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The Forest Regeneration after Gregarious Flowering of Bamboo (*Cephalostachyum pergracile*) at Mae Klong Watershed Research Station, Kanchanaburi

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ABSTRACT

The forest regeneration after gregarious flowering bamboo (*Cephalostachyum pergracile*) in the Mixed deciduous forest was carried out at Mae Klong Watershed Research Station, Kanchanaburi Province in 2002. A permanent plot of 50 m × 50 m was established and the 24 litter traps with mouth size of 0.5 m^2, each adjacent to a seedling quadrat (1.5 m × 1.5 m) were set in a regular matrix with 10 m distance between each one. Seedling census was done every two weeks. At each census all new tree and bamboo seedlings were tagged, identified and seedling mortality were also recorded.

The results showed that the forest structure was dominated by undergrowth bamboo in the middle layer. *Cephalostachyum pergracile* had gregarious flowered in November 2001 which had the clump and culm density as 0.06 m^{-2} and 11.10 $clump^{-1}$, while, the average seed production was 2,442 ± 1,243 seed/m^2. Forest fire occurred after bamboo died and burnt all above ground parts of them in which they provided large vacant spaces to forest regeneration. Both forest tree regeneration and bamboo dynamics showed high corresponded to soil moisture content. The annual survival rate of bamboo seedlings was quite high, 58 %, with the annual average of growth height rate about 22.8±1.45 cm. The seedling emergence of dominance species was very high rate, especially in the first year after bamboo died and followed by forest fire. Thus, both the bamboo undergrowth and frequent forest fires could be the dominant factors that prevent the continuous of forest regeneration.

Key words: gregarious flowering, recovery bamboo, forest fire, forest regeneration, mixed deciduous forest

INTRODUCTION

The suppression on tree regeneration by undergrowth bamboos has been reported from several types of forests (Taylor and Zisheng, 1992). Bamboos grow rapidly, intercept the light efficiently and cast a deep shade on the forest floor up to several decades (Janzen, 1976). Thus, once they are established, they prevent tree regeneration but their simultaneous death after gregarious flowering can provide a large vacant space for tree regeneration episodically (Nakashizuka, 1991). Mixed deciduous forest (MDF) is a type of tropical seasonal forests found in Thailand (Blasco *et al.*,

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1996), covers large areas with high variation in species composition as *Tectona grandis*, *Pterocarpus macrocarpus*, *Xylia xylocarpa* var. *kerrii*, *Afzelia xylocarpa*, and *Vitex peduncularis*. (Bunyavejchewin, 1983). However, the middle layer of MDF is usually dominated by bamboos in which *Gigantochloa albociliata*, *Bambusa tulda*, and *B. nutans* are the most common among them (Marod *et al*., 1999). Forest fire usually burns during the dry season and may be one of the environmental factors to control this forest structure. The flowering of bamboo provided an opportunity to study the effects of bamboo die-back on the forest regeneration. Thus, the objectives of this study focused on 1) the forest structure of mixed deciduous forest, MDF, with bamboo dominance and 2) the effects of forest fire and undergrowth bamboo on the regeneration dynamic process.

MATERIALS AND METHOD

The studies were conducted during January 2002 – May 2004 in a natural MDF at Mae Klong Watershed Research Station, Thong Pha Phoom district, Kanchanaburi province, western Thailand, which had the specific methods as follows;

1. A permanent plot (50 m × 50 m) was established in the MDF where the bamboos had flowered and died. All trees with diameter at breast height (DBH) over 4.5 cm were tagged, identified and measured.

2. The 24 sets of seed trap each adjacent to seedling quadrat (1.5 m × 1.5 m) were set up in a regular matrix with 10 m distance between each one. The monitoring was done every two weeks. All bamboo seeds were classified and counted to their condition as sound seed and incomplete seed (empty or insect attacked seed). Tree and bamboo seedlings were tagged and the causes of seedling death were recorded every census in seedling quadrat.

