60	2.40	175	
C	27—28	9.20	2.90	217	
D	24—26	9.60	2.80	243	
E	21—23	9.80	3.40	188	
F	18—20	8.70	4.60	89	white zone
G	15—17	1.70	0.90	89	
VII(6.00m)					
A	phloem	3.00	1.20	150	
B	29	5.00	1.60	213	
C	27—28	5.00	1.70	194	
D	24—26	5.00	1.40	257	
E	21—23	5.00	1.50	233	
F	18—20	5.00	2.30	117	
G	16—17	5.00	3.00	67	white zone
VIII(7.00m)					
A	phloem	5.00	1.70	194	
B	29	5.00	1.70	194	
C	27—28	5.00	1.70	194	
D	24—26	7.00	2.20	218	
E	21—23	5.00	2.90	90	
F	18—20	3.50	2.30	52	white zone
IX(8.00m)					
A	phloem	5.00	1.60	213	
B	29	5.00	1.60	213	
C	27—28	5.00	1.60	213	
D	24—26	5.00	2.00	150	
E	22—23	3.50	2.00	75	
X(9.00m)					
A	phloem	5.00	1.70	194	
B	29	5.50	1.90	189	
C	27—28	5.50	1.90	189	
D	24—26	5.00	2.60	92	
X I (10.00m)					
A	phloem	4.50	1.70	165	
B	29	9.50	2.80	239	
C	27—28	7.00	2.60	169	
D	25—26	1.50	0.70	114	
X II (11.00m)					
A	phloem	6.00	2.20	173	
B	28—29	2.00	0.90	122	
X III(12.30m)					
A	29	6.10	1.80	239	

Tree (2) [harvesting date : 12/ 9/83]
(abbreviated)

Tree (3) [harvesting date : 5/16/84]

Position		Fresh weight	Dry weight	Moisture* content	Notes
I (0.55m)					
A	phloem	2.00 g	0.70 g	186%	
B	32(years old)	1.10	0.35	214	
C	30—31	1.60	0.50	220	

Position		Fresh weight	Dry weight	Moisture* content	Notes
D	28—29	3.80 g	1.05 g	262%	
E	26—27	2.30	0.70	229	
F	24—25	3.80	1.30	192	
G	22—23	1.50	0.50	200	
H	20—21	0.80	0.50	60	} white zone
I	18—19	1.00	0.60	67	} white zone
J	16—17	2.05	0.70	193	
K	14—15	1.80	1.00	80	
L	12—13	4.20	1.50	180	
M	10—11	1.70	0.65	162	
N	8— 9	1.50	0.60	150	
O	6— 7	1.20	0.50	140	
P	4— 5	1.20	0.55	118	
Q	1— 3	1.20	0.55	118	
II (1.55m)					
A	phloem	1.90	0.70	171	
B	32	3.40	1.10	209	
C	30—31	5.00	1.60	213	
D	28—29	5.70	1.75	226	
E	26—27	5.80	1.80	222	
F	24—25	5.20	1.55	235	
G	22—23	5.80	1.70	241	} white zone
H	20—21	4.90	1.40	250	} white zone
I	18—19	2.70	1.65	64	
J	16—17	5.60	2.45	129	
K	14—15	5.20	1.75	197	
L	12—13	5.10	1.55	229	
M	10—11	5.50	1.90	190	
N	8— 9	4.40	1.70	159	
O	5— 7	2.20	0.80	175	
III (3.55m)					
A	phloem	1.50	0.60	150	
B	32	1.20	0.40	200	
C	30—31	2.80	0.90	211	
D	28—29	5.80	1.80	222	
E	26—27	5.50	1.70	224	
F	24—25	4.90	1.40	220	
G	22—23	2.10	1.20	75	} white zone
H	20—21	2.40	1.35	78	} white zone
I	18—19	2.00	1.15	74	
J	16—17	2.90	1.70	71	
K	14—15	3.15	1.30	142	
L	11—13	2.40	1.00	140	
IV (5.55m)					
A	phloem	2.00	0.85	135	
B	32	4.10	1.30	215	
C	30—31	3.80	1.30	192	
D	28—29	5.70	1.70	235	
E	26—27	7.20	2.25	220	
F	25	6.10	1.80	239	
G	24	8.10	2.30	252	
H	23	5.10	2.80	82	} white zone
I	22	4.90	3.20	53	} white zone
J	21	4.20	2.45	71	
K	19—20	2.00	1.20	67	
L	17—18	1.10	0.60	83	

