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Population Structure and Substrates of Taiwan Yellow False Cypress (*Chamaecyparis obtusa* var. *formosana*) in Yuanyang Lake Nature Reserve and Nearby Szumakuszu, Taiwan

Chi-Cheng Liao[(1)], Chang-Hung Chou[(2)], Jiunn-Tzong Wu[(1,3,4)]

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ABSTRACT: *Chamaecyparis obtusa* Sieb. & Zucc. var. *formosana* (Hayata) Rehder (Taiwan yellow false cypress) is one of the most important sources of timber in Taiwan. For sustainable use of this species, basic information about its regeneration under natural conditions is required, but this has been few until now. In this paper, the composition, population structure, growing substrates, and recruitment of Taiwan yellow false cypress were studied in Yuanyang Lake Nature Researve (YYL) and nearby Szumakuszu (SMKS) area, Taiwan. Two study sites in YYL were selected for comparison: one near a lakeshore (LS) and another at a mountain ridge top (MR). A site also was studied at SMKS, located 2 km west of the lake. Within each site, all woody plants with basal diameters larger than 1 cm, and population structures were recorded and analyzed in order to elucidate the recruitment pattern of Taiwan yellow false cypress. It was documented that floristic composition and canopy structure differed among the sites. An inverse J-shaped size distribution pattern for plants growing on down logs at the LS and MR sites suggests a stable and continuous recruitment of Taiwan yellow false cypress at both YYL locations. In contrast, the Taiwan yellow false cypress at SMKS had a discontinuous size distribution, independent of inhabited substrate type. For regeneration of Taiwan yellow false cypress in SMKS, a large-scale disturbance, instead of single uprooted trees, may be necessary. The results indicate that down log is important substrate for regeneration of Taiwan yellow false cypress, particularly in forests at the YYL, LS and MR. Based on the findings in YYL, some down logs are suggested to leave in clear cutting plantation, because they might provide suitable space for regeneration of Taiwan yellow false cypress. This suggestion is expected to reduce the cost and work frequency of management.

KEY WORDS: *Chamaecyparis obtusa* var. *formosana*, Down log, Growing substrate, Population structure, Regeneration.

INTRODUCTION

Temperate coniferous forests is one of the vegetation types in Taiwan. Distributed between evergreen broadleaf forests and cool temperate coniferous forests, their elevation ranges from 1,500 to 2,500 m above sea level (a.s.l.) (Su, 1984), and accounted for 48,500 ha (2.3%) of natural forests (Taiwan Forest Burean, 1995). The dominant species, *Chamaecyparis formosensis* Matsum. (Taiwan red false cypress) and *Chamaecyparis obtusa* Sieb. & Zucc. var. *formosana* (Hayata) Rehder (Taiwan yellow false cypress), are important for wood production. Therefore, they have suffered from timber harvesting (Su, 1984; Jen, 1995). Although deforestation ceased in 1985, large portions of the virgin false cypress forests were fragmented and had been transformed into man-made plantations. In view of this situation, investigations on compositional and distribution patterns of false cypress forest vegetation are important.

1. Department of Botany, National Taiwan University, Taipei 106, Taiwan.
2. Graduate Institute of Tropical Agriculture, National Pingtung University of Science and Technology, Pintung 912, Taiwan.
3. Institute of Botany, Academia Sinica, Taipei 115, Taiwan.
4. Corresponding author. Tel: 886-2-2789-9590 Fax: 886-2-2782-7954 E-mail: jtwu@gate.sinica.edu.tw

The Yuanyang Lake Natural Reserve Area (YYL), located in northern Taiwan, is the only site declared to protect the lake and Taiwan yellow false cypress forest ecosystem (Liu and Hsu, 1973; Hwang *et al.*, 1996; Chou *et al.*, 2000). Though the floristic composition and population structure of Taiwan yellow false cypress in YYL have previously been described (Liu and Hsu, 1973; Chou *et al.*, 2000), there is a controversy over regeneration of the species. Evidences from the fossil pollen (Chen and Wu, 1999) and population structure (Chou *et al.*, 2000) within YYL determined that Taiwan yellow false cypress could regenerate without anthropogenic disturbance. On the contrary, the species regenerate well in the plantation after clear cutting and removing down logs and standing snags (Hung, 1984; Lo-Cho *et al.*, 1999). In order to provide critical information for management of the remaining natural forests, the major objective of this research was to expand our knowledge about this ecosystem, by considering community composition, population structure, and, importantly, characteristics on the regeneration of Taiwan yellow false cypress.

MATERIALS AND METHODS

Site description

The Yuanyang Lake Nature Reserve (YYL) is located near the windward slope of Hsehshan Mountain Range in northern Taiwan, with elevation ranging between 1650 to 2432 m (24°35′ N and 121°24′ E). The windward slope of Hsehshan Mountain Range accepts heavy precipitation from northeast monsoon and typhoon (Su, 1984; Wang and Li, 2000). From the data of precipitation stations around YYL, a steep precipitation gradient from 4000 to 2000 mm were found from the east to the west slope of Hsehshan Mountain Range (Figs. 1 and 2) (modified from Wang & Li, 2000). Heavy cloud and fog are so frequent that solar radiation is considerably reduced. Heavy moisture resulted in abundant growth of mosses on the forest floor, tree trunks, and down logs in the YYL (Hwang *et al.*, 1996; Chang *et al.*, 2002). The average annual air temperature is 13 °C; the highest monthly mean is 27 °C in June, and the lowest temperature is 10 °C in January (Hwang *et al.*, 1996). The temperature is rarely lower than 0 °C, and snowfall is rare in winter.

Taiwan yellow false cypress generally dominates the forest within the YYL, which is characterized by simple and open canopy structure that mostly composed by Taiwan yellow false cypress. The broadleaf species densely occupied the shrub layer, and few can reach the canopy. The undergrowth was different along the elevation. It was dominated by *Plagiogyria euphlebia* at lower elevation as compared to higher elevation where dense bamboo, *Yushania niitakayamensis* (Hayata) Keng, typically occupies the forest floor (Liu and Hsu, 1973; Chou *et al*., 2000). Two major vegetation types were recognized by different undergrowth in YYL.

