การรอดตายของกล้าไม้สองชนิดวงศ์อบเชยในป่าดิบเขาภาคเหนือของประเทศไทย

The Seedling Survivorship of Two Climax Lauraceae Species in Tropical Montane Forest, Thailand

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บทคัดย่อ: การศึกษาการรอดตายของกล้าไม้สองชนิดวงศ์อบเชย ดำเนินการในแปลงวิจัยถาวรขนาด 15 เฮกแตร์ บริเวณอุทยานแห่งชาติดอยอินทนนท์ระหว่างปี 2541-2543 โดยวางแปลงสี่เหลี่ยมขนาด 1x1-1.5 m^2 สำหรับ *Cryptocarya densiflora* และขนาด 2x2 m^2 สำหรับ *Cinnamomum soegengii* ชนิดไม้ทั้งสองชนิดมีความแตกต่างทั้งลักษณะการงอกและปัจจัยที่ทำให้เมล็ดและกล้าไม้ตายซึ่งแสดงให้เห็นถึงความความแตกต่างกันของถิ่นนิเวศที่ส่งผลต่อการสืบต่อพันธุ์ ในระยะที่เป็นเมล็ด การเข้าทำลายของแมลงคือสาเหตุหลักของการตายของเมล็ด *Cryptocarya densiflora* ร้อยละ 44-47 ของเมล็ดที่ร่วงหล่น ในทางตรงข้ามเชื้อราเป็นสาเหตุหลักทำลายเมล็ดให้เน่าเสียและตายในที่สุดของเมล็ด *Cinnamomum soegengii* ถึงร้อยละ 46 ของเมล็ดที่ร่วง การเข้าทำลายของแมลงยังคงเป็นสาเหตุหลักของการตายของกล้าไม้ *Cryptocarya densiflora* แต่ความแห้งแล้งเป็นสาเหตุหลักในการตายของกล้าไม้ *Cinnamomum soegengii*

ปัจจัยจากสิ่งมีชีวิต (การเข้าทำลายของแมลง) ยังคงทำลายกล้าไม้ ของ *Cryptocarya densiflora* อย่างต่อเนื่อง ตั้งแต่ระยะที่เป็นเมล็ดจนถึงระยะกล้าไม้ สำหรับ *Cinnamomum soegengii* ในระยะเมล็ดสาเหตุหลักของการตายเกิดจากเชื้อรา เนื่องจากเมล็ดมีโปรตีนและไขมันสูง ประกอบกับ ร่วงหล่นในฤดูฝนซึ่งพื้นป่ามีความชื้นสูงจึงช่วยกระตุ้นการเข้าทำลายของเชื้อรา ในระหว่างเดือน ตุลาคม 2541 ถึง มกราคม 2542 เป็นช่วงที่กล้าไม้ *Cinnamomum soegengii* เติบโต แต่เป็นช่วงที่เข้าสู่ฤดูแล้ง ปริมาณฝนน้อยจึงส่งผลต่อการขาดน้ำบนผืนป่าส่งผลให้กล้าไม้แห้งตายในที่สุด

คำสำคัญ: การรอดตายของกล้าไม้ วงศ์อบเชย ป่าดิบเขาเขตร้อน

Abstract: The study was carried out within the 15-ha permanent plot at Doi Inthanon Park during 1998-2000. We used the quadrat belt transect method (1x1-1.5 m^2 for *Cryptocarya densiflora* and 2x2 m^2 for *Cinnamomum soegengii*) to monitor seed and seedling survivorship. Seed and seedling of *Cinnamomum soegengii* (one mother tree) and *Cryptocarya densiflora* (three mother trees) were different not only

germination trait aspects but also mortality factors affecting seedling establishment aspects. This suggests that they have diverged in their regeneration niches and that these differences may affect the structure of the seedling community in the study forest. During seed phase herbivore was a major mortality factors for *Cryptocarya densiflora*. For *Cryptocarya densiflora*, 44-57% of the dispersed seed was damaged by herbivore on the forest floor on seed phase. In contrast, fungal pathogens were a major mortality factor for *Cinnamomum soegengii* accounted for 46% of seedling die on seed phase. On seedling phase, the major cause of mortality appeared to be herbivore and wilting (drought) for *Cryptocarya densiflora* and *Cinnamomum soegengii*, respectively.

