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Thinned Wood of *Cryptomeria japonica* and *Chamaecyparis obtusa* for Production of *Pholiota nameko* Mushrooms in Japan

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We experimentally examined the artificial cultivation of *Pholiota nameko*, a hardwood–rotting and excellent edible mushroom, on beds of logs from thinned *Cryptomeria japonica* and *Chamaecyparis obtusa*. The water content of logs was 62.43% for *Cr. japonica* and 51.11% for *Ch. obtusa*. The sapwood, bark, and hardwood water contents were similar in the two species. Both tree species were suitable for *P. nameko* cultivation, but the numbers and fresh weight of fruiting bodies were higher on *Ch. obtusa* than on *Cr. japonica*. The number of pores drilled into logs for inoculation with fungal mycelia influences mushroom production. The number of inoculated pores per log did not affect mushroom production in *Ch. obtusa*, but more pores were required to produce more mushrooms in *Cr. japonica*. Hence, logs of *Ch. obtusa* are more suitable than logs of *Cr. japonica* to produce this mushroom because the fruiting bodies form on both the cross–sectional surfaces of *Ch. obtusa*, as well as on the bark.

INTRODUCTION

Artificial plantations composed mainly of *Cryptomeria japonica* D. Don and *Chamaecyparis obtusa* Endl. were established in Japan after the Second World War and cover about 1000 million ha. Currently, more than half of these plantations require thinning for the conservation of forest resources and planning for development in local forestry towns (A Society for Research on Promoting Tree Thinning, 1983). However, there is little demand for the thinned wood, and labor costs are high for such operations in Japanese forests.

To promote the thinning or cleaning of conifers including *Cr. japonica* and *Ch. obtusa*, several studies have shown that the wood removed in such operations is useful as bed logs for the cultivation of mushrooms such as *Lentinula edodes* (Berk.) Pegler, one of the best cultivated edible mushrooms in the world (Kido and Inagaki, 1978; Nakazawa *et al.*, 1979; Tajima *et al.*, 1980, 1981; Shinoda *et al.*, 1981). However, another excellent edible mushroom, *Pholiota nameko* (T. Ito) S. Ito and Imai in Imai, naturally forms clumps of fruiting bodies on cut trunks or fallen logs of broadleaf trees (Imazeki and Hongo, 1995). Therefore, sawdust or bed logs from broadleaf trees such as *Betula* spp. and *Fagus crenata* are used in the artificial cultivation of this mushroom in Japan (Kinukawa and Ogawa, 2000; Oomori and Koide, 2001). However, few studies have investigated the use of bed logs from conifers for *P. nameko* cultivation (Yazawa, 1980).

While conifers such as *Cr. japonica* and *Ch. obtuse* are not suitable for *L. edodes* cultivation, there are no reports on the use of logs from *Cr. japonica* or *Ch. obtusa* for artificial *P. nameko* cultivation. Therefore, we examined the artificial cultivation of *P. nameko* on bed logs from these trees as a possible use for thinned logs from these tree species.

MATERIALS AND METHODS

Preparation of bed logs from thinned wood

One meter long bed logs of 24–year–old *Cr. japonica* and *Ch. obtusa* were obtained from the Wakayama Experimental Forest of Hokkaido University in Japan. To estimate the wood water content, 5 cm thick disks were cut from 10 bed logs of each species. The dry weights of the bark, sapwood, hardwood, and whole disks were measured after drying at 105 °C for 1 week. The volume and surface area, excluding the cut ends, of 10 bed logs of each species were measured.

Inoculation and harvesting of *P. nameko*

Pholiota nameko grown on sawdust was obtained from company H and used as the fungal inoculum. Two types of holes for inoculation were made in the bed logs using a drill: treatment 1, 5×10 cm (diameter × depth); and treatment 2, 5×5 cm (diameter × depth). After the pores were inoculated with fungal mycelia they were covered with melted wax (Figs. 3A, B). The logs were inoculated on 5 October 2000 and covered with branches of *Cr. japonica* to prevent desiccation and exposure to sunlight (Fig. 3B). The number of pores inoculated with fungal mycelia was 31.6 for *Cr. japonica* and 34 for *Ch. obtusa* in treatment 1 and 72.4 for *Cr. japonica* and 73

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for *Ch. obtusa* in treatment 2 on average. To induce fruiting bodies, the logs were transferred to an outdoor compound and covered by a screen to reduce light levels to 50% (Fig. 3C). Mushrooms were collected every 2 to 3 days, and their numbers and fresh weights were determined.