In contrast, the forest which sits on the mountain saddle of west side area about 2 km away from the lake is different from the forest in YYL. By preliminary observation, the forest near SMKS has relatively lower density of shrubs, less coverage of mosses and herb layer. Most importantly, the canopy structure is complex, closed and formed by broadleaf trees. Taiwan yellow false cypress emerged from the canopy.

Field study and data analysis

1. Forest analysis in YYL

The forests at lakeshore area (LS) and mountain ridge top (MR) are recognized as homogeneous. The locations of study sites were selected to avoid visitor's interference. Two

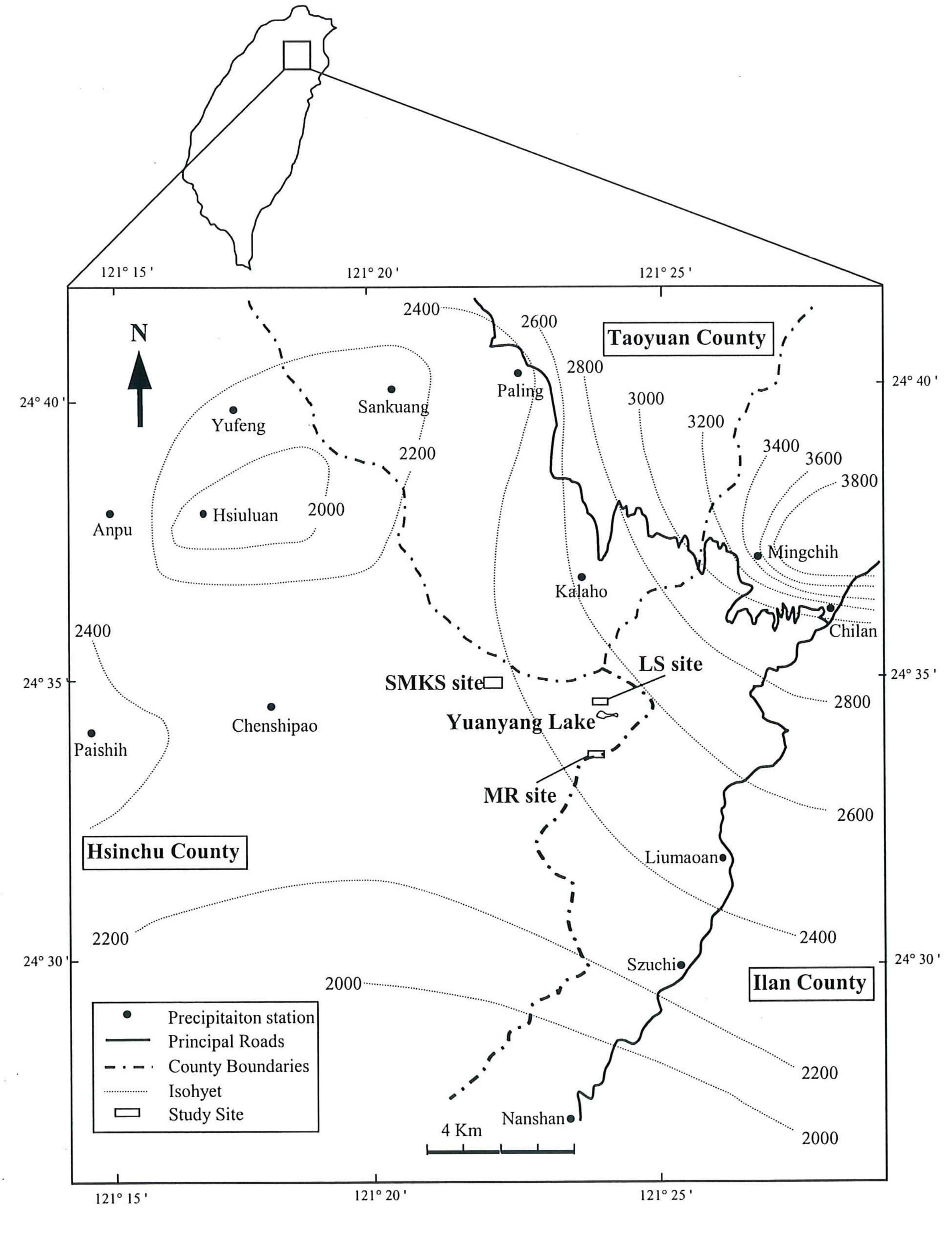

Fig. 1: Map of Chi-lan-shan area with the isohyet showing the locations of study sites in Yuanyang Lake Nature Reserve. (LS and MR sites) and Szumakuszu (SMKS site).

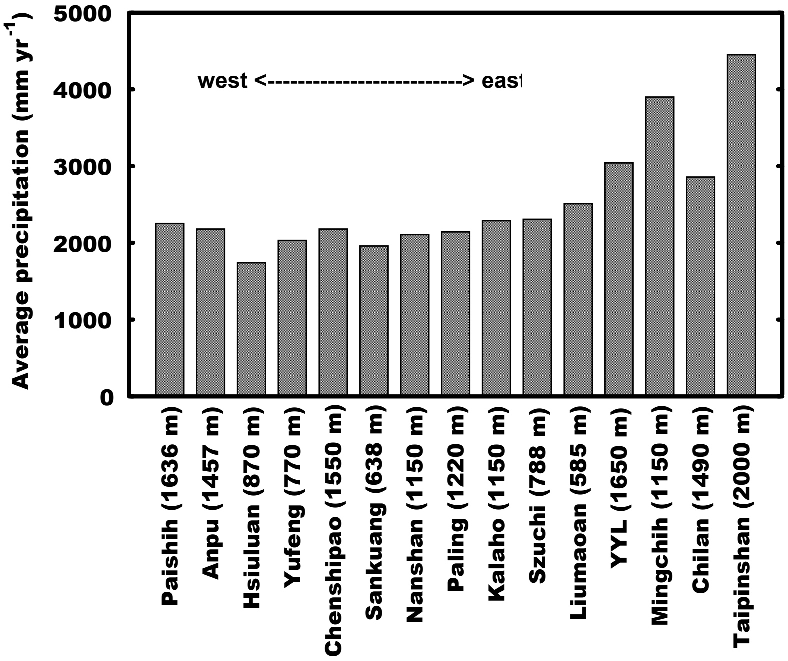

Fig. 2: The average precipitations at various stations (with elevation in brackets) around the area of Yuanyang Lake Nature Reserve (YYL) with respect to their relative position.