After shoot emerged from seed (seedling phase), the important factors on seedling survivorship were different between *Cryptocarya densiflora* and *Cinnamomum soegengii*. Biotic factors (herbivore) simultaneously damaged seedling of *Cryptocarya densiflora* from seed phase till seedling phase. With respect to seedling survivorship of *Cinnamomum soegengii*, different mortality factors in different regeneration phase: seed phase, seedling phase, was conspicuously detected. On seed phase, fungal pathogens played an important role to damaged seed. It might be due to seedcoat of *Cinnamomum soegengii* rather thin and seed contain high protein and lipid content In parallel to this, seed of *Cinnamomum soegengii* dispersed on rainy season in which high moisture and humidity that can promote fungal pathogens activities, resulting in 46% of seedling die in seed phase. In addition to this, From October 1998 till January 1999, this period was a critical time of seedling phase of *Cinnamomum soegengii* since it was a lower rainfall regime during the key period of seedling establishment, resulting in water shortage affecting to water stress of new seedling.

Keywords: Seedling survivorship, Lauraceae, Tropical Montane forest

INTRODUCTION

The spatial distribution of dispersed seeds around their source is called a 'seed shadow' (Janzen 1978). Seed-dispersal studies can have substantial consequences for the conservation of forests. The dispersal of seeds is an important stage in the life-cycle of plants; yet we know very little about the scheduling of reproduction or magnitude of annual and individual variation in fruit production in most tropical tree species (Janzen 1978). Moreover, the ability of plants to reproduce successfully depends on the dispersal of their seeds into locations that offer greater chances of germination and survival. Grubb (1974) stated that attaining suitable sites for germination is considered to be a critical factor affecting seedling establishment and hence the regeneration and maintenance of plant species populations. Howe (1983) also reported that the distance and location of dispersal could have significant impact on the survival of the seed. On any given plant, the number of seed production may be limited by many factors such as the amount of nutrients and photosynthate available for allocation to fruit and seeds, the presence of herbivores, predators and disease, and by annual variations (Wheelwright 1986).

The seedling establishment and the survival of two climax species in a lower montane forest, *Cryptocarya densiflora* and *Cinnamomum soegengii* have been studied in 1998. Their regeneration processes and the mechanisms of their coexistence in lower montane forest are very important to investigate in order to gather more knowledge for the rehabilitation of montane forests in Thailand. Thus, the objective in this study was to clarify the germination traits and the factors affecting the survivorship of these two species.

MATERIALS AND METHODS

1. Study site

The study site is a tropical lower montane forest in Doi Inthanon National Park (18°24′N to 18°40′N latitude, and 98°24′E to 98°42′E longitude) located 70 km southwest of Chiang Mai city, Northern Thailand. The park is characterized by the hilly and mountainous terrain (ca. 400-2565 m a.s.l.). The main mountain ranges of which the elevation is above 2000 m at sea level lie near the center of the park. Three majors rock types; gneiss, granite and limestone are found (Pendelton 1962). Gneiss rock occupied nearly half of the area and is oriented north-south and westward of the park. The park occupied totaling 482.4 square kilometer of which approximately 41.50 % of the area is covered with montane forest (Faculty of Forestry 1992).

The average annual rainfall is 2279.3 mm (1982-1999) at a radar base of the Royal Thai Air Force on the summit (2565 m a.s.l.). Climate of the area is recognized as monsoonal type. In general, three distinct seasons- rainy season from June to October, cool and dry period from November to February and hot and dry season from March until May-are recognizable.

We used a half of 15-ha Forest Dynamics Plot established in a lower montane forest located about 7 km south of the summit of Doi Inthanon at

an altituded of ca. 1700 m to monitor the seedling survivorship of two climax species in this studied.