3. To estimate light conditions within each seedling quadrat, under gap and closed canopy, the hemispherical photos were taken at a height of 50 cm above ground with a fish-eye camera (Nikon, F8mm) twice, at the end of the rainy season (early November) and at the end of the dry season (April). The relative light intensity was analyzed by the FEW52b program for Windows'95. The relative light intensity in each quadrat was estimated as the percentages of standard overcast sky distribution (SOC, %). Soil samples were collected every month from the depth of 0 - 15 cm to investigate soil moisture content.

RESULTS AND DISCUSSION

Climatic regime

The rainfall and soil moisture fluctuated in a correlated manner every year, producing distinct wet and dry seasons (Figure 1). Annual rainfall in the study area normally exceeds 1,650 mm and is concentrated from late April to October. The rainfall season was distinct through the study period. In general, the rainy period started in late April and extended until late October. Rainfall was very low during the dry season (from November to March), although only a small amount of rainfall occurred occasionally. Soil water tension corresponded well to the amount of rainfall (Figure 1), and the soil was almost saturated from May to September.

The light conditions on the ground were rather uniform among seedling quadrats in the same season, but it was different between seasons. Mean standard overcast sky distribution (SOC, %) over all the seedling quadrats in the rainy season and the dry season were 4.5 and 29.5 %, respectively. Light was poor during the rainy season and much better during the dry season under closed canopy. The light conditions under gap and closed canopy showed significantly different during both rainy and dry seasons ($df = 5$, $t = 8.24$, $p < 0.001$ and $t = 7.42$, $p < 0.001$, respectively).

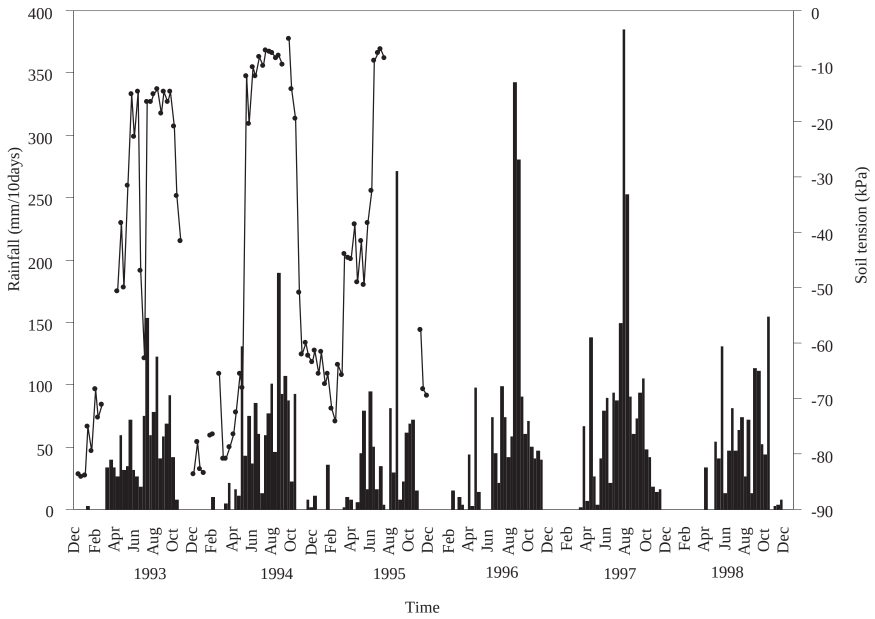

Figure 1 Seasonal changes of rainfall (black bars) related with soil water tension (lines) in the studied site from January 1993 to November 1998. Soil water tension was measured at depth of 15 and 30 cm and the data were combined. The discontinuous part of the lines shows missing observations (modified from Marod *et al*. 2002).

Forest fire occurred after bamboo flowering and burnt all bamboo dead culms. The forest fire not only provided large vacant space to the forest regeneration but also killed tree saplings surrounding the areas which were less resistant to fire.