Study sites in the YYL, one near the lakeshore (LS) at elevation 1,650 m, and another at the mountain ridge top (MR) at elevation ca. 2,000 m were selected for this study (Fig. 1). The 0.25 ha square LS site was divided into 25 plots by compass determining the WE and NS lines. Each plot in the three sites measured 10 x 10 m^2. The slope was averaged 8.5°. Because of the restriction of steep slope, the MR site had only 0.17 ha and was divided into 17 plots. It was established along the mountain ridge, and the slope was averaged 30°. A third site, located near the vicinity of Szumakuszu (SMKS), at an elevation of ca. 1,800 m, also was 0.25 ha and was divided into 25 plots. The slope of the SMKS site was averaged 18.6°. All trees with basal diameter larger than 1 cm were measured. Basal diameter measured the trunk base at 30 cm above ground. The type of substrate on which Taiwan yellow false cypress occurred was also recorded. The sums of relative density and relative basal area of each plant species at the study sites were calculated and designated as the dominance value (DV).

2. Growing substrate of Taiwan yellow false cypress

For a stable and continuously regenerating population, its size class distribution should approach an inversed J-shaped curve (Daubenmire, 1968; Veblen *et al.*, 1979). Size class distributions of broadleaf trees and Taiwan yellow false cypress that presented the dynamics of the population from seedlings to adults were obtained from the census data of the three sites. Growing substrates of Taiwan yellow false cypress that included soil and down logs were recorded to analyze its regeneration characteristics in different forest types. The use of size-class analysis to assess the regeneration status of a population requires an assumption of significant positive correlation between tree diameter and age (Veblen *et al.*, 1979; Pederson *et al.*, 1997). The annual ring vs. basal diameter of Taiwan yellow false cypress were analyzed 118 individuals and formulated as annual ring = 37.62 + 6.04 ×diameter ($r^2 = 0.72$; $p<0.001$) (Fig. 3).

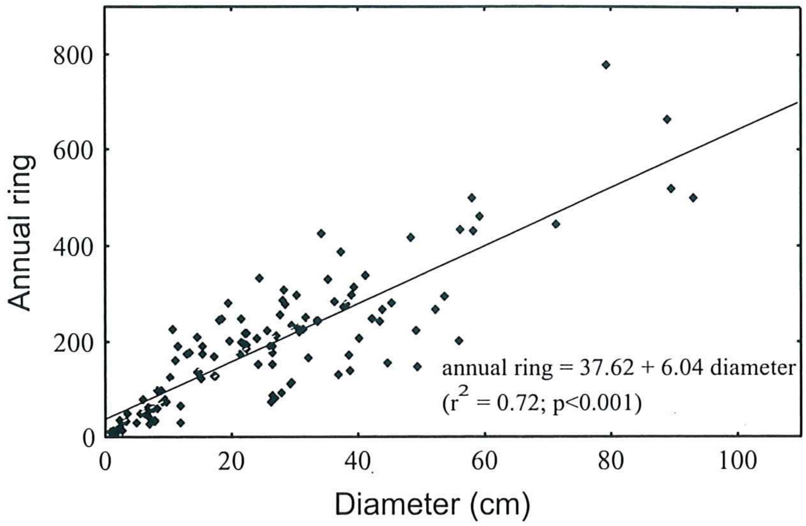

Fig. 3: Correlation between annual ring and basal diameter of Taiwan yellow false cypress.

RESULTS

Characteristics of the YYL Taiwan yellow false cypress forest

A total of 66 plant species was recorded in the YYL. Of these plants, 42, 39, and 31 species were found at the LS, MR, and SMKS sites, respectively (Table 1). Densities of Taiwan yellow false cypress at the three sites differed, although floristic composition at the LS site was quite similar to that at MR (Table 2). The densities of plants at LS and MR were higher, with 848 and 1271 individuals/ha^{-1}, respectively, than at SMKS, where only 48 individuals ha^{-1} were recorded (Table 1). The densities of broadleaf trees were: 5,840 stems ha^{-1}, 8,823 stems ha^{-1}, and 4,392 stems ha^{-1} at LS, MR and SMKS, respectively. Most of the dominant broadleaf species at LS and MR were shrubs, whereas at SMKS the giant tree was dominant (Table 2). Differences in floristic composition among these three study sites reflected the diversity of forest structures within them.

Table 1. Summary of forest characteristics at each study sites.

	LS site	MC site	SMKS site
Area of site (ha^{-1})	0.25	0.17	0.25
Number of plant species	42	39	31
Number of individual recorded	1807	1761	1148
Total basal area (m^2 ha^{-1})	58.55	72.55	133.18
Density of false cypress (individuals ha^{-1})	848	1271	48
Density of broadleaf trees (individuals ha^{-1})	5840	8823	4392

The canopy structures at LS and MR were significantly different from that at SMKS. Over 98% of broadleaf trees were <10 m tall at the LS and MR sites. Only a few broadleaf trees reached the canopy layer. Consequently, the first canopy layer consisted almost entirely of Taiwan yellow false cypress, forming a discontinuous canopy layer. The broadleaf species in the dense shrub layer were *Illicium philippinense*, *Rhododendron formosanum*, *Dendropanax pellucidopunctata*, *Adinandra formosana*, and *Barthea formosana.*

Table 2. Percentages of relative basal area (BA), relative density (RD) and the dominance value (DV) of plant species at each study site.