2. Species selected for the study

Cryptocarya densiflora Bl

Cryptocarya densiflora is a large evergreen tree species having the largest total basal area in the study plot. The maximum dbh and height in the plot are 55.5 cm and 31.2 m, respectively. This species showed a peculiar characteristic of vigorous forking ability of stems. The mean number of forks per individual is 3.30. Immature fruits of *Cryptocarya densiflora* are green, and they become blue-black when it matures. The sizes of a fruit and a seed are 20.722.147 mm x 19.631.918 mm (n=170) and 17.581.616 mm x 17.521.579 mm (n=250), respectively. The mean dry weight of a fruit is 2.47 g (n = 270). Data are not available for seed dry weight. Seeds of this species have no dormancy, and the germination type is hypogeal.

Cinnamomum soegengii Kostermans

This species is the canopy tree in the study forest. The number of individuals, maximum dbh and maximum height are 145/7.5ha, 95.8 cm and 37.5 m, respectively. The size of a fruit and a seed are 16.652.125 mm x 24.442.365 mm (n=212) and 14.470.588 mm x 22.100.984 mm (n=71), respectively. The mean dry weight of a fruit and seed are 2.54 g (n=212) and 1.76 g (n=71), respectively. Seeds germinated without prolonged dormancy and display immediate hypogeal germination after dispersal.

Fruits of these two species are one-seeded berries and seem to be dispersed by vertebrates judging from the scar on the fruit. They have no special characteristics for wind dispersal. We will refer the fruits as seeds in this paper.

3. Seedling establishment and survival

Seedling establishment and survival were studied during the mast fruiting years of the two species: (1) *Cryptocarya densiflora* (CRD) and (2) *Cinnamomum soegengii* (CIS). Three isolated fruiting trees of *Cryptocarya densiflora*, except for *Cinnamomum* (n = 1), were selected inside or near the 15-ha plot (Figure 1). Two belt transects were established from the base of each sample tree of *Cryptocarya* and *Cinnamomum*. The directions of the two transects of each sample tree were selected to make the two transects straight and minimize the slope inclination along the transects. We used 1-m-width transects for *Cryoptocarya* and 2-m-width for *Cinnamomum* because the density of fallen seeds were lower for *Cinnamomum*. Length of each transect was decided so that no seeds was found in the transect. The transects were divided into 1 m x 1 m quadrats (1 m x 1.5 m for one mother tree of *Cryptocarya* and 2 m x 2 m for *Cinnamomum*). Details of the belt transects are summarized in Table 1. All mature seeds falling in each quadrat were checked and labeled by numbered flags; observations were made at irregular intervals of one week to one month during the periods January-September 1999 for *Cryptocarya* and June 1998 - February 1999 for *Cinnamomum*, which included the seed dispersal periods of all sample trees.

4. Germination, establishment and survival of dispersed seeds

Germination, establishment and survival of dispersed seeds were studied. Germination, survival and (if possible) mortality factors were monitored for each dispersed seed in the belt transects used for the seed dispersal study at intervals of 1 week to 2 months from seed dispersal (June 1998 for *Cinnamomum* and January 1999 for *Cryptocarya*) until May 2000. We used two growth phases, seed phase and seedling phase. The former includes the seeds before germination and those that germinated and the roots were not yet penetrated into the soil. The seeds were classified to the seedling phase when their roots penetrated into the soil. We identified four mortality factors: 1) Herbivore: seeds/seedlings killed with apparent damages by animals including insects; disappeared seeds were classified into this since they were most likely to be eaten by vertebrates, 2) Fungi: seeds/seedlings killed by fungi, 3) Wilting: seedlings which died standing with wilting leaves, and 4) Unidentified: seeds/seedlings killed by unknown factors.