Position		Fresh weight	Dry weight	Moisture* content	Notes
V (7.50m)					
A	phloem	1.20 g	0.50 g	140%	
B	32	1.70	0.85	100	
C	30—31	3.90	1.20	225	
D	28—29	4.50	1.20	275	
E	26—27	6.00	1.80	233	
F	24—25	7.50	2.15	249	
G	23	3.20	2.20	46	} white zone
H	22	3.50	2.15	63	} white zone
I	20—21	0.80	0.50	60	
VI (9.20m)					
A	phloem	2.50	1.05	138	
B	32	2.80	0.95	195	
C	30—31	2.50	0.75	233	
D	28—29	2.50	0.70	257	
E	26—27	2.30	0.70	229	
F	24—25	2.20	1.00	120	
G	23	1.40	1.00	40	white zone, heartwood
VII (9.55m)					
A	phloem	1.50	0.60	150	
B	32	1.90	0.75	153	
C	30—31	2.40	0.80	200	
D	28—29	2.60	0.75	247	
E	26—27	1.70	0.50	240	
F	25	1.50	0.95	58	
G	24	1.60	1.00	60	white zone
VIII (10.30m)					
A	phloem	1.90	0.85	124	
B	32	1.80	0.70	157	
C	30—31	2.70	0.80	238	
D	28—29	2.00	0.60	233	
E	26—27	2.60	0.80	225	
F	25	2.90	1.50	93	
IX (10.55m)					
A	phloem	1.40	0.70	100	
B	32	1.10	0.45	144	
C	30—31	4.30	1.30	231	
D	28—29	4.20	1.25	236	
E	26—27	1.80	0.80	125	
X (12.55m)					
A	phloem	1.10	0.50	120	
B	32	1.80	0.70	157	
C	30—31	3.00	1.30	131	
D	29	0.90	0.40	125	

Tree (4) [harvesting date : 10/ 3/84]
(abbreviated)

Tree (5) [harvesting date : 10/ 3/84]

Position		Fresh weight	Dry weight	Moisture* content	Notes
I (0.50m)					
A	phloem	1.90 g	0.75 g	153%	
B	17(years old)	2.60	0.80	225	
C	15—16	4.40	1.10	300	
D	13—14	3.90	0.95	311	
E	12	2.60	0.65	300	

Position		Fresh weight	Dry weight	Moisture* content	Notes
F	11	2.70 g	0.95 g	184%	
G	10	4.80	2.40	100	
H	9	2.20	1.50	47	white zone
I	8	2.00	1.35	48	white zone
J	7	2.80	1.75	60	
K	5—6	3.60	2.00	80	
L	3—4	3.10	1.75	77	
M	1—2	1.20	0.70	71	
II (1.50m)					
A	phloem	1.30	0.50	160	
B	17	5.20	1.50	247	
C	15—16	5.00	1.60	213	
D	13—14	5.00	1.40	257	
E	11—12	3.90	1.30	200	
F	10	4.30	1.40	207	
G	9	4.90	2.75	78	white zone
H	8	3.30	2.00	65	white zone
I	6—7	4.80	3.20	50	
J	4—5	3.70	2.40	54	
K	3	4.70	2.60	81	
III (2.50m)					
A	phloem	1.30	0.50	160	
B	17	3.30	1.00	230	
C	15—16	4.30	1.40	207	
D	13—14	3.50	0.90	289	
E	11—12	3.60	1.45	148	
F	9—10	1.50	0.90	67	white zone
G	7—8	1.60	1.10	46	white zone
H	5—6	5.90	3.30	79	
I	4	1.10	0.40	175	
IV (3.50m)					
A	phloem	2.90	1.20	142	
B	17	3.90	1.25	212	
C	15—16	7.20	2.10	243	
D	13—14	2.50	0.80	213	
E	12	0.80	0.35	129	
F	11	2.40	1.40	71	white zone
G	10	1.50	0.95	58	white zone
H	8—9	1.80	0.95	90	
I	7	1.70	0.85	100	
V (4.50m)					
A	phloem	4.30	1.60	169	
B	17	5.00	1.45	245	
C	15—16	4.80	1.40	243	
D	13—14	6.90	2.15	221	
E	11—12	6.90	2.80	146	
F	10	3.40	1.70	100	white zone
G	9	4.60	3.20	44	white zone
H	8	6.20	3.80	63	white zone
VI (5.50m)					
A	phloem	3.00	1.15	161	
B	17	4.90	1.50	227	
C	15—16	5.30	1.55	242	
D	13—14	6.40	2.10	205	
E	11—12	7.10	3.20	122	
F	10	2.20	1.50	47	white zone

Position		Fresh weight	Dry weight	Moisture* content	Notes
VII(6.50m)					
A	phloem	2.50 g	1.00 g	150%	
B	17	7.20	2.20	227	
C	15—16	7.30	2.50	192	
D	13—14	4.90	2.25	118	
E	12	1.30	0.80	63	white zone
VIII(7.50m)					
A	phloem	1.90	0.70	171	
B	17	5.20	1.60	225	
C	15—16	4.70	1.75	169	
D	14	3.00	1.60	88	
IX(8.50m)					
A	phloem	1.25	0.50	150	
B	17	5.40	1.75	209	
C	16	2.50	1.05	138	
X(9.50m)					
A	17	1.90	0.50	280	

