Research note

Natural Seeding and Seedling Occurrence in the *Chamaecyparis* Forest at Chilan Mt. Area

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【Summary】

Chamaecyparis formosensis and *Chamaecyparis obtusa* var. *formosana* are 2 important tree species in the cloud forest zone in Taiwan. Because their wood quality and price are high, they have long been the major harvested timber species. Whether current harvesting of snags and downed logs in the natural *Chamaecyparis* forest at Chilan, north Taiwan, causes negative or positive impacts on *Chamaecyparis* regeneration is a concern of all parties involved in *Chamaecyparis* forest management issues. We tried to estimate natural seeding and seedling survivor patterns on forest floors with different time spans after harvesting of snags and downed logs at Chilan. Three sites along forest roads 130, 160, and 170 were selected to represent sites 1, 8, and 14 years after snag and downed log harvesting, respectively. Results indicate that the numbers of seeds collected at the 3 sites did not significantly differ from each other, but their germination rates differed. As to weeding and weeding with soil disturbance, these 2 practices did not significantly enhance seedling occurrence or survival rates. The *Chamaecyparis* forest has a very obvious recurring mast year every 3-5 years, and it is recommended that harvesting operations be conducted in mast years. Under such circumstances, the seedbed would have been recently prepared, and weed and shrub competition eliminated by the harvesting operation. On the other hand, the higher survival rate of seedlings on downed logs indicates that leaving some large downed logs on the ground is beneficial to seedling establishment. But, the number of large downed logs that should be left needs to be further studied.

Key words: *Chamaecyparis formosensis*, *Chamaecyparis obtusa* var. *formosana*, snags, downed logs.

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研究簡報

棲蘭山區檜木林天然下種及種苗發生之研究

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摘 要

紅檜及台灣扁柏為台灣山區霧林帶的重要構成分子，木材質佳，價格昂貴，多年來為林業收穫的主要樹種，但近年來在棲蘭山區收穫倒木及枯立木是否會對檜木森林更新造成影響，一直被許多關心檜木林經營問題的團體關注著。

我們嘗試不同年度枯立倒木整理的林地內找尋檜木林天然下種及幼苗發生、存活的形式，也希望多少能夠知道該地區枯立倒木整理及收穫是否會影響檜木林的天然更新能力。在170 、160 、130線三個地區選定三個樣區來代表整理後14 、 8及1年三個區隔，檜木種子天然下種量在三個地區差異不顯著，但種子發芽率則差異甚大。除草或除草加土壤干擾兩種處理對種子發芽率和存活的比例上並沒有差別，根據所得到的結果來看，如果枯立倒木的整理能夠配合豐年期來作業，並在種子成熟期之前結束，空出來的林床即可提供種子著床發芽且亦能減少幼苗遭受雜草競爭的壓力而提高存活率。調查結果亦顯示，在枯倒木上的幼苗存活率最高，這樣的結果是因為較高位置的枯木可以降低幼苗與雜草的競爭，因此，要留存多少較大徑級的枯木(較小徑級枯木並不能提供類似的環境)在林床上才足夠，是後續值得研究的課題。

關鍵詞：紅檜、台灣扁柏、枯立木、倒木。

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TEXT

Chamaecyparis formosensis and *Chamaecyparis obtusa* var. *formosana* are 2 important tree species in the cloud forest zone in Taiwan. Because of their valuable wood, they have long been the major harvested timber species. In recent years, some environmental groups have claimed that if no urgent action is taken to protect Taiwan's *Chamaecyparis* natural forests, islandwide, *Chamaecyparis* will disappear or even become extinct in Taiwan. The *Chamaecyparis* natural forest at Chilan, northern Taiwan, is the focal point of their concern. However, natural regeneration of *Chamecyparis* at Chilan is viewed as being extremely successful and has attracted the attention of forestry professionals in Taiwan and from around the world as well.

A Japanese forest scientist conducted a pioneering but very intensive study on the natural regeneration of the *Chamaecyparis* forest in the vicinity of Chilan during 1930S (Matuura 1942). Since then, many statements concerning the mast year, seed dispersal patterns, seed germination on the forest floor, and seedling establishment and growth have been derived from observations and experience, especially by Lo-cho (1989). Recently, Lin and Lai (1999) studied the natural regeneration of *Chamaecyparis formosensis* in central Taiwan, and obtained good information. But whether the current practice of harvesting snags and downed logs in the natural *Chamaecyparis* forest at Chilan causes negative or positive impacts on *Chamaecyparis* regeneration still concerns all parties involved in *Chamaecyparis* management issues.

The purpose of this study was to estimate natural seeding and seed germination on the forest floor with different time spans after harvesting of snags and downed logs at Chilan. It was hoped that natural regeneration patterns of the *Chamaecyparis* forest in the seedling stage at Chilan could be clarified, and the impact of snag and downed log harvesting on their natural regeneration could be evaluated.