RESULTS AND DISCUSSION

1. Germination of fallen seeds

The fallen seeds of *Cinnamomum* germinated immediately after dispersal, while those of *Cryptocarya* took longer to germinate. Though the seed fall of *Cryptocarya* started in the dry season, the fallen seeds did not germinate until April, the beginning of rainy season (Figure 2). As a result, the periods from seed fall to germination were longer for *Cryptocarya* than for *Cinnamomum*. Of the total seeds germinated (n = 787 for *Cinnamomum*, n = 486 for *Cryptocarya*), 68.6% germinated within one month in *Cinnamomum*, while only 16.3 % germinated within one month in *Cryptocarya*; 35.7% of the *Cryptocarya* seeds needed more than two months to germinate having the longest period of 202 days. (Figure 3)

2. Survival of seeds and seedlings

Germination rates and initial survival rates of dispersed mature seeds were significantly different between *Cryptocarya* and *Cinnamomum* and between mother trees of *Cryptocarya* . Figure 4 shows the survivorship of each cohort of dispersed seeds, which consisted of seed whose dispersal was observed at the same census date, for three mother trees of *Cryptocarya* and *Cinnamomum*. For *Cinnamomum*, the mortality of the early cohorts was high before the beginning of germination period (August). More or less constant and relatively high mortality was observed for all cohorts during the germination period and continued until January 1999. After that mortality became low. The high-mortality period occurred from the middle of the rainy season until the beginning of dry season. For *Cryptocarya*, mortality was relatively constant during the study period through the germination period, the rainy and dry seasons for any cohorts except for one mother tree (CRD1). The early cohorts of CRD1 showed higher mortality before germination period (May 1999) and the late cohorts had lower mortality for all periods than other cohorts.

3. Factors of mortality

Mortality rates by various factors during the seed and seedling phases are shown in Table 2 and Figure 5.

The importance of mortality factors during the seed phase was significantly different between *Cryptocarya* and *Cinnamomum*, though the differences between mother trees of *Cryptocarya* were also significant. The most important mortality factor is herbivore for *Cryptocarya* and fungi for *Cinnamomum*; no mortality by herbivores was observed for *Cinnamomum*. During the seedling phase, the major mortality of *Cinnomomum* was wilting, which occurred at the beginning of the dry season (Fig. 5). Dead seedlings standing intact with wilted leaves were observed again one year later in the dry season of 2000. Thus, the wilting seedlings may have been suffered water stress. The major mortality factor of *Cryptocarya* was herbivore during the seedling phase. Mortality by herbivores was observed continuously for *Cryptocarya*, especially CRD2 and CRD3, during the study period regardless of the germination period, the rainy and the dry seasons.

4. Seed and seedling dynamics of two climax species

The seed and seedlings dynamics were notably different for the two climax species, *Cinnamomum* and *Cryptocarya*. This suggests that they have diverged in their regeneration niches (Grubb 1974) and that these differences may affect the structure of their populations in the study forest.

Cryptocarya showed longer periods from seed dispersal to germination than *Cinnamomum* did. This seemed to be related to the difference in the seed dispersal periods of the two species: gradual and long-time seed dispersal of *Cryptocarya* in the dry season and concentrated and short-time one of *Cinnamomum* in the rainy season. Because germination of *Cryptocarya* occurred only in the rain season, the seeds dispersed early in the dry season did not germinate for long periods.

There are various possible explanations why *Cryptocarya* seeds did not germinate until the rainy season. One possibility is the early-dispersed seeds were not mature completely and required some time for maturation. Ng (1991) reported that the seeds of *Cryptocarya ferrea*, which have similar stony seed coats as *Cryptocarya densiflora* do, needed 41 to 170 days for germination under nursery conditions. Another possibility is that the seeds require favorable environmental conditions to stimulate germination, i.e. humidity, temperature, soil moisture, etc. We need further germination experiments to confirm the reason of the delayed germination. In contrast, seeds of *Cinnamomum* germinated immediately after dispersal without prolonged dormancy. This may be partly because seed dispersal of *Cinnamomum* was relatively short and it occurred in the rainy season.

The major mortality factors were different between *Cryptocarya* and *Cinnamomum*. Herbivore was the most important mortality factor for both seeds and seedlings in *Cryptocarya*. Especially for the seed phase, 44 to 57% of the

dispersed seeds was killed by herbivores. The severe herbivore attack in *Cryptocarya* might relate to the phenology of seed dispersal, as is mentioned before. While, the major mortality causes of *Cinnamomum* were fungal pathogen and wilting (water stress) for the seed and seedling phase, respectively. The low predation rate of *Cinnamomum* seeds might be due to that they contain some chemicals for defense against herbivores. Most species of the genus *Cinnamomum* contain defense chemicals, which are used for spice, medicine and local perfumes (Lemmens 1995). The high mortality by fungi might be because the seed coat of the *Cinnamomum* is rather thin and because the fruits contain a high protein and lipid (Wheelwright et al 1984).