Forest structure and species composition

Tree density and basal area of MDF were 170.75 individual/ha and 17.25 m^2/ha, respectively. Low stem density and basal area with relatively discontinuous canopy layer and large canopy gap proportion characterized the forest. A relatively low tree density and basal area is a common structural feature among seasonally dry forests (Gerhardt and Hytteborn, 1992), however, these values of this forest are particularly low. Forest structure could be classified into 3 layers: crown layer (over 25 meters height), middle layer (15-20 meters height), and the undergrowth layer (less than 1 meter height). The dominant species in the crown layer were *Xylia xylocarpa* var. *kerrii, Vitex peduncularis*, *Schleichera oleosa* and *Pterocarpus macrocarpus*. However, in some areas other species which occurred less in the MDF as *Dipterocarpus alatus* and *Shorea siamensis* could be found. In middle layer, it was covered by bamboos in which four bamboo species, *Gigantochloa albociliata*, *G. hasskarliana*, *Cephalostachyum pergracile*, *and Bambusa tulda*, were found. Most of the forest understorey was dominated by one or two of these species. Bamboo culm density in the MDF was very high about 8,500 culm/ha of all species, while, the clump and culm density of *Cephalostachyum pergracile* before flowering were 0.06 and 11.10 individual/ m^2, respectively, and the average of culm size was 5.08±1.14 cm. In the undergrowth layer, it was almost dominated by herbs and shrubs, despite of tree seedlings, and very high abundance during the rainy season.

Forest regeneration dynamics

The patterns of emergence and mortality for tree seedlings displayed large variation (Figure 2). Most tree seedlings had high emergence, especially, in the first year after bamboo flowering and died. The emergence pattern showed high correlation with the amount of rainfall, however, the number of seedling emergence in the second year was lower than the first year due to the high density of recovery bamboo. Seedling emergence and mortality pattern could be classified into 2 types as 1) rapidly emerged in the early rainy season and began to decrease in the dry season; this pattern was mainly characterized by dominant tree species as *Vitex canescense*, *Lagerstroemia tomentosa*, *Xylia xylocarpa* var. *kerrii*, *Shorea siamensis* and *Pterocarpus macrocarpus*. However, *Pterocarpus macrocarpus* showed the different mortality pattern in which they died soon after emerged although in the rainy season due to damping-off disease from fungi attack. 2) Seedlings emerged in the mid of the rainy season and started to decrease in the dry season such as *Artocarpus rigidus*. Forest fire also could be activated the germination rate of wild banana and some species with seed bank characteristics, especially after bamboo died and then some forest fires occurred.

Bamboo seedlings rapidly emerged in the early rainy season after shedding their seeds and seedling density could reach to 1,250 culm/m^2, especially in the open canopy where bamboo death and burnt by forest fire. The annual survival rate of bamboo seedling displayed the high rate about 58% at which they had the average annual height growth rate of 22.8±14.5 cm. The growth height rate of bamboo seedling in the rainy season was 0.99 cm/month. After one year old seedling, they rapidly developed the new lateral rhizome for resprouting in the next year when the above ground part of the previous-year seedlings died (Figure 3).

