Electrical Resistance of Wood Tissue and Water Relation Parameters of Leaves in "Over-Year Wilt" of Pines Induced by Pine Wilt Disease

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Key words: "over-year wilt", pine wilt disease, electrical resistance, *P-V* analysis.

Pine wilt disease caused by *Bursaphelenchus xylophilus* (Steiner et Buhrer) Nickle is the most serious epidemic disease of Japanese red pine, *Pinus densiflora* Sieb. et Zucc., and Japanese black pine, *Pinus thunbergii* Parl., and now is spreading to the northern part of Japan. In the south-western Japan, most trees infected with pine wood nematode die within the year of infection, however, in the newly infested low temperature regions, such as Tohoku district, the disease develops more gradually, and most of infected trees remain alive throughout the winter, and die in the following spring^{1,2)}. We call this phenomenon "over-year wilt" of pines.

In these cases, cessation of oleoresin exudation and attack of a pine sawyer, *Monochamus alternatus* Hope, and a wood wasp, *Sirex nitobei* Matsumura, are often observed in the autumn. To clarify the physiological processes in the infected trees in the course of disease development from the infection of summer to the death of spring is not only of a scientific interest, but also of an urgent political demand for prediction of the over-year wilt of pines.

For this purpose, some investigations were made about the physiological status of Japanese red pine, naturally infected with pine wood nematodes. And the water relation parameters of leaves and electrical resistance of wood tissue are discussed as the disease develops.

Investigations were made at a 32~33 year-old Japanese red pine stand 100 m above the sea level, at Ichinoseki, northern part of Japan. Thirteen trees were selected for the investigations in September 29, 1986.

Table 1 shows symptoms of the trees examined from September 1986 to June 1987. Trees diagnosed as healthy throughout the investigation period were designated H-1~4. Trees with some disorder but which didn't die in the period were designated S-1~6. Trees dead or dying in the spring of 1987 were designated D-1~3.

In S-1, cessation of oleoresin exudation and yellowing of leaves were observed in September 1986, and foliage symptom developed in winter. In S-2 and S-3, death of crown top was observed in September 1986, but they showed no advances in symptoms during the investigation period. S-4~6 are trees which were attacked by some wood- and bark-boring insects during the investigation period, but showed neither foliage nor resin symptoms.

In D-1 and D-2, foliage symptoms were observed in September 1986, and advanced gradually in winter, and in D-3, the disease symptoms developed clearly in the spring of 1987. In these trees, an oviposition of a wood wasp, *Sirex nitobei*, and attack by a bark beetle, *Tomicus piniperda* Linné, were observed in the autumn of 1986 and the spring of 1987, respectively.

For monitoring the changes in microflora in the wood tissue of diseased trees, electrical resistance (ER) was measured after Suzuki *et al.*³⁾ The measurements were made in each 5

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1) Jinno, Y. (1984). Forest Pests 33: 4-8. 2) Kishi, Y. (1980). Bull. Ibaraki Pref. For. Exp. Stn. 11: 1-83. 3) Suzuki, K., Yoshida, N., Dozono, Y., Hashimoto, H. and Kobayashi, T. (1984). Bull. For. For. Prod. Res. Inst. 328: 107-117.

Table 1. Symptom development in Japanese red pine trees

No.	DBH (cm)	Symptoms	1986		1987			
			Sept. 3	Nov. 28	Feb. 19	Apr. 18	June 8	
H-1	11.5	Insects Resin	- +			- +	-	
H-2	11.0	Insects Resin	- +			- +
H-3	14.5	Insects Resin	- +			- +
H-4	12.8	Insects Resin	- +			- +
S-1	18.5	Insects Resin	- -			- -
S-2	16.0	Insects Resin	- +			- +
S-3	22.0	Insects Resin	- +			- +
S-4	11.4	Insects Resin	Sn +			- +		Tp
S-5	12.0	Insects Resin	- +			- +		Pn
S-6	13.0	Insects Resin	Sn +			- +		-
D-1	16.5	Insects Resin	Sn +			Tp +		Tp, Pn
D-2	10.3	Insects Resin	Sn, Ma -			Tp -		Tp
D-3	18.5	Insects Resin	Sn +			Tp +		Tp

no foliage symptoms

yellowing

death of top

death of branches

death of half crown

death of almost whole crown

Sn : *Sirex nitobei*Ma : *Monochamus alternatus*Tp : *Tomicus piniperda*Pn : *Pissodes nitidus*

cm depth of the trunk from the cambia inserting the probe into a drilled hole of 6 mm diameter. ER value to direct current less than 180~200 k Ω is considered to indicate the discolored or decayed woods as in the previous paper³⁾. Table 2 shows the minimum ER values of each tree during the investigation period. Until April 27, all of the examined trees except D-3 in September 29, showed high ER values above 180 k Ω . In June 9, all of the five trees (S-1, S-4, S-5, D-2, D-3) with low ER values showed some disorder or death (Table 1). However, D-1 showed high ER values throughout the period with a heavy chlorosis and necrosis of the whole crown.