It is interesting that water stress affected largely the seedling survival of *Cinnamomum*. This is probably the first report that soil water stress is important for early establishment of trees in tropical montane forests. Since seeds of *Cinnamomum* germinated at late rainy season, seedlings were still small when the dry season began. Therefore, seedlings of *Cinnamomum* may have been suffered water stress more than those of *Cryptocarya*, which germinated earlier at the beginning of the rainy season. This result suggests the importance of phenology of seed dispersal and germination for seedling dynamics. Importance of soil water conditions has been also reported for many tree seedling species in tropical rain forests. For example, Turner (1990) found that *Shorea curtisii, Shorea multiflora* and *Shorea pauciflora* (Dipterocarpacea) lost approximately 6%, 27% and 39% of the initial seedling numbers during dry season which had only 0.4 mm of rain in two months. Itoh (1995) found that water conditions of the forest floor largely affected the establishment rates of two *Dryobalanops* (Dipterocarpaceae) species in a Bornean tropical rain forest.

The significant difference in mortality between the *Cryptocarya* seeds derived from different mother trees suggests the significant effects of environments for seed and seedling dynamics. The seeds of a mother tree, which was located in a gap on the upper slope experienced higher seedling survival and a lower degree of herbivore damage than the other mother trees, which were located in the understory on the lower slope. However, it is not clear which of slope position or light conditions affected more to the survival. Since herbivore was the major mortality factor, environmental effects may be through the difference in density and/or activity of herbivores between the sites. In order to know the mechanisms of environmental effects, we need to specify the herbivores and to study their ecology.

Although we studied only one mother tree of *Cinnamomum*, environmental factors may also affect the seed dynamics because the major mortality factor was fungal pathogens. Vaartaja (1952) reported that the resistance of seedlings to fungal diseases appears to be low in the weak light condition. Augspurger (1984) also found that light conditions affected disease activity, and that 15 of 16 species with disease-caused mortality showed higher survival in gaps in a neotropical forest.

Table 1 Conditions of the quadrats establishment for a study of the seedling dynamics (four mother trees: CRD1, CRD2, CRD3, CIS) of the Lauraceae species in lower montane forests in Doi Inthanon National Park. The two species of the four mother trees are *Cryptocarya densiflora* (CRD) and *Cinnamomum soegengii* (CIS).

Species	Canopy cover	Size (mxm)	No. of quadrat	Quadrat type	Topography	Month of establishment
CRD1	Gap	1 x 1.5	8	Belt transect	Ridge	Jun-98
CRD2	Understory	1 x 1	19	Belt transect	Upper slope	Jan-99
CRD3	Understory	1 x 1	20	Belt transect	Lower slope	Jan-99
CIS	Understory	2 x 2	8	Belt transect	Lower slope	Jun-98

Table 2 Number of seeds/seedlings killed by various factors during the seed and seedling phases of three *Cryptocarya densiflora* (CRD) mother trees and one *Cinnamomum soegengii* (CIS) mother tree for 17 months from seed dispersal. The observation periods were between January 1999 and May 2000 for *Cryptocarya densiflora* and between May 1998 and October 1999 for *Cinnamomum soegengii*. See text for the descriptions of the seed and seedling phases. N stands for the sample size.