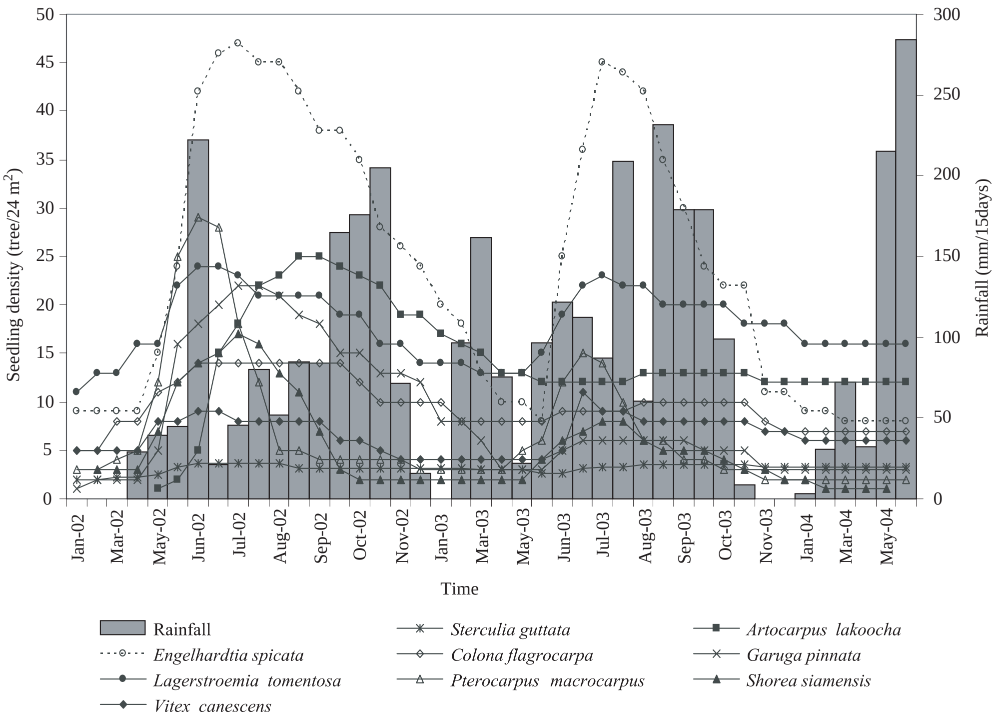

Figure 2 Some dominant tree seedlings showed high emergence relating to the amount of rainfall, especially, after bamboo flowered and died.

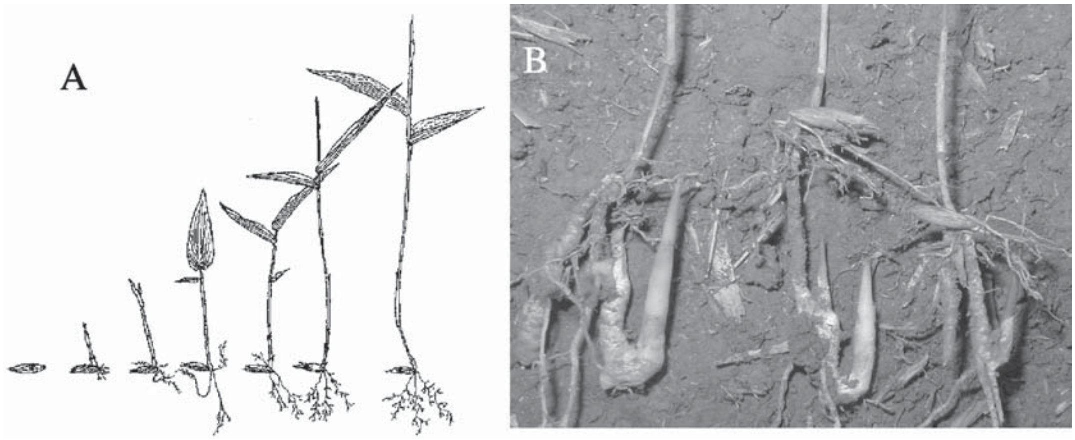

Figure 3 Bamboo seedling (*Cephalostachyum pergracile*) establishment from seed (A), and rhizome development in one-year-old seedlings (B).

Phenology of dominance tree species

The leaf fall pattern of dominant tree species in this forest occurred in the early dry season (December) and remained with no leaves about 3-4 months before flushing into the rainy season. In contrast, the dominance tree species produced seeds during the time they shed their leaves and the main pattern of seed fall usually starts in the late dry season (March-April) despite of different time period among species. Some species, especially tree species in Dipterocarpaceae family had different pattern of seed production in which they had seed-year (once per 3-4 years) and off-year pattern *as Dipterocarpus alatus* and *Shorea siamensis* (Marod *et al*., 2002).

The period of bamboo flowering varied among species, however the pattern of flowering could be classified into three types as 1) only some culms in the clump flowered, 2) only some clumps flowered in the whole clump, and 3) the whole clumps and culms flowered in the whole area. In case of *Cephalostachyum pergracile*, all culms and clumps flowered in the study area. The average seed production was very high about 2,442±1,243 seed/m^2 after flowering. However, only 12.8 % of total seed production could be germinated and classified as sound seeds while the others were uncompleted as empty seeds or insect attack about 64.5 and 22.7 %, respectively.