Tree (6) [harvesting date : 12/14/84]

Position		Fresh weight	Dry weight	Moisture* content	Notes
I (0.30m)					
A	phloem	5.30 g	2.40 g	121%	
B	18(years old)	5.00	1.60	213	
C	17	5.30	1.50	253	
D	16	5.30	1.60	231	
E	15	5.60	1.90	195	
F	14	5.30	1.70	212	
G	13	5.60	2.10	167	
H	12	5.90	2.10	181	
I	11	6.30	2.30	174	
J	10	5.60	2.60	115	white zone (J–L)
K	9	5.10	2.50	104	
L	8	5.10	2.40	113	
M	7	4.30	2.90	48	
N	6	5.00	3.20	56	
O	5	6.00	3.60	67	
P	4	8.10	4.20	93	
Q	2— 3	5.50	2.80	96	
II (1.30m)					
A	phloem	2.70	1.10	146	
B	18	2.30	0.80	188	
C	17	5.80	1.80	222	
D	16	6.00	1.80	233	
E	15	4.30	1.20	258	
F	14	3.40	1.00	240	
G	13	6.60	1.90	247	
H	12	6.60	2.00	230	
I	11	4.40	1.60	175	
J	10	4.20	1.80	133	white zone (J–L)
K	9	2.70	1.40	93	
L	8	1.70	1.10	55	
M	7	3.20	2.00	60	
N	6	2.95	1.80	64	
O	5	2.40	1.50	60	
P	4	1.80	0.80	125	

Position		Fresh weight	Dry weight	Moisture* content	Notes
III(2.50m)					
A	phloem	3.00 g	1.30 g	131%	
B	18	5.10	1.60	219	
C	17	5.60	1.60	250	
D	16	4.90	1.60	206	
E	15	4.60	1.50	207	
F	14	5.30	1.70	212	
G	13	4.40	1.40	214	
H	12	5.10	1.70	200	
I	11	6.40	2.30	178	white zone
J	10	5.50	2.50	120	white zone
K	9	3.00	1.90	58	white zone
L	8	3.30	2.10	57	
M	7	1.10	0.70	57	
N	5— 6	3.40	2.00	70	
IV(3.70m)					
A	phloem	3.50	1.60	119	
B	18	4.70	1.40	236	
C	17	5.10	1.50	240	
D	16	5.60	1.60	250	
E	15	5.70	2.00	185	
F	14	5.40	1.80	200	
G	13	5.20	1.60	225	
H	12	5.90	2.00	195	
I	11	5.50	1.90	190	white zone
J	10	4.90	2.70	82	white zone
K	9	4.10	2.80	46	white zone
L	8	5.20	3.40	53	
M	7	3.30	1.90	74	
V(4.90m)					
A	phloem	3.80	1.70	124	
B	18	5.10	1.70	200	
C	17	5.30	1.40	279	
D	16	6.30	1.90	232	
E	15	4.50	1.50	200	
F	14	5.70	1.80	217	
G	13	5.00	1.60	213	
H	12	6.60	2.40	175	white zone
I	11	6.80	3.30	106	white zone
J	10	2.60	1.80	44	white zone
K	9	2.00	1.20	67	
L	8	0.25	0.13	92	
VI(6.10m)					
A	phloem	1.80	1.00	80	
B	18	3.20	1.00	220	
C	17	6.20	1.80	244	
D	16	7.40	2.20	236	
E	15	4.80	1.50	220	
F	14	4.60	1.50	207	
G	13	4.80	1.80	167	white zone
H	12	3.00	1.30	131	white zone
I	11	2.50	1.70	47	white zone
J	10	0.90	0.50	80	
VII(7.30m)					
A	phloem	2.40	1.00	140	
B	18	5.90	1.60	269	
C	17	5.50	1.50	267	

Position		Fresh weight	Dry weight	Moisture* content	Notes
D	16	2.00 g	0.60 g	233%	
E	15	5.10	1.50	240	
F	14	4.00	1.30	208	
G	13	2.20	0.80	175	} white zone
H	11—12	2.70	1.70	59	} white zone
VIII (8.50m)					
A	phloem	2.10	1.00	110	
B	18	4.80	1.50	220	
C	17	7.40	2.10	252	
D	16	4.30	1.40	207	
E	15	6.40	2.30	178	
F	14	5.00	2.20	127	} white zone
G	13	3.10	2.00	55	} white zone
IX (9.70m)					
A	phloem	4.00	1.90	111	
B	18	4.80	1.40	243	
C	17	4.10	1.30	215	
D	16	4.00	1.70	135	
E	15	2.60	1.40	86	white zone
X (10.90m)					
A	phloem	2.30	1.10	109	
B	18	6.00	2.20	173	
C	16—17	10.10	4.50	124	
X I (11.50m)					
A	17—18	5.00	2.20	127	
X II (12.60m)					
A	18	0.80	0.30	167	