	LS site			MR site			SMKS site		
	BA	RD	DV	BA	RD	DV	BA	RD	DV
Chamaecyparis obtusa var. *formosana*	69.54	10.07	39.81	73.22	13.00	43.11	64.08	1.03	32.56
Rhododendron formosanum	16.71	20.48	18.60	1.89	3.69	2.79	0	0	0
Adinandra formosana	1.96	15.55	8.76	0.99	4.71	2.85	0	0	0
Illicium philippinense	5.99	10.90	8.45	1.56	5.85	3.71	1.79	13.59	7.69
Schefflera taiwaniana	0.52	10.90	5.71	0.63	4.49	2.56	0.13	3.05	1.59
Barthea formosana	0.30	10.29	5.30	0.88	10.96	5.92	0	0	0
Viburnum sympodiale	0.18	4.26	2.00	0.5	5.74	3.12	0	0	0
Dendropanax pellucidopunctata	1.15	2.10	1.63	3.99	7.16	5.58	0	0	0
Skimmia arisanensis	0.06	3.15	1.61	0.01	0.23	0.12	0	0	0
Ternstroemia gymnanthera	1.29	1.44	1.37	0.43	0.85	0.64	0	0	0
Neolitsea acuminatissima	0.13	1.11	0.62	3.77	10.16	6.97	1.16	10.89	6.03
Rhododendron kawakamii var. *flaviflorum*	0	0	0	1.60	5.28	3.44	0	0	0
Neolitsea variabillima	0	0	0	4.43	9.77	7.10	0.01	0.35	0.18
Cyclobalanopsis sessilifolia	0	0	0	0	0	0	3.60	8.97	6.29
Cyclobalanopsis glauca	0	0	0	0	0	0	5.16	3.05	4.11
Camelia tenuifolia	0	0	0	0	0	0	0.43	7.58	4.01
Daphniphyllum glaucescens var. *oldhamii*	0	0	0	0	0	0	6.53	7.14	6.84
Ilex uraiensis	0	0	0	0	0	0	0.63	9.58	5.11
Eurya acuminata	0	0	0	0	0	0	0.43	5.05	2.74
others	2.17	9.75	6.18	6.10	18.11	12.11	16.05	29.72	22.89

There were 147 individuals of broadleaf trees higher than 10 m at SMKS. They formed a continuous canopy layer. In contrast to the other two sites, the major components of canopy broadleaf species at SMKS were *Cyclobalanopsis sessilifolia*, *Cyclobalanopsis glauca*, and *Daphniphyllum glaucescens* subsp. *oldhamii*. Taiwan yellow false cypress occurred only as emergent trees in the canopy layer. Plants such as *I. philippinense*, *Neolitsea acuminatissima*, *Camelia tenuifolia*, *Ilex uraiensis, Eurya acuminata,* and *Schefflera actinophylla* were the dominant species in the shrub layer. Among these plants, *I. philippinense, N. acuminatissima*, and *S. actinophylla* were evenly distributed at all three study sites, while *C. tenuifolia*, *I. uraiensis*, and *E. acuminata* were only found at SMKS site (Table 2). In comparing with LS and MR sites, the density of shrubs was lower at SMKS.

The components of undergrowth of the forests were quite different between the study sites. Plentiful mosses covered the under-layers at sites in YYL, whereas they were seldom observed in SMKS. A substantial amount of bamboo (about 116 ± 10 culms/m^2) was found at the MR, but not at the other two sites.

Size structure of Taiwan yellow false cypress on different substrates in YYL

The number and the size of Taiwan yellow false cypress plants growing on various substrates within the study sites were recorded. A majority of young Taiwan yellow false cypress was found to inhabit down logs rather than soil (Fig. 4). On soil, there were only 28 and 3 individuals, respectively, at LS and MR. This indicates that soil plays a less important role than down logs for regeneration of Taiwan yellow false cypress at these locations.

At the SMKS site, there were 2 seedlings and 10 amture trees of Taiwan yellow false cypress, respectively, on down logs and soil. This suggests that down logs are less important than soil for regeneration at this location.

Size structure of dominant broadleaf species

The sizes of dominant broadleaf trees varied among the study sites. However, the pattern of size distribution always was an inverse J-shape (Fig. 5). There was a difference in tree size between sites. At SMKS, there were 71 individuals with BD larger than 20 cm, whereas only 15 and 0 individuals, respectively, had such sizes at LS and MR. At LS, all dominant broadleaf trees exhibited an inverse J-shape pattern in size distribution (Fig. 6). At MR, five of the dominant species, *N. acuminatissima*, *R. formosanum*, *D. pellucidopunctata*, *Rhododendron kawakamii* var. *flaviflorum*, and *Neolitsea variabillima*, had many more plants with basal diameters between 4 and 7 cm than any other size, while other plants had inverse J-shape patterns in their size distribution, similar to that observed at LS (Fig. 7). At SMKS, the size distribution patterns were somewhat different from those observed at other sites. Both the L-shape and inverse J-shape distribution patterns were observed for all of the dominant plant species except *Cyclobalanopsis glauca*, which displayed an irregularly distributed pattern (Fig. 8).

DISCUSSION

The forests in YYL and SMKS are both free from anthropogenic disturbance. The differences in floristic composition, tree density, canopy structure, and undergrowth among the three sites must be contributed by variations in natural environmental factors. According to Su (1984), there are two major factors that influence vegetation type in Taiwan: elevation