Within mixed deciduous forests extremely low tree density and basal area are formed under the influence of severe seasonal water stress, two other factors may also be important, i.e. the dominance of undergrowth bamboos and the frequent occurrence of fire. Bamboos were the dominated species in the middle layer and the deep shade of them may prevent the regeneration of tree seedlings (Veblen *et al*., 1980; Nakashizuka, 1988; Taylor and Zisheng, 1992). The forest dynamics after the local die-back of bamboos clearly showed the importance of the bamboo life history on the dynamics and structure of the mixed deciduous forest and forest fire followed just after the bamboo die-back also indicated the complexities of forest regeneration (Phillips, 1974; Gill *et al*., 1990; Mueller-Dombois and Goldammer, 1990; Tyler, 1995).

CONCLUSION

The gregarious bamboo flowering followed by forest fire had very high influenced on forest regeneration. Tree seedling regeneration including bamboo themselves had increased in the first year due to the proper environments to their regeneration after bamboo death and burnt by forest fire, however, they were decreased in the number of seedlings in the second year due to their high competition among seedling tree species and bamboo themselves. The annual survival rate and height growth rate of bamboo seedling were 58% and 22.8±14.5 cm, respectively, and their one-year-old seedlings rapidly developed the new lateral rhizome for resprouting in the next year.

Short-term dynamics after the local die-back of bamboos although showed the importance role of bamboo life history, however, the interaction of bamboo and forest fire on forest regeneration should be clarified on Long-term Ecological Research.

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LITERATURE CITED

Blasco, F., M. F. Bellan and M. Aizpuru. 1996. A vegetation map of tropical continental Asia at scale 1:5 million. **J. Veg. Sci**. 7: 623-634.

Bunyavejchewin, S. 1983. Analysis of tropical dry deciduous forest of Thailand. I. Characteristics of dominance types. **Nat. Hist. Bull. of Siam Soc.** 31:109-122.

Gerhardt, K. and H. Hytteborn. 1992. Natural dynamics and regeneration methods in tropical dry forests–an introduction. **J. Veg. Sci.** 3: 361-364

Gill, A. M., Hoare, J. R. L. and Cheney, N. P. 1990. Fires and their effects in the wet-dry tropicals of Australia. pp. 159-178. *In* J.G. Goldammer (ed.). **Fire in the Tropical Biota. Ecosystem Processes and Global Challenges**, Springer-Verlag, New York.

Janzen, D. H. 1976. Why bamboos wait so long to flower. **Ann. Rev. Eco. Sys.** 7: 347-91.

Marod, D., K. Utis , Y. Chanchai, T. Hiroshi and T. Nakashizuka. 1999. Structural dynamics of the natural mixed deciduous forest in western Thailand. **J. Veg. Sci.** 10: 777-786.

Marod, D., K. Utis, T. Hiroshi and T. Nakashizuka. 2002. The effects of drought and fire on seed and seedling dynamics in a tropical seasonal forest in Thailand. **J. Plant Eco.** 161: 41-57.

Mueller-Dombois, D. and Goldammer, J.D. 1990. Fire in tropical ecosystems and global environmental change: An introduction. pp. 1-10. *In* J.G. Goldammer (ed.). **Fire in the Tropical Biota: Ecosystem Processes and Global Challenges**, Springer-Verlag, New York.

Nakashizuka, T. 1988. Regeneration of Beech (*Fagus crenata*) after the simultaneous death of undergrowing bamboos (*Sasa kurilensis*). **Ecol. Res**. 3: 21-35.

Nakashizuka, T. 1991. Population dynamics of coniferous and broad-leaved trees in a Japanese temperate mixed forest. **J. Veg. Sci.** 2: 413-418.

Phillips, J. F. V. 1974. Effects of fire in forest and savanna ecosystems of subsaharan Africa. *In* pp. 23-28. T. T. Kozlowski and C. E. Alghren (eds.). **Fire and ecosystems**. Academic Press, London.

Taylor, A. H. and Q. Zisheng. 1992. Tree regeneration after bamboos die-back in Chinese *Abies-Betula* forest. **J. Veg. Sci.,** 3: 253-260.

Tyler, C. M. 1995. Factors contributing to postfire seedling establisment in chaparral: direct and indirect effects of fire. **J. Ecol.** 83: 1009-20.

Veblen, T. T., Schlegel, F. M. and R. B. Escobar. 1980. Structure and dynamics of old-growth Nothofagus forests in the Valdivian Andes, Chile. **J. Ecol.**, 68: 1-31.