Tree (7) [harvesting date : 3/26/85]

Position		Fresh weight	Dry weight	Moisture* content	Notes
I (0.15m)					
A	phloem	3.90 g	1.50 g	160%	
B	27(years old)	4.70	1.50	213	
C	26	3.20	1.10	191	
D	25	5.90	1.80	228	
E	24	4.70	1.55	203	
F	23	2.60	0.80	225	
G	22	4.20	1.70	147	
H	21	4.00	2.35	70	
I	20	4.30	2.85	51	
J	19	4.80	2.10	129	
K	18	4.60	2.00	130	} white zone
L	17	5.70	2.50	128	} white zone
M	16	1.90	0.80	138	} white zone
N	15	3.80	1.75	117	
O	14	5.60	3.00	87	
P	12—13	2.70	1.40	93	
Q	10—11	3.10	1.85	68	
R	8— 9	2.50	1.50	67	
S	6— 7	1.30	0.75	73	
T	3— 5	2.70	1.50	80	
II (1.15m)					
A	phloem	4.60	1.80	156	
B	27	5.00	1.40	257	
C	26	4.30	1.25	244	

Position		Fresh weight	Dry weight	Moisture* content	Notes
D	25	5.70 g	1.70 g	235%	
E	24	6.00	1.60	275	
F	23	5.20	1.35	285	
G	22	5.50	1.65	233	
H	21	6.00	1.80	233	
I	20	5.20	1.75	197	
J	19	5.30	1.50	253	
K	18	5.80	1.90	205	
L	17	6.10	2.50	144	
M	16	5.30	2.55	108	white zone (M–O)
N	15	6.00	3.80	58	
O	14	5.20	3.50	49	
P	12—13	5.90	3.50	69	
Q	10—11	4.40	2.30	91	
R	8— 9	4.90	2.60	89	
S	6— 7	5.30	3.10	71	
T	5	3.60	2.05	76	
III(3.15m)					
A	phloem	5.00	1.80	178	
B	27	5.50	2.00	175	
C	26	5.00	1.75	186	
D	25	5.00	1.80	178	
E	24	4.90	1.20	308	
F	23	4.50	1.40	221	
G	22	6.30	1.80	250	
H	21	5.10	1.85	176	
I	20	5.10	2.00	155	
J	19	5.80	2.00	190	
K	18	5.10	2.00	155	
L	17	5.00	2.10	138	
M	16	4.00	2.70	48	white zone (M–N)
N	15	4.90	3.10	58	
O	14	5.40	2.30	135	
P	13	5.10	2.10	143	
Q	11—12	3.40	1.65	106	
IV(5.15m)					
A	phloem	5.50	2.00	175	
B	27	5.20	1.70	206	
C	26	3.00	1.15	161	
D	25	5.50	1.80	206	
E	24	3.60	1.30	177	
F	23	2.80	1.05	167	
G	22	4.00	1.50	167	
H	21	3.40	1.60	113	
I	20	5.10	3.00	70	
J	19	4.90	3.10	58	white zone (J–L)
K	18	5.50	2.40	129	
L	17	5.50	2.00	175	
M	16	3.20	1.20	167	
N	14—15	2.50	0.90	178	
V(7.15m)					
A	phloem	5.40	2.00	170	
B	27	5.00	1.90	163	
C	26	5.10	2.20	132	
D	25	5.80	2.10	176	
E	24	6.20	2.30	170	
F	23	6.40	2.40	167	
G	22	7.20	2.50	188	

Position		Fresh weight	Dry weight	Moisture* content	Notes
H	21	5.30 g	1.80 g	194%	white zone
I	20	3.20	1.70	88	white zone
J	18—19	5.00	3.05	64	white zone
VI(9.15m)					
A	phloem	5.20	2.10	148	
B	27	5.50	1.90	190	
C	26	6.50	2.35	177	
D	25	5.50	2.10	162	
E	24	5.30	2.30	130	
F	23	5.60	2.90	93	
G	21—22	4.00	2.45	63	white zone
VII(10.15m)					
A	phloem	4.00	1.85	116	
B	27	6.90	2.20	214	
C	26	6.10	2.25	171	
D	25	6.00	3.10	94	
E	24	4.70	2.80	68	
VIII(12.50m)					
A	27	2.10	1.00	110	