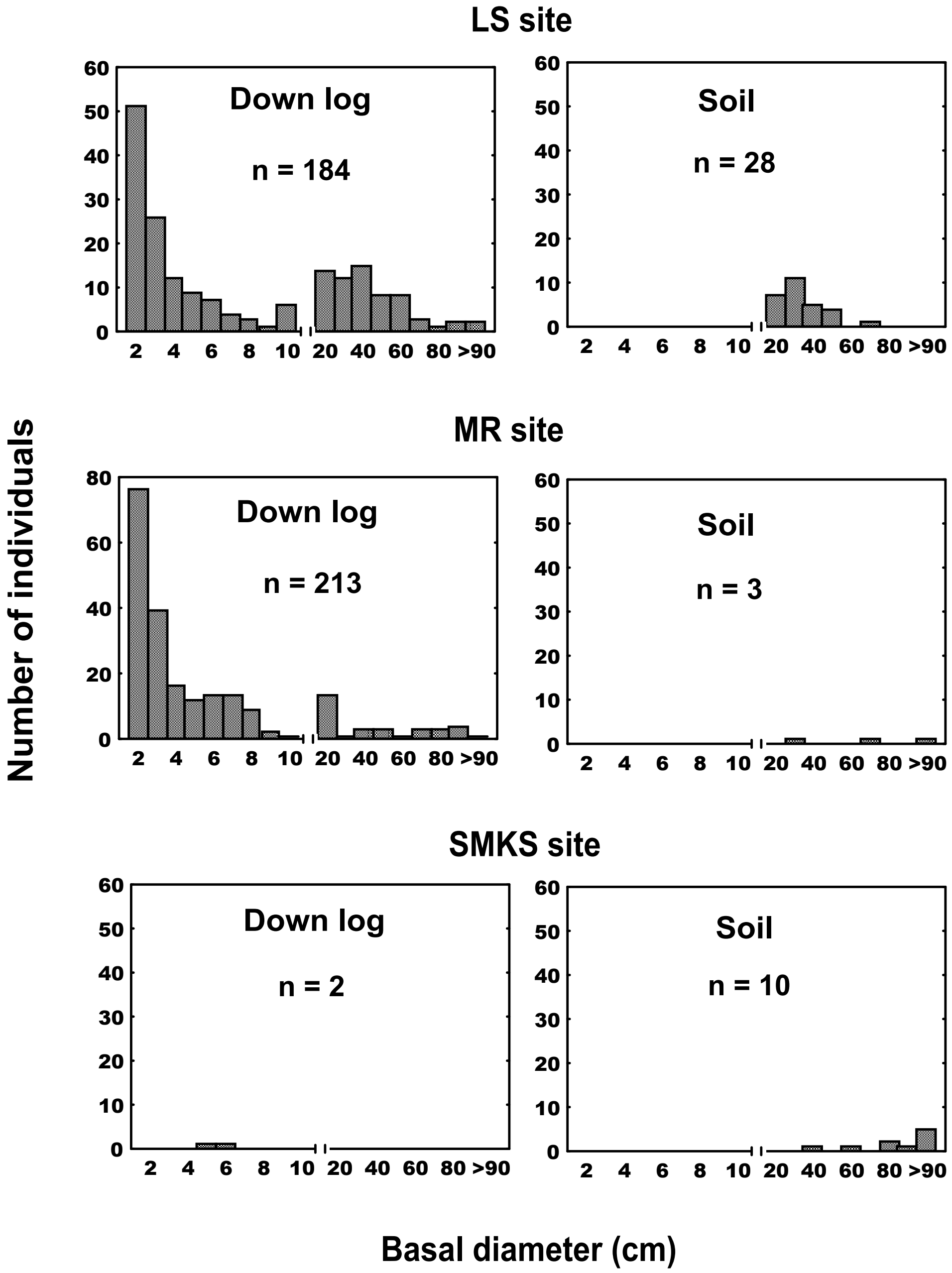

Fig. 4: Comparisons of size class (basal diameter) compositions of yellow cypress plants grown on down logs and with that on soil at three study sites.

and precipitation. Any general explanation of *Chamaecyparis* forest distribution must emphasize limitation by water (Zobel, 1998). Thus, precipitation is considered to play a more important role in affecting vegetations of the three sites. Though SMKS is very close to YYL, their precipitation regime is different (Fig. 1). In YYL, monsoon brings in a significant amount of precipitation every year, but that is not the case for SMKS area. SMKS located at the leeward side of the mountain slope, and in general is drier than YYL. This makes a steep precipitation gradient from YYL to SMKS even within a short distance (about 10 km), and thus the differences in vegetation composition and structures.

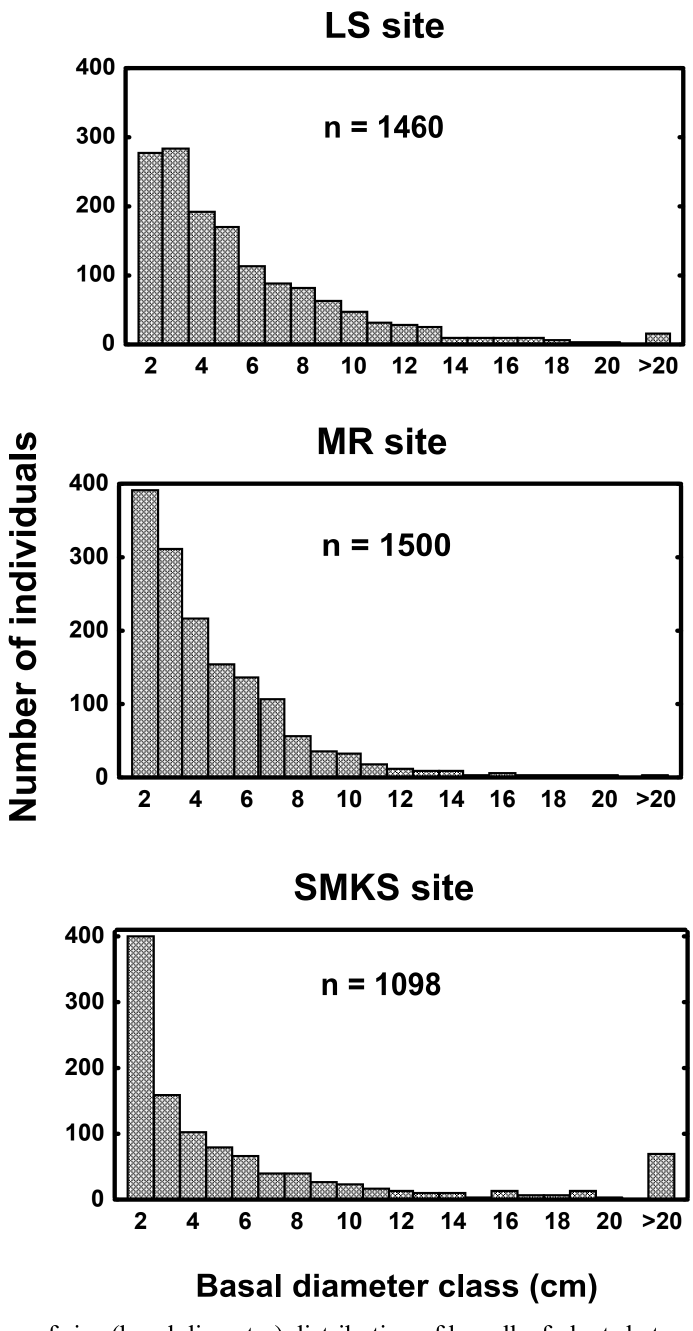

Fig. 5: Comparisons of size (basal diameter) distribution of broadleaf plants between three study sites.