In November 1999, 3 sites, 1 each along forest road 130 (site #130) (logged in 1997-98), 160 (site #160) (logged in 1990-91), and 170 (site #170) (logged in 1984-85), were selected to represent sites 1, 8, and 14 years after snag and downed log harvest, respectively. These sites have not been planted or tended after harvesting. Currently site #160 consists of a *Chamaecyparis obtusa* and *Chamaecyparis formosensis* mixed stand, has a hardwood subcanopy, and a 90% ground vegetation cover, but sites #170 and #130 consist of pure *Chamaecyparis obtusa* stands with no hardwood subcanopy, and there is 80% and 30% ground vegetation cover, respectively. At each site, ten 1 × 1 m traps were installed 1 m above the ground under tree crowns or in gaps, with traps being at least 30 m away from each other. The 30 m we selected is presumably the dispersal distance of *Chamaecyparis* seeds, based on past experience of dispersal distance being 1.5 times the mean tree height and 20-25 m being the natural tree height of the *Chamaecyparis* forest at Chilan. However, the actual distances of the traps installed in gaps were not so precise. For each trap, the canopy status was recorded as gap or non-gap. In January, March, and April 2000, seeds fallen in the traps were collected, counted, mixed with 5 times the volume of wet sphagnum, sealed in plastic bags, and places in 20℃ incubators for 1 month to estimate germination rates.

At each of the 3 sites, 2 canopy statuses, gap and non-gap, were selected. For each canopy status, 2 strips of weeding and 2 strips of weeding with soil disturbance to 5 cm deep were established with a control strip in November 1999. Each strip was 1 × 10 m. In March and April 2000, newly germinated seedlings were marked and counted. The seedling occurrence on microsites (bare ground, downed logs and rock) was counted separately. Seedling survival rates were compared in term of percent of seedling surviving at each microsite after 5 months (residual no. of seedlings after 5 month/ total no. of seedling occurring).

Data analysis

Natural seeding and seed germination rates were analyzed using ANOVA with a split-plot design. The main plots included 3 sites, and the subplots included 2 canopy statuses (gap and non-gap), with 4 replicates for each of the total 6 treatments. ANOVA with a spilt-plot design was applied to analyze the effect of site, canopy status, and ground treatment on seedling occurrence and survival, with sites as whole plots, canopy statuses as mid-plots, and ground treatments (weeding, or weeding with soil disturbance) as subplots. Each treatment had 4 replicates.

Chamaecyparis natural seeding and seed germination

The number of seeds collected at the 3 sites did not significantly differ from each other (Table 1). This implies that fruiting rate is not influenced by snag and downed log harvesting, despite the existence of various conditions of living trees at the sites. The germination rate under growth chamber conditions (20℃) was significantly lower for seed of site #160 (26%) (Tables 1 and 2). But the number of seeds collected for the non-gap status was 1.3-4.0 times higher than that for the gap status, which significantly differed. The openness of the gap might not be beneficial to trap seeds falling from above. However, seed germination rates between seeds collected from gap and non-gap areas did not significantly differ. Because traps situated in gap areas were 30 m away from tree crowns, results might imply that lighter

Table 1. ANOVA of seeds and their germination rates of 3 sites, with 2 canopy statuses

Source of variance	Df	Seeds colleted	Germination rates
Replication	3		
Site [1]	2	0.43ns [2]	35.89a [3]
Error A	6		
Canopy status [4]	1	21.19a	2.77ns
Site × canopy status	2	2.54ns	1.00ns
Error B	6		

[1] Site: 3 sites are coded as road, #130, #160, and #170.

[2] ns: non-significant at the 5% level.

[3] a: difference significant at the 1% level.

[4] Canopy status: non-gap and gap status.

Table 2. Number of seeds/m^2 collected in traps and their germination rates

Site	Gap (n = 10)		Non-gap (n = 10)		Mean	
	No. of seed	Germ. (%)	No. of seed	Germ. (%)	No. of seed	Germ. (%)
#130	1506	43.8	2851	39.6	1952a[1]	40.1a
#160	1998	24.6	2708	29.9	2353a	26.5b
#170	891	45.2	3740	48.4	2316a	45.4a
mean	1316b		3100a			

[1] Values labeled by the same letter in a column do not significantly differ at the 5% level according to Duncan's multiple range analysis.

defective or empty seeds flew no farther than did well-developed seeds. If seed dispersal is quite even in a well-stocked stand, approximately 20 million seeds/ha will be produced and nearly 6.5 million viable seeds/ha will be available for natural generation in natural *Chamaecyparis* forests of Chilan.