Mother tree	*N*	Seed phase				Seedling phase				
		Herbivore	Fungi	Unidentified	Total	Herbivore	Fungi	Wilting	Unidentified	Total
CRD1	277	121^{a}	79^{ab}	1	201	14^{a}	2^{a}	18^{a}	0	34
CRD2	851	473^{b}	198^{a}	107	778	22^{ab}	5^{ab}	17^{a}	15	59
CRD3	704	399^{b}	234^{b}	36	669	16^{b}	3^{ab}	4^{a}	3	26
CIS	1630	0^{c}	756^{c}	314	1070	41^{c}	90^{b}	366^{b}	3	500
χ^2		896.3	566.3	--	--	190.3	12.5	50.8	--	--

Same letter indicate insignificant difference between mother trees by χ^2 - test at P=0.05

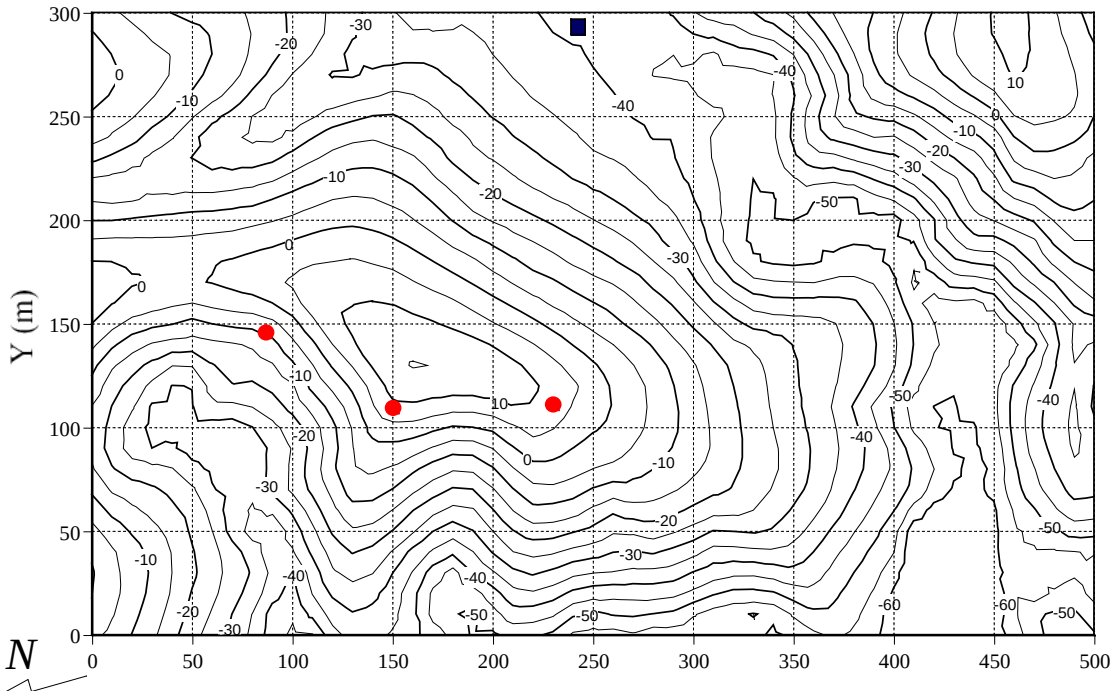

Figure 1 The location of three mother trees of *Cryptocarya densiflora* (○) and one mother tree of *Cinnamomum soegengii* (■) within the study plot. Contours are 5 m interval and figures are in relative elevation. Numbers inside the map indicate relative elevation (meters) from the point, (X, Y) = (0 m, 150 m)