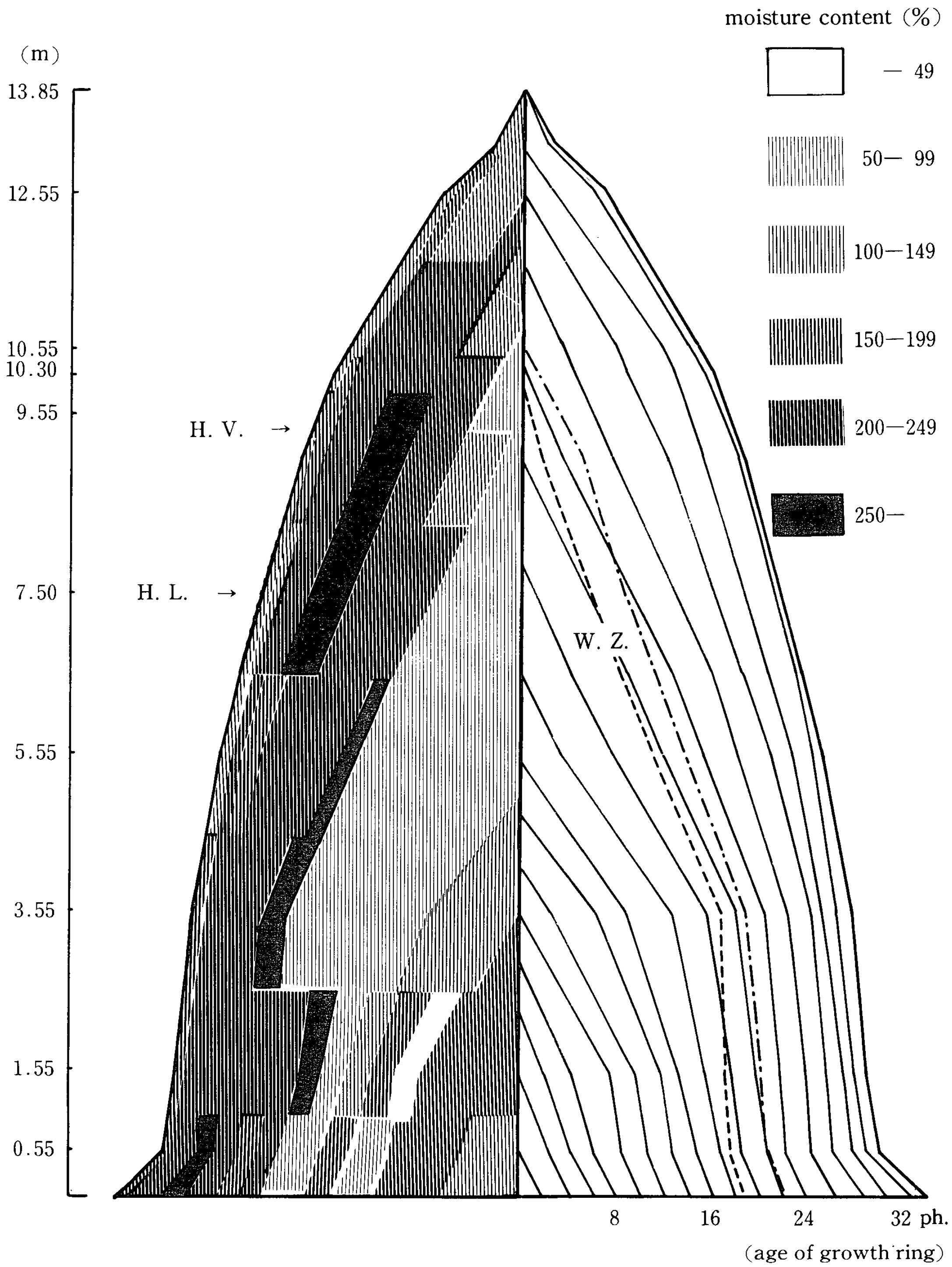
* Calculated on the basis of dry weight.

lower portion of the trunk in both the heartwood and sapwood (Plate 3).

It was revealed by microscopic technique that the stain went up the tracheid in summer wood (Plate 9, 10). The alleyway was forked at the vanishing point of heartwood (Plate 4). In the stem of tree top, the stain was cone-shaped (Plate 4). The difference of fuchusine development phase in the lower stem was not recognized in the direction of treatment (Plate 5). Thus, no serious difference in phase could be observed between the two-way absorptions of top and bottom. Nevertheless, when the stain was absorbed by way of the bough, the developing phase changed entirely as shown in Plate 6. Also, at the reaction wood, the development of fuchusine was changed ; the stain path moved smoothly on the tension side, but stemmed on the compression side (Plate 7). The same fact was also recognized in the bough. Thus, fuchusine moved to the upper side and stagnated in the lower side. Other conifer trees such as pine and Japanese cypress presumably had different stain paths, especially with respect to the position of the water alleyway, though more detailed investigation is necessary (Plate 8).