Seedling occurrence and initial survival

Seedling occurrence and initial survival rates significantly differed among the 3 sites (Table 3). The ground vegetation coverage rate was 30%, 80%, and 90% for sites #130, #170, and #160, respectively. This shows a trend of increasing coverage with time after snag and downed log harvesting of 1, 8, and 14 years, respectively. Of these 3 sites, only site #160 contains a subcanopy of hardwood trees. Seedling occurrence and survival rates at sites #160 and #170 were apparently lower than these of site #130 (Table 4). The dense subcanopy of hardwood trees at site #160 and ground vegetation coverage at sites #160 and #170 may have contributed to this result. Some degree of artificial disturbance, such as weeding and/or seedbed preparation may be favorable (Hung 1984). Zobel (1980) indicated that soil disturbance was beneficial to seedling establishment of *Chamaecyparis lowsoniana* in Oregon, USA. The highest seedling survival rate at site #130, disturbed recently by removal of snags and downed logs, supports this view. Weeding or weeding with soil disturbance between gap and non-gap plots within the 3 sites did not significantly increase seedling occurrence or survival rates when compared to the control strips, although their performance appeared

Table 3. ANOVA for the number of seedlings and their survival rates with the split-split-plot design

Source of variance	Df	Calculated F	
		No. of seedlings	Survival rate
Replication	3		
Site	2	67.08a [1)]	14.76a
Error A	6		
Canopy status	1	1.12ns [2)]	3.12ns
Site × canopy status	2	0.61ns	1.68ns
Error B	6		
Treatment [3)]	2	0.13ns	0.00ns
Site × treatment	4	0.68ns	0.45ns
Canopy status × treatment	2	0.20ns	1.62ns
Site × canopy status × treatment	4	0.08ns	1.21ns
Error C	36		

1) a: difference significant at the 1% level.

2) ns: non-significant at the 5% level.

3) Treatment: weeding, and weeding plus soil disturbance.

Table 4. Mean number of seedlings and survival rates among different sites

Site	Canopy status	No. of seedlings /m²			Avg. survival rate (%)
		Treat. w [1)]	Treat. d [2)]	Control	
#130	gap	84.2	75.0	75.0	40
	non-gap	97.3	92.7	51.1	
#160	gap	4.0	6.4	3.2	17
	non-gap	2.2	4.5	1.1	
#170	gap	8.6	13.7	5.8	21
	non-gap	9.0	26.7	6.1	

1) Treat. w: weeding treatment.

2) Treat. d: weeding treatment with soil disturbance.

Table 5. Occurrence of *Chamaecyparis* seedlings on microsites at Chilan

Microsite	Survival rate (%)		
	#130	#160	#170
Downed logs	52.0a	25.7a	28.4a
Rocks	17.9b	23.0a	20.8a
Bare soil	39.8a	17.3a	14.5a

Values labeled by the same letter in a column do not significantly differ at the 1% level according to Duncan's multiple range analysis.

to be better then the control (Table 4). This might be due to the disturbance of recent logging at site #130 being more intense than the disturbance treatment we carried out.

As to the effect of microsites formed by downed logs, rocks, and bare soil, the seedling survival rates on these 3 microsites differed between site #130 and the other 2 sites. At site #130, seedling survival rates on both downed logs and bare soil were significantly greater than that on rock, while at sites #160 and #170, no significant differences were found among the 3 microsites (Table 5). The low ground cover (30%) at site #130 may have caused this difference from the other sites. We presume that higher seedling survival rates on both downed logs and bare soil at site #130 would decrease to nearly similar rates as those occurring at sites #160 and #170 when the vegetation coverage increased to 80%.

Weeding and weeding with soil disturbance did not significantly enhance seedling occurrence or survival rates although survival rates in control strips were low. More replicates are needed to obtain a solid conclusion for this aspect.

Although seed germination rates in the forest were estimated to be only 0.05-2 % in this apparent mast year, the forest would still recruit nearly 10,000 seedlings at the initial stage of natural regeneration. If the lowest initial survival rate is applied, at least 1,660 seedlings will survive on the site with a dense subcanopy of hardwood trees at site #160. This is not bad for *Chamaecyparis* natural regeneration. For the recently harvested site with few subcanopy hardwood trees at site #130, seedling occurrence might reach 150, 000 seedlings/ha. This can be described as a bumper year. Lin and Lai (1999) estimated that seed production was about 1.5 million seeds/ha, and the germination rate was 0.81% in an old-growth *Chamaecyparis formosensis* natural stand in central Taiwan in 1996. Both results are quite close. Lo-cho (1989) reported that there was a very distinct cycling of mast years, and natural seedling occurrence could reach 7,000-12,000 seedlings/ha in a mast year at Chilan.

Consequently, the *Chamaecyparis* forest has a very obvious recurring mast year every 3-5 years. It is recommended that harvesting operations (if necessary) be conducted in mast years. Under such circumstances, the seedbed would have been recently prepared, and weed and shrub competition eliminated by the harvesting operation. On the other hand, the higher survival rate of seedlings on downed logs indicates that leaving some large downed logs on the ground is beneficial to seedling establishment. But, the number of large downed logs that should be left needs to be further studied.

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