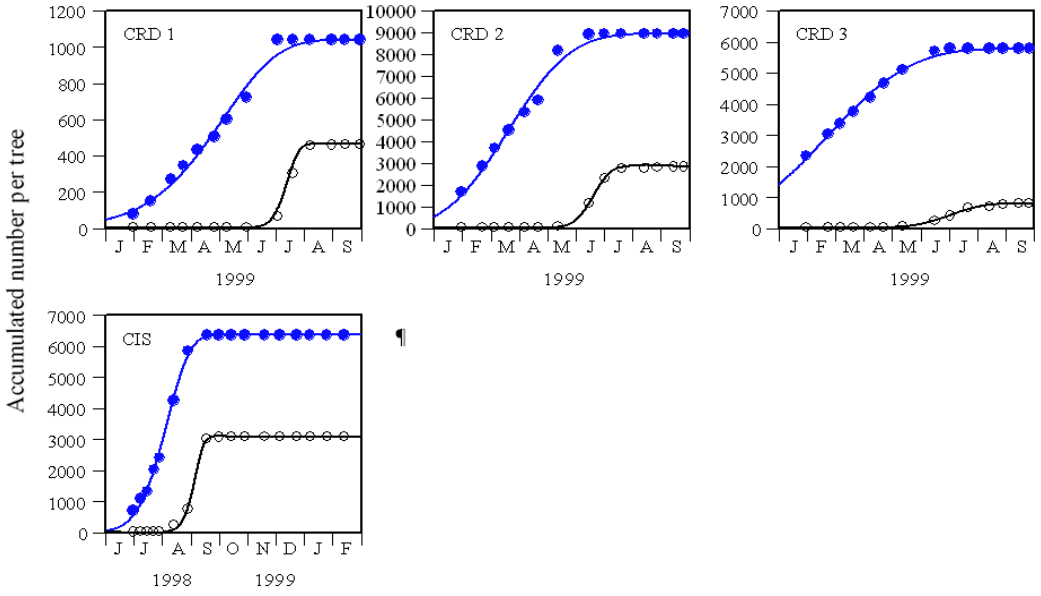

Figure 2 A cumulative representations of yearly seedfall and germinated seed for each mother tree. Solid circles indicate accumulated seed fall. Open circles indicate the accumulated of germinated seeds. The three mother trees were observed in 1999 were *Cryptocarya densiflora* (CRD) and *Cinnamomum soegengii* one mother tree was observed during 1998 to 1999.

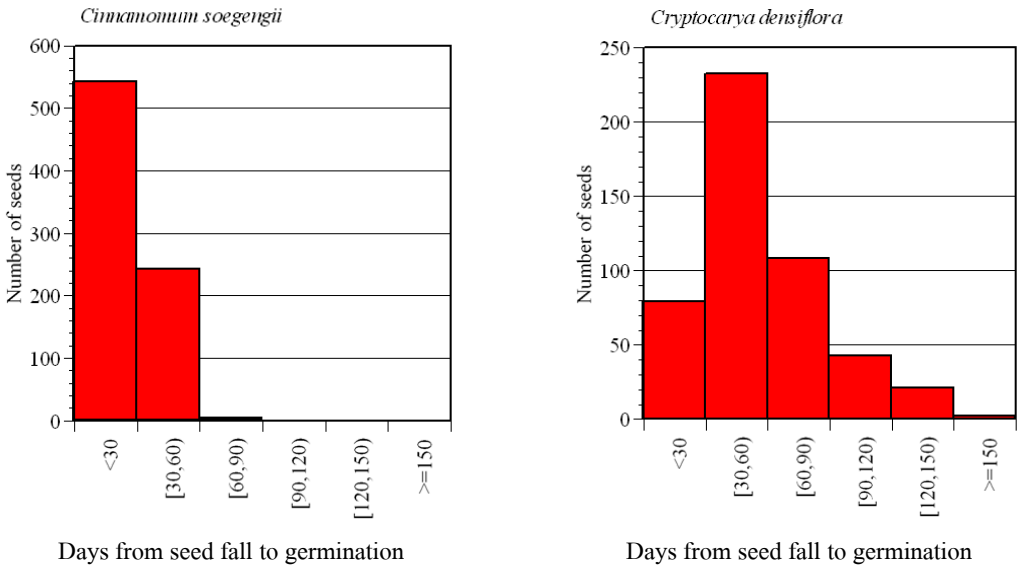

Figure 3 The duration until germination after seedfall for *Cinnamomum soegengii* and *Cryptocarya densiflora* in the forest floor conditions. Matured *Cinnamomum soegengii* and *Cryptocarya densiflora* seed were firstly dispersed in June 1998 and January 1999, respectively.