RESULTS AND DISCUSSION

Water content of *Cr. japonica* and *Ch. obtusa* bed logs

The average water content of the whole disks of the two tree species was 62.43% in *Cr. japonica* and 51.11%

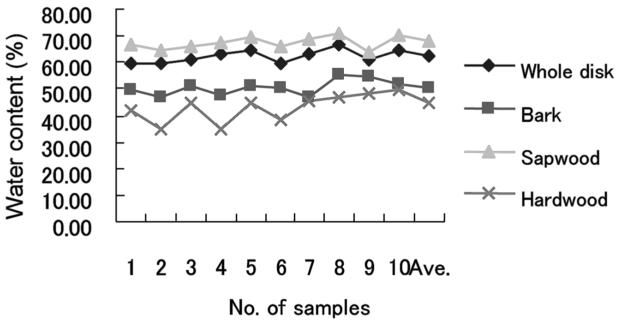

Fig. 1. Water content of the whole disk, bark, sapwood and hardwood in *Cr. japonica* bed log.

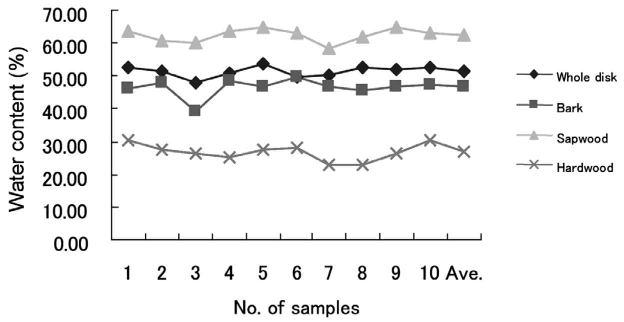

Fig. 2. Water content of the whole disk, bark, sapwood and hardwood in *Ch. obtusa* bed log.