These results suggest that changes in microflora in wood tissue were not accompanied with various symptoms in winter.

In pine wilt disease, water stress plays an important role in disease development⁴⁾ and water relation parameters in diseased tree show some characteristic changes such as an increase in bulk

Table 2. Electrical resistance ($k\Omega$) of wood tissue in Japanese red pine trees

No.	1986		1987		
	Sept. 29	Nov. 28	Feb. 10	Apr. 27	June 9
H-1	290	400	220	220	180
H-2	210	400	320	270	250
H-3	230	280	180	500	210
H-4	360	380	350	470	270
S-1	270	300	240	400	160
S-2	350	500	360	700	500
S-3	450	320	300	270	200
S-4	320	600	430	280	160
S-5	250	650	450	350	160
S-6	300	450	320	400	230
D-1	450	350	350	400	230
D-2	410	250	600	350	130
D-3	120	450	240	260	110

Fig. 1. P - V curves in Japanese red pine trees. a: a healthy tree (H-1), b: a diseased tree (D-1). An arrow shows a turgor loss point (ψ_w^{tip}).

elastic modulus (ϵ) of cell wall and a reduction in osmotic adjustment⁵). To investigate the water relation parameters of leaves in over-year wilt of pines, pressure-volume (P - V) curves^{6,7}) were examined. Sample twigs were taken for P - V analysis, and brought to the laboratory with

4) Suzuki, K. and Kiyohara, T. (1978). Eur. J. For. Path. 8: 97-107. 5) Fukuda, K. and Suzuki, K. (1988). J. Jpn. For. Soc. 70: 390-394. 6) Tyree, M.T. and Hammel, H.T. (1972). J. Exp. Bot. 23: 267-282. 7) Suzuki, K., Hiratsuka, Y. and Ayer, W.A. (1987). Ann. Phytopath. Soc. Japan 53: 39-44.

sealed conditions in a plastic bag within an ice box⁸⁾. P - V curves were composed within two days after sampling, and some water relation parameters were estimated such as wilting point (ϕ_w^{tip} ; tlp: turgor loss point⁹⁾) and bulk elastic modulus (ϵ).

P - V curves in a sound-looking tree were shown in Fig. 1a. ϕ_w^{tip} was -2.7 MPa in September 29, and it decreased to -3.3 MPa gradually until February 10. When the winter was over, ϕ_w^{tip} turned back upward in April 27, and returned to -2.7 MPa in June 9. These changes in ϕ_w^{tip} were regarded as a seasonal osmotic adjustment to cold hardiness^{9, 10)}.

P - V curves in a pine wood nematode infested tree (Fig. 1b) showed a normal osmotic adjustment, and no remarkable differences were recognized between healthy and diseased trees. Also, no differences between healthy and diseased trees were observed in the maximum values of bulk elastic modulus (ϵ^{max}) estimated from P - V curves.

The results suggest that physiological changes observed in ER and water relation parameters are not correlated to the development of visible symptoms during autumn and winter. And, physiological changes occur abruptly in the next spring. This is a marked characteristics on over-year wilt of pines.

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和 文 摘 要

福田健二・鈴木和夫：材線虫病による年越し枯れアカマツ材部の電気抵抗値および葉の水分生理特性の経時的変化

材線虫病による年越し枯れのアカマツについて、病徴の進展に伴う材部の電気抵抗値および葉の水分生理特性の変化について検討を加えた。材部の電気抵抗値は、秋から冬にかけてはほとんどが正常な値を示したが、感染翌年の春～初夏にかけて $180\text{ k}\Omega$ 未満の値をとるものが多く、春季の材内におけるマイクロフロラの変化が示唆された。 P - V 曲線から得られた葉の水分生理特性は、枯死直前の春～初夏まで正常な季節変化を示して、細胞壁弾性率 (ϵ) には変化が認められなかった。

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8) Kaufmann, M.R. and Thor, G.L. (1982). Can. J. For. Res. 12: 969-972. 9) O'Neill, S.D. (1983). Plant Physiol. 72: 938-944. 10) Doi, K., Morikawa, Y. and Hinckley, T.M. (1986). Can. J. For. Res. 16: 74-77.