The inversed J-shaped pattern of size distribution of a tree species is considered to be stable and continuously regenerating (Hett and Loucks, 1976; Veblen *et al.*, 1979; Read and Hill, 1988; Ohsawa, 1991). At both study sites in YYL, Taiwan yellow false cypress exhibited such a size distribution pattern, whereas at SMKS the size distribution was irregular. Although the detailed mechanism is remain investigated, size class distribution revealed a well regeneration of Taiwan yellow false cypress on down logs in YYL.

The regeneration of a forest is affected by a number of factors. Light factor is investigated in some researches. Light intensity over 40% of full sunlight was favorable for the growth of

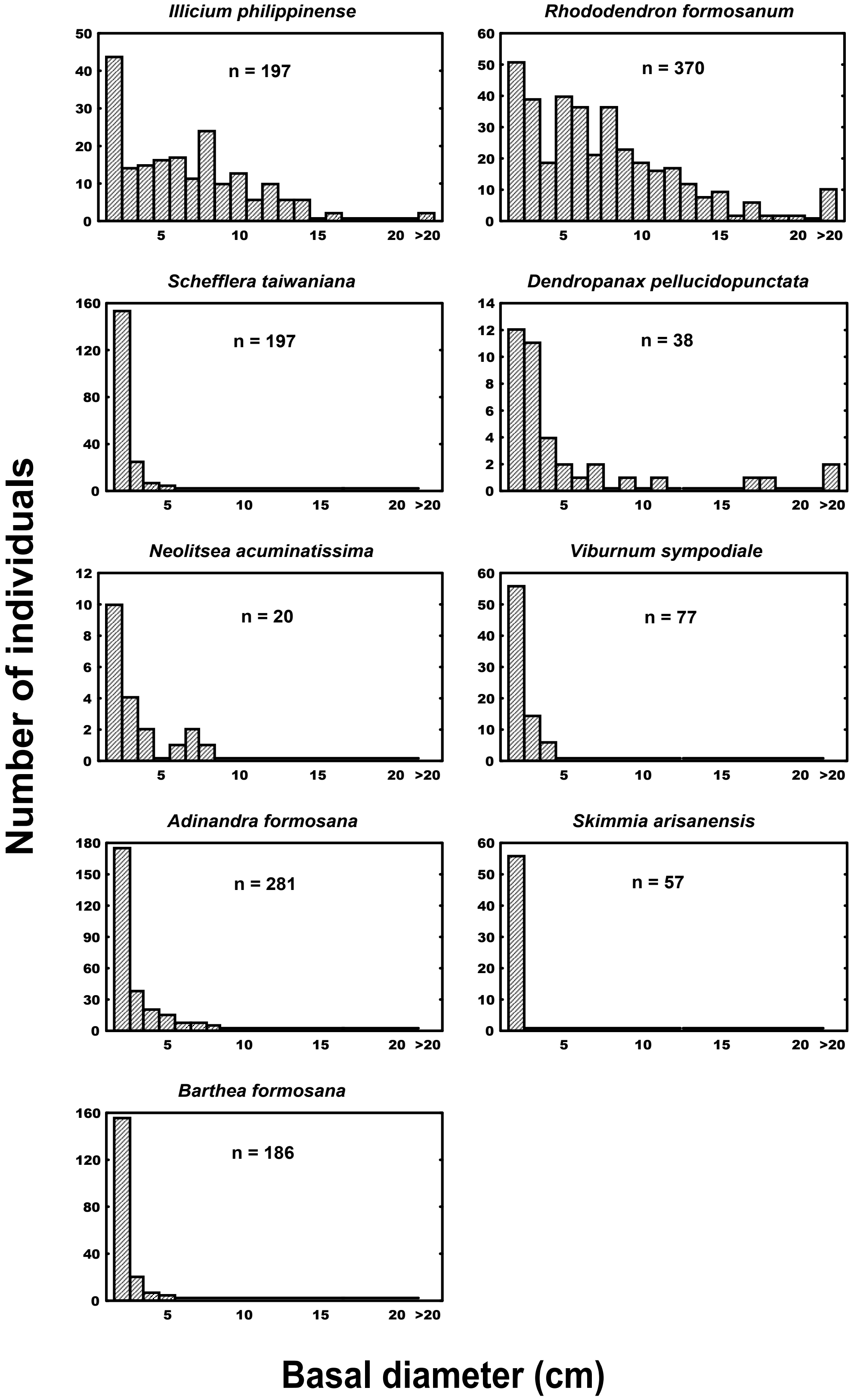

Fig. 6: Size (basal diameter) distributions of 9 dominant broadleaf plant species at LS site in YYL.