There was a difference in the physiological reaction between a growing tree and cut tree, though they were both living ; the former kept alive, while the latter was moribund. Then, in order to distinguish the developments of acid fuchusine between a growing tree and cut one, and experiment was carried out using that stain. The same development was recognized in the stem of a growing tree (Plate 11). The existence of water alleyway could be ascertained between the white zone and the most damp zone in the Sugi. The position may be useful to explain the physiological role of the white zone in heartwood formation. In other words, the sufficient water supply with the alleyway would insure smooth physiological action in the white zone, though it was a question surrounded with controversy.

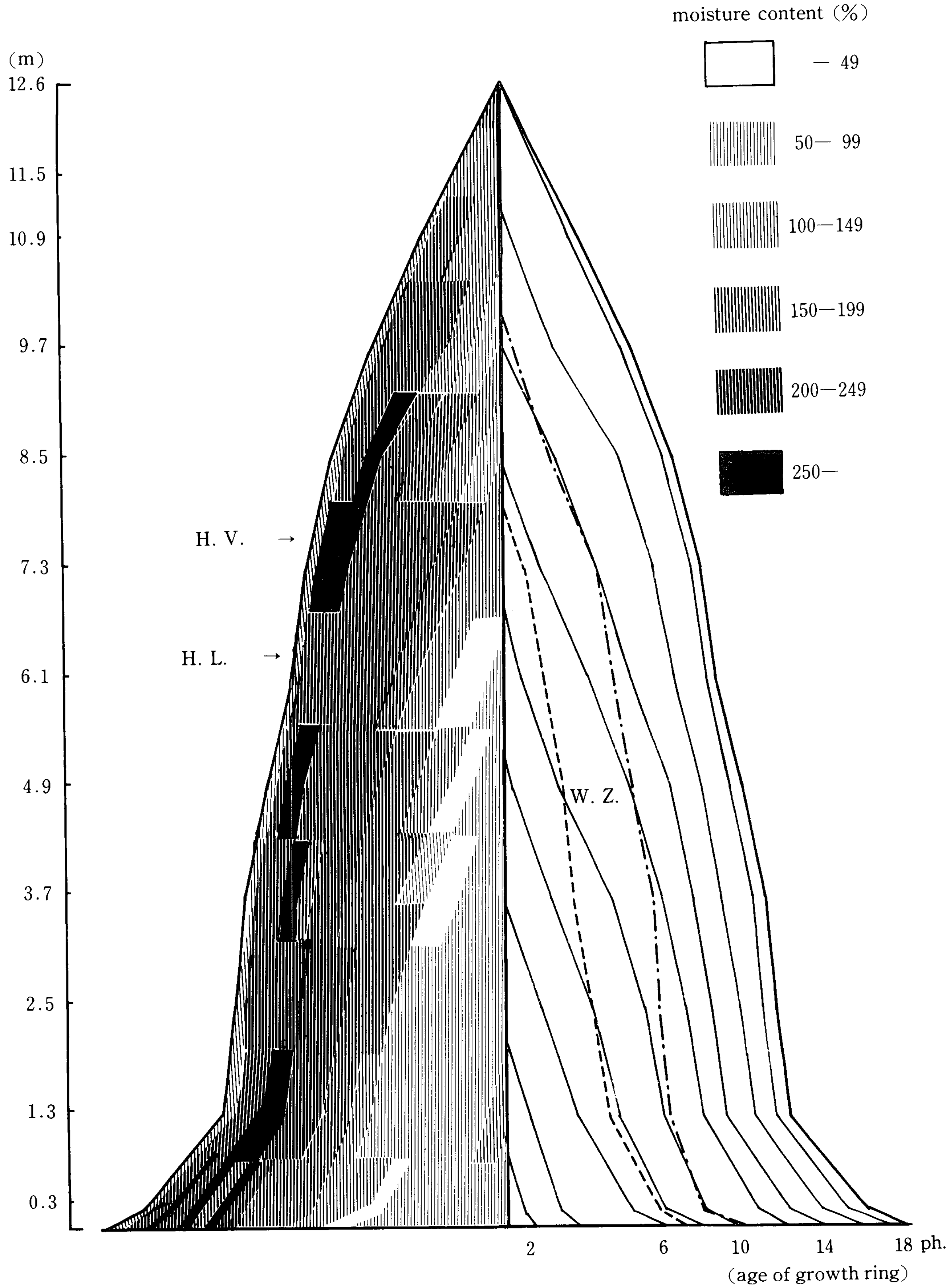
The seasonal change in water alleyway was observed for about one year. The change of stain developing phase could not be recognized above the vanishing point of heartwood. But, below the point, the ascending ability of stain at the water alleyway zone fell to about half in autumn and winter (Table 4). The increased stain ascent was noted on the outside of sapwood in winter and early spring. It might be that the current alleyway was filled with some scale (the so-called heartwood constitu-



W. Z. : white zone ; H. V. : height at the vanishing point of heartwood ; H. L. : height at the lowest branch.

Fig. 1. Water distribution in the living stem of *Cryptomeria japonica* harvested in May.

ents) build up in time, so became new white zone and, of course, its outside took over the alleyway function. Thus, in conclusion, this might indicate that the water alleyway participate in the heartwood formation in the living Japanese cedar.