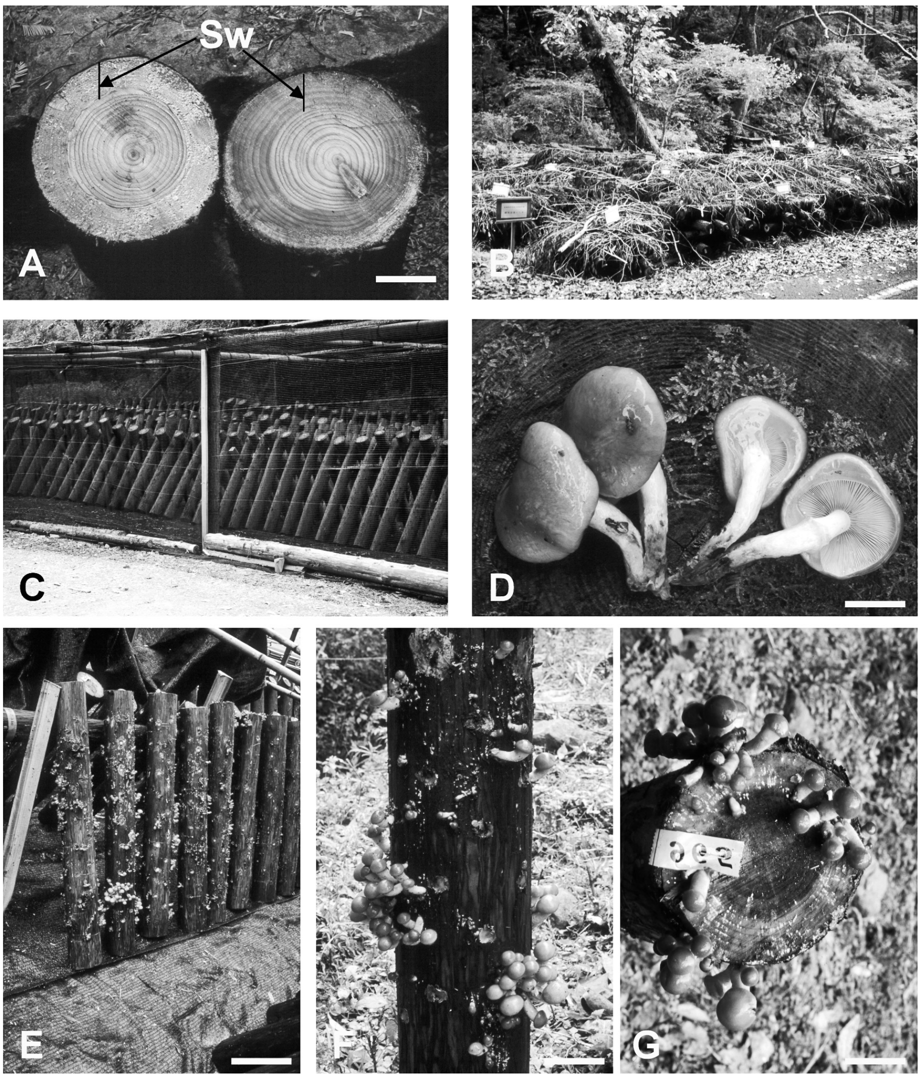

Fig. 3. Sapwood occupied by *P. nameko* hypha (Sw) on the bed logs of *Ch. obtusa* (left) and *Cr. japonica* (right)(A); Bed logs covered with branches during before development mushrooms (B); Outdoor compound for developing mushrooms (C); Matured *P. nameko* (D); *P. nameko* on the surface (E, F) and on the cross–sectional surface (G) of bed logs in *Ch. obtusa*. Yellowish bars A, 8 cm; D, 3 cm; E, 25 cm; F, 10 cm; G, 7 cm.

in *Ch. obtusa* (Figs. 1 and 2). The water content of the sapwood, bark, and hardwood was similar in *Cr. japonica* and *Ch. obtusa*, and the mean water content in the hardwood of *Ch. obtusa* was 26.62%. However, the water content of the whole disk affects that of the sapwood (Figs. 1 and 2).

Although *P. nameko* has strong wood–decaying ability and naturally forms fruiting bodies on both the wood and bark of stumps or fallen logs of broadleaf trees, mycelial growth is considered to differ between sapwood and hardwood in coniferous trees. In fact, the good mycelial growth on sapwood was because the bed logs have high water content (Fig. 3A), do not contain fungal–inhibiting compounds, and contain sufficient water for growth. In contrast, the hardwood, which contains antibiotic components, is not suitable for growing this mushroom (Nakamura, 1982). Hence, the ability of the mycelia to grow on hardwood is considered an important factor for mushroom production on coniferous bed logs.

Mushroom harvests

The volume of bed logs used in this experiment was approximately 0.01 m^3 in each case (Tables 1 and 2), whereas the surface area, excluding the cut ends, was 0.36 m^2 (range: 0.33–0.38 m^2) for *Cr. japonica* and 0.38 m^2 (range: 0.35–0.41 m^2) for *Ch. obtusa*. for *Cr. japonica*, fruiting bodies of *P. nameko* appeared on all but two bed logs in treatment 1, but the numbers and fresh weights varied widely among logs (Fig. 3E). The number of harvested mushrooms and the fresh weight of mushrooms in treatment 1 were 1.3 and 2 times, respectively, those in treatment 2. In contrast, for *Ch. obtusa*, mushrooms were harvested from all bed logs, with little variation between the treatments. Moreover, mushrooms developed on *Ch. obtusa* over approximately 3 months, compared with 2 months for *Cr. japonica*. Clearly, it is possible to use the thinned wood of *Cr. japonica* and *Ch. obtusa* as bed logs for the cultivation of *P. nameko*.

Broadleaf tree species such as birch or beech have been used as bed logs or sawdust for the farm–scale cultivation of *P. nameko*, but cultivation using coniferous tree species such as *Cr. japonica* and *Ch. obtusa* has not previously been examined in Japan. Our results indicate that bed logs of *Ch. obtusa* could be suitable for the farming of this mushroom (Fig. 3F). Although the number of inoculated pores per bed log was not important for mushroom production in *Ch. obtusa*, more pores were required in *Cr. japonica* to achieve a similar har-

Table 1. The situations on each bed log of *Cr. japonica* for inoculation, and *P. nameko* harvest