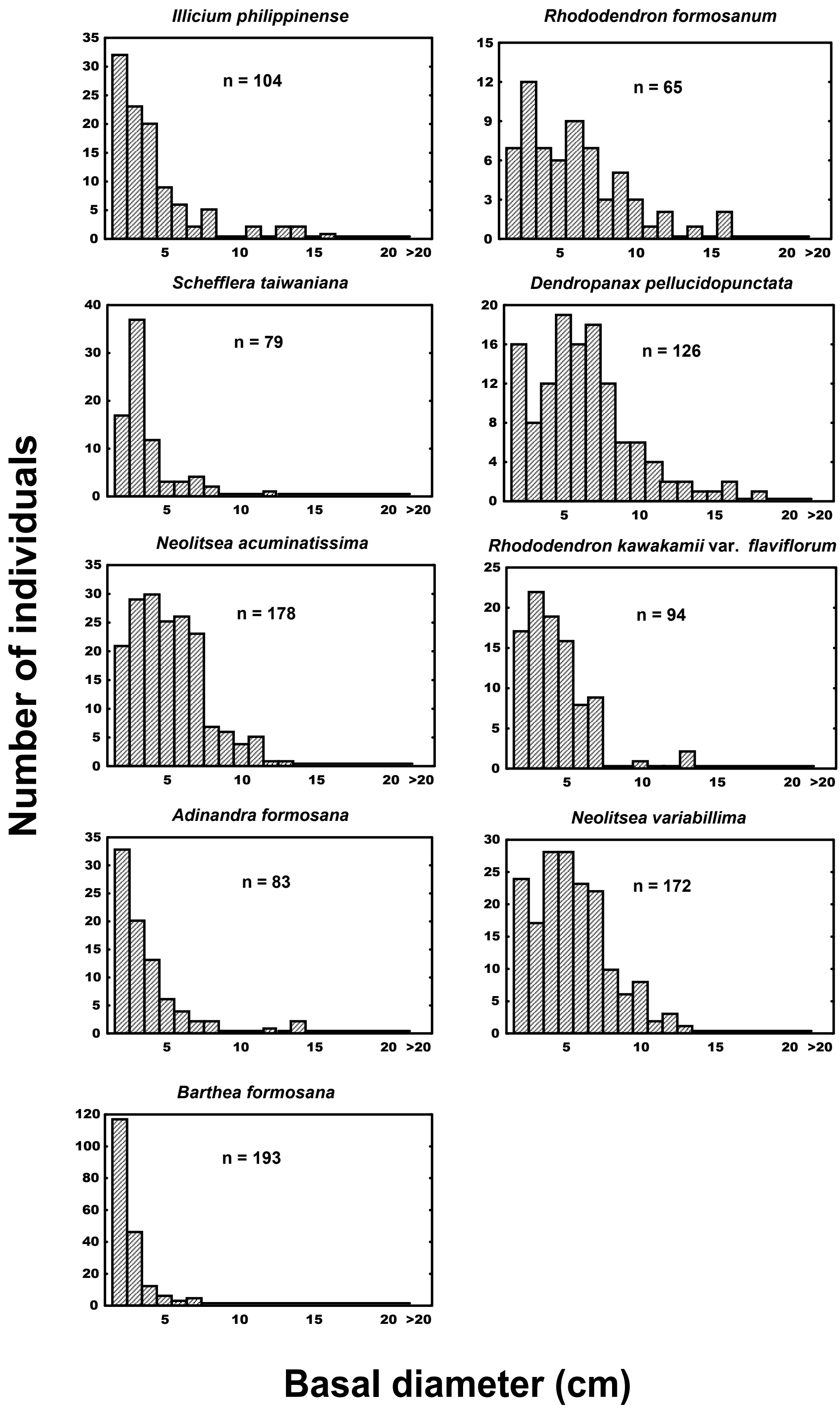

Fig. 7: Size (basal diameter) distributions of 9 dominant broadleaf plant species at MR site in YYL.

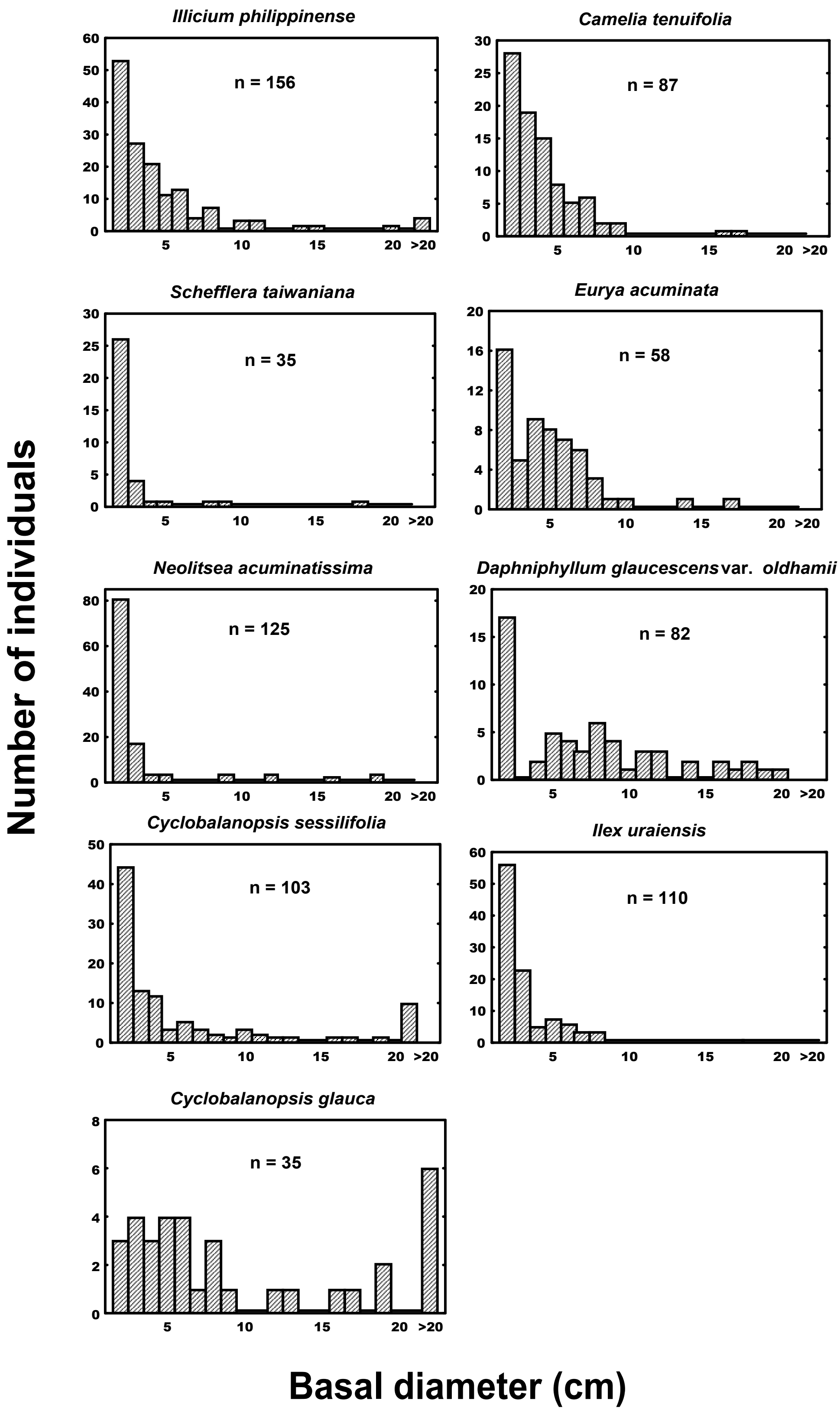

Fig. 8: Size (basal diameter) distributions of 9 dominant broadleaf plant species at SMKS site.