W. Z. : white zone ; H. V. : height at the vanishing point of heartwood ; H. L. : height at the lowest branch.

Fig. 2. Water distribution in the living stem of *Cryptomeria japonica* harvested in December.

Table 3. Horizontal moisture distribution in stem of *Cryptomeria japonica* (1.20m)*

Tree age	15	14	13	12	11	10	9	8	7	6
Moisture content(%)**	203	241	288	271	259	183	131	79	78	94

* harvesting date (1/25/84)
** calculated on the basis of dry weight.
9 ... 7 : white zone.

Table 4. Seasonal change of fuchsine mobility in stem of *Cryptomeria japonica*

Sample (harvesting date)	Fuchsine mobility (A : B)*
5/16/84	1 : 3.1
7/end/84	1 : 6.8
10/ 3/84	1 : 4.7
10/end/84	1 : 4.4
12/14/84	1 : 4.1
1/25/85	1 : 4.2
3/26/85	1 : 3.0

* ratio of movement distance of Fuchsine at outside of sapwood (A) to outside of white zone (B).

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生きたスギ樹幹内の水分布と狭水路

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(1985年7月31日受理)

要　　約

心材形成に関する基礎的知見を得るために,生きているスギ樹幹内での水分布とその季節的変化を調べ,また,樹幹中の樹液流を色素でマーキングして調べた。

水分布のダイヤグラムによると,250%以上の含水率を有するよく湿った領域が辺材中に存在することが追認できた。また,それは季節によって水平方向に移動していることが示唆された。すなわち,春から夏にかけてその湿った領域は内部辺材に認められ,秋から冬にかけては外部辺材に移動するようであった。

酸性フクシンでモニターすることで,生きている樹幹内で,樹高によって樹液流相の違いのあることが確かめられた。辺材と心材が共存する領域で,特異的な水供給系,狭水路の存在が白線帯外方に確認された。辺材だけからなる上方では水は幹全体を使って上方に供給されていた。この狭水路は春から夏にかけてその働きが高くなる傾向にあり,秋から冬にかけては低くなる傾向にあった。

また,この狭水路が心材形成に関係している可能性を指摘した。

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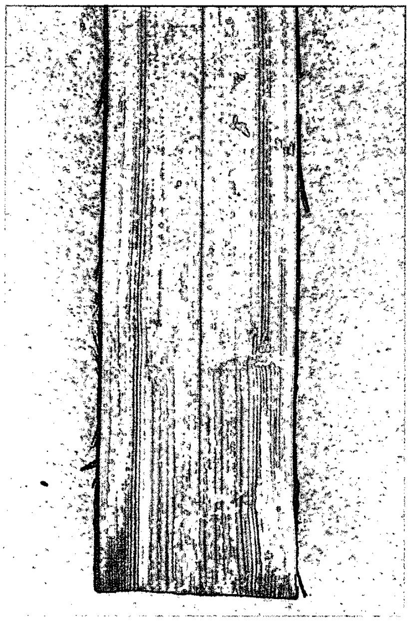

Plate 1. Fuchusine ascent in the living stem of *C. japonica.*

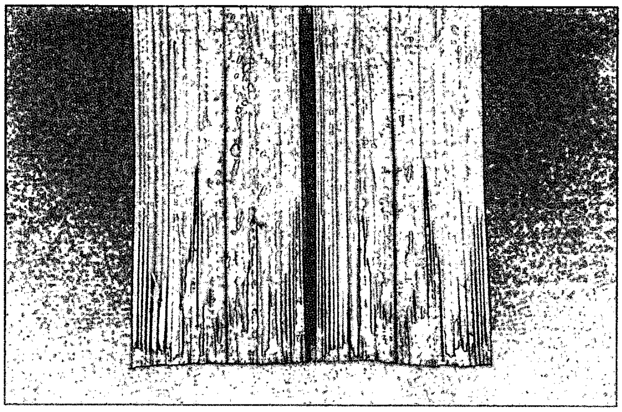

Plate 2. Fuchusine ascent in the dead stem of *C. japonica.*

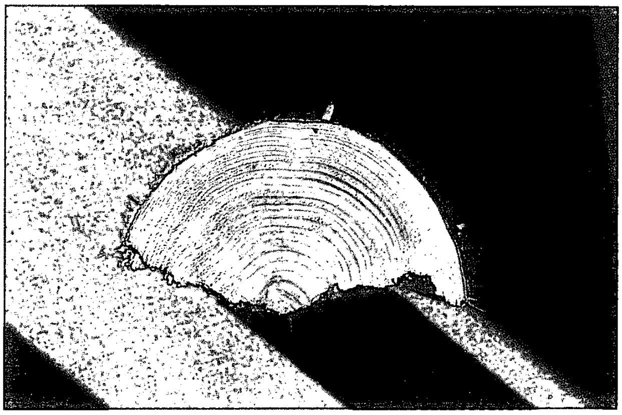

Plate 3. Fuchusine ascent in the living stem of *C. japonica* (cross section)