Treatment	No. of bed log	Volume (m^3)	Surface area (m^2)	Inoculated pores	Pores /m^2	Developed number	Raw weight (g)	Developed period Mon./date/2001
1	961	0.01	0.36	31	86	119	154.7	9/18–12/4
	962	0.01	0.37	31	83	45	80.2	10/9–10/10
	963	0.01	0.36	27	75	0	0	–
	964	0.01	0.37	32	87	0	0	–
	965	0.01	0.35	37	105	13	29.2	10/10
2	966	0.01	0.35	68	197	23	46.3	10/9–11/22
	967	0.01	0.36	72	199	134	161.5	9/28–11/22
	968	0.01	0.35	68	193	58	144.3	9/13–12/7
	969	0.01	0.33	77	233	71	264.4	9/28–11/6
	970	0.01	0.38	77	204	108	253.9	9/18–11/22
	total	0.1	3.58	520		361	978.8	

Table 2. The situations on each bed log of *Ch. obtusa* for inoculation, and *P. nameko* harvest

Treatment	No. of bed log	Volume (m^3)	Surface area (m^2)	Inoculated pores	Pores /m^2	Developed number	Raw weight (g)	Developed period Mon./date/2001
1	961	0.01	0.39	32	83	181	234.9	9/10–12/7
	962	0.01	0.41	32	78	269	319.2	9/10–11/9
	963	0.01	0.38	39	102	351	441.2	9/13–12/7
	964	0.01	0.39	36	91	389	388.8	9/10–12/14
	965	0.01	0.35	31	89	168	216.5	9/10–12/4
2	966	0.01	0.36	68	188	150	287.2	9/12–11/6
	967	0.01	0.39	80	205	371	469.1	9/10–12/4
	968	0.01	0.36	68	190	410	493.9	9/10–12/7
	969	0.01	0.36	75	208	138	162.7	9/10–10/31
	970	0.01	0.36	74	206	418	376	9/10–12/7
	total	0.1	3.75	535		2,845	3.,389.50	

vest.

The fruiting bodies of *P. nameko* formed not only on the bark of *Ch. Obtusa*, but also on the cross–sectional surfaces of the logs, which would favor the use of coniferous bed logs (Fig. 3G). The ability of *P. nameko* to form on cross–sectional surfaces may be due to the thin, friable bark of conifers compared to broadleaf trees.

Although some researchers (Tajima *et al*., 1980, 1981) have obtained good results for *L. edodes* production on bed logs of *Larix kaempferi* Carr. and *Ch. obtusa*, other conifers such as *Cr. japonica* had been considered unsuitable for cultivation of this mushroom as compared with cultivation on *Quercus* spp. (Kido and Inagaki, 1978; Tajima *et al*., 1980, 1981). In particular, the quality of *L. edodes* produced from conifers was low, and in nature this species usually grows on fallen broadleaf trees (Kido and Inagaki, 1978). However, the present study produced *P. nameko* mushrooms of good shape and quality that did not differ from natural mushrooms found on fallen logs of broadleaf trees (Figs. 3D–G). The problem in using the conifer *L. kaempferi* as bed logs for *P. nameko* was that it was less profitable than using broadleaf trees (Yazawa, 1980). Nevertheless, further work will be needed for selection of the best strains of P. nameko for good growth on conifers such as *Cr. japonica* and *Ch. obtusa*.

CONCLUSIONS

In Japan, 70% of the forest area on the main island is covered by *Cr. japonica* and *Ch. obtusa* plantations. This percentage is highest in Wakayama Prefecture, in the Wakayama Experimental Forest of Hokkaido University. Forest cleaning and thinning operations entail high labor costs and produce only low–quality wood; therefore, we attempted to find a solution to this problem by identifying a use for such disposable wood. Our results indicate that this wood can be used to farm *P. nameko* mushrooms. Mushroom farming will not only provide a financial source to underwrite forest management costs, but will also aid in promoting forest preservation in Japan.

The results reported here were obtained for only 1 year after inoculations on the bed logs. Therefore, it is necessary to undertake further research to identify the length of time that *P. nameko* can be produced from each type of bed log. If production starts to decrease after 1 or 2 years due to reduced mycelial growth in the hardwood part of the logs, a new strategy may be necessary, such as using the hardwood part as material for charcoal making. Nevertheless, this study suggests an effective use for the disposable logs of *Cr. japonica* and *Ch. obtusa*, namely for mushroom production of *P. nameko*.

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