Taiwan yellow false cypress seedlings (Lin *et al.*, 1958; Fang *et al.*, 1991). Thinning and pruning could also promote growth of the species (Hung, 1984; Chiu *et al.*, 1993; Lo-Cho *et al.*, 1999). Consequently, Taiwan yellow false cypress is inferred to be a shade-intolerant species. At the SMKS site, Taiwan yellow false cypress seedlings might be stressed by a low light regime, because the canopy structure is closed. Thus, three hypotheses are proposed in regard to the regeneration of Taiwan yellow false cypress. First, species without suppressed saplings and gap successors cannot regenerate in gaps under current gap-disturbance regime; thus large scales disturbances may be needed for their regeneration (Yamamoto, 1992). In this case, extensive open areas caused by massive disturbance might be necessary for Taiwan yellow false cypress regeneration under multiple canopy coverage (Liu, 1975). Second, most conifers have a very long life span, so that one generation can dominate at a site for a long period of time without regeneration (Liu, 1975). In this case, few seedlings are necessary to maintain the populations within a community (Read and Hill, 1988). Because two saplings were found, Taiwan yellow false cypress is considered to use this kind of regeneration strategy in SMKS. Third, the discontinuous population structure of Taiwan yellow false cypress was sustained on the upslope of the SMKS site by tiny seeds that can disperse from the upslope forests and become established on the rare suitable regeneration sites in SMKS.

Small seedlings on down logs might avoid competition and suppression from undergrowth, such as bamboo, in temperate beech and mixed hardwood-conifer forests in Japan (Nakashizuka, 1989; Abe *et al.*, 2001). A similar situation seems to occur in the YYL forest. Dense bamboo on the ground of MR site was supposed to suppress seedlings of woody species. However, there are numerous Taiwan yellow false cypress seedlings on down logs, giving rise to an avoidance of suppression from bamboo. Apparently, down logs provide substrate that ensures the regeneration of young Taiwan yellow false cypress.

Disturbance could promote establishment of *Chamaecyparis lawsoniana* in Oregon, USA (Hawk, 1977; Zobel, 1980; Zobel and Hawk, 1980) and *Chamaecyparis obtusa* in Japan (Yamamoto, 1988). It is also necessary for Taiwan yellow false cypress in Taiwan (Hung, 1984). One of the former management strategies for Taiwan yellow false cypress plantations was to remove down logs, to thin the broadleaf trees, and to disturb the herb layers in order to promote establishment of seedlings on the forest floor (Hung, 1984; Chiu *et al.*, 1995; Lo-Cho *et al.*, 1999). This management strategy has successfully established Taiwan yellow false cypress forests, and provides sustainable use of the species. However, forest managed in this manner requires frequent work with a high cost. In the present study, down logs occupied 1.33 % of the forest floor area at LS site (unpublished data) provided suitable space for regeneration of young Taiwan yellow false cypress, as well as reduced suppression from bamboo. Without anthropogenic disturbance, down log was not removed and might affect on the regeneration of Taiwan yellow false cypress. This finding might be helpful on improving management strategy. If some down logs were leaved in clear cutting area, seedlings might recruit on the down logs and avoid inter-species competition. This suggestion is expected to reduce the frequency of disturbance work and the cost in plantation management.

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鴛鴦湖保留區及司馬庫斯森林內台灣扁柏的族群結構與生長基質

廖啟政[1]、周昌弘[2]、吳俊宗[1,3,4]

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摘　　要

台灣扁柏是台灣重要的木材資源，為了永續利用此資源，有必要瞭解其在天然情況下的更新情形。然而，此方面的研究至今尚十分欠缺，本論文嘗試在塔克金溪流域的鴛鴦湖自然保留區及鄰近司馬庫斯的森林中，研究台灣扁柏所生長的林相組成、族群結構、生長基質及更新特性。在保留區內選定鄰近湖泊 (LS) 及接近稜線 (MR) 處各一個樣區；並在湖泊西邊兩公里的鞍部，接近司馬庫斯村落的附近也選定一樣區(SMKS 樣區)，作為比較。樣區中每一株木本植物其離地面 30 公分處的直徑 (地徑) 大於 1 公分者，皆列入種類及地徑之紀錄。此外，並對台灣扁柏在不同基質上的族群結構加以分析，以瞭解其更新的特性。研究結果發現，植物組成及樹冠結構在三個樣區中皆有差異。而台灣扁柏的族群結構在 LS 樣區及 MR 樣區的枯倒木生長基質上呈現反 J 型，代表在鴛鴦湖保留區的森林中，台灣扁柏有持續更新的現象。不過在 SMKS 樣區則顯示非連續的族群結構，並且與生長基質沒有明顯的相關性。據此推論在 SMKS 附近的森林中，台灣扁柏在大面積干擾後的更新機會比在小面積干擾後的機會大，顯示在鴛鴦湖保留區內枯倒木對於台灣扁柏的更新有其重要性。因此，散置的枯倒木可提供年幼的台灣扁柏小苗一個生長的基質，因而增強其與其他植物的競爭能力。此同時可以減少除草和疏伐等干擾的頻率，而節省林業經營所需的花費。

關鍵詞：台灣扁柏、枯倒木、生長基質、族群結構、更新。

1. 國立台灣大學植物學系，台北市 106，台灣。
2. 國立屏東科技大學熱帶農業學系，屏東 912，台灣。
3. 中央研究院植物研究所，台北市 115，台灣。
4. 通信聯絡員。