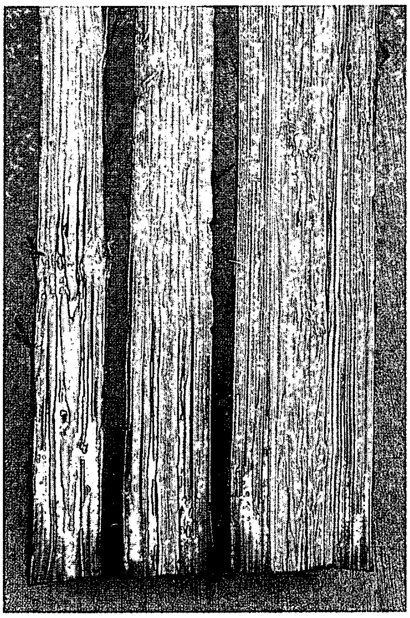

Plate 4. Fuchusine ascent in the upper part of living stem of *C. japonica.*

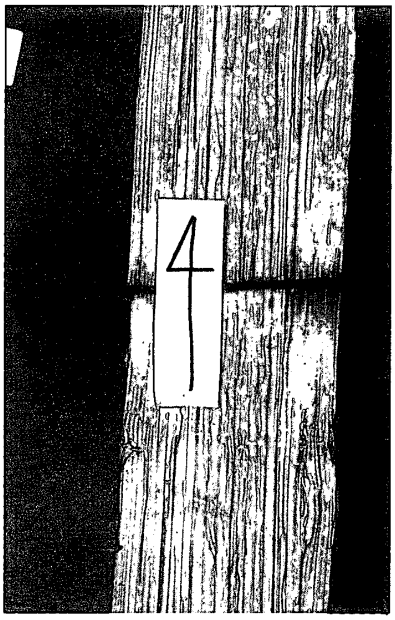

Plate 5. Movement of fuchusine in the top and bottom directions.

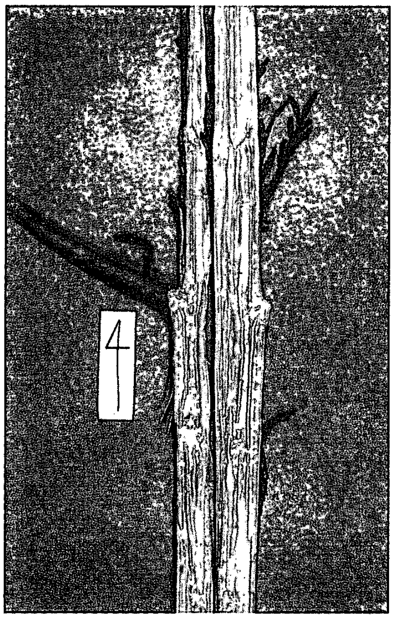

Plate 6. Absorption of fuchusine from the bough of *C. japonica.*

Plate 7. Fuchusine ascent in the living stem of *C. japonica*.

Plate 8. Fuchusine ascent in the living stem of Japanese cypress (*Chamaecyparis obtusa*).

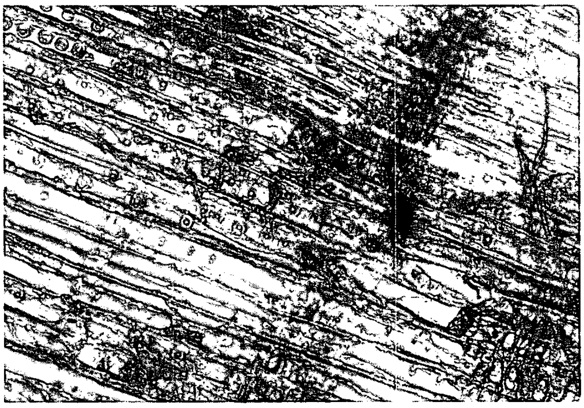

Plate 9. Micrograph of fuchusine ascent in the living stem of *C. japonica* (radial section).

Plate 10. Micrograph of fuchusine ascent in the living stem of *C. japonica* (tangential section).

Plate 11. Fuchusine ascent in the stem of Vegetating *C. japonica*.