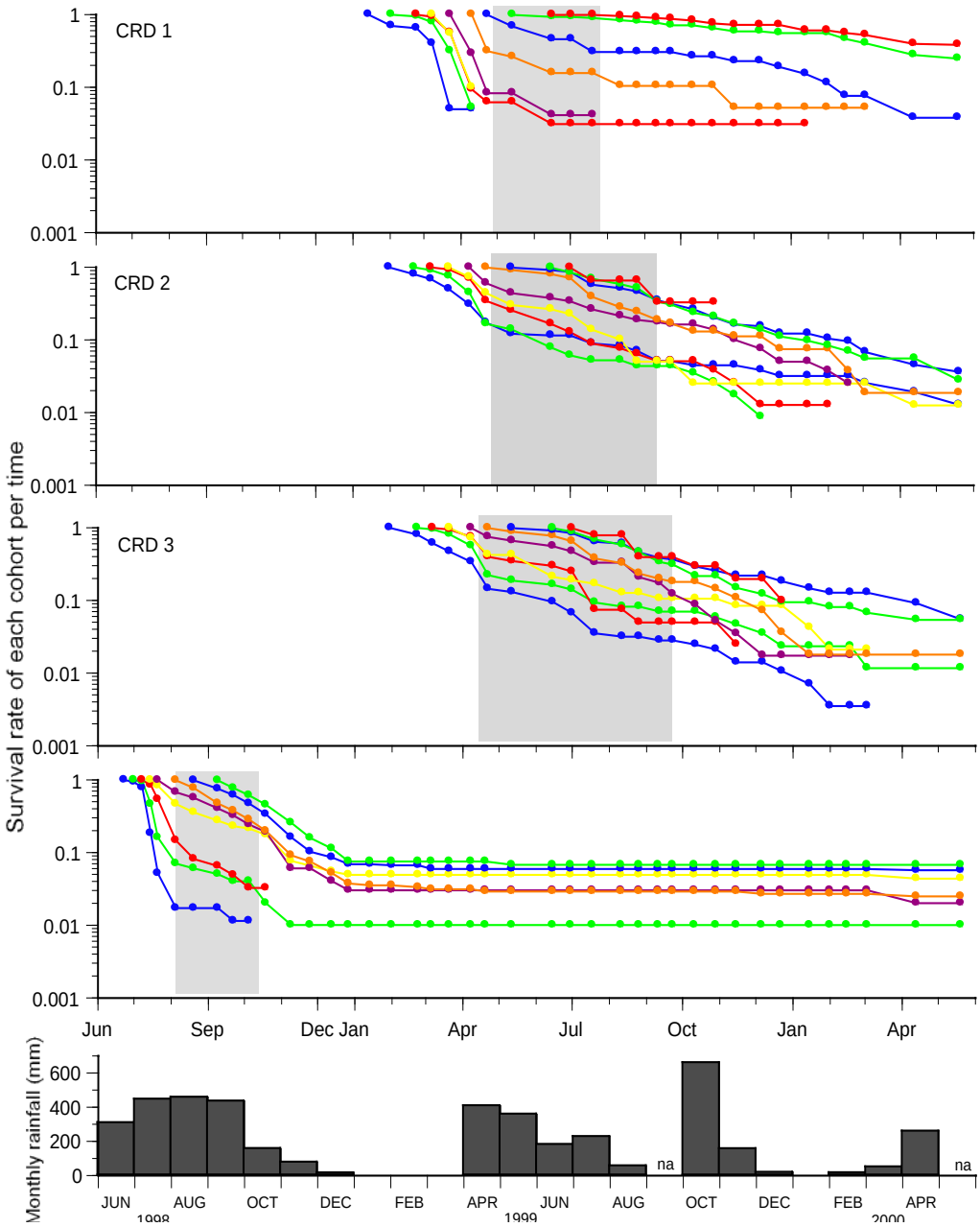

Figure 4 Survival rate of each cohort per each census for three mother trees of *Cryptocarya densiflora* (CRD) and one mother tree of *Cinnamomum soegengii* (CIS) after seedfall. The observation months were 17 months between January 1999 and May 2000 and 24 months between June 1998 and May 2000 for *Cryptocarya densiflora* and *Cinnamomum soegengii*, respectively. Solid circle exhibited survival rate of each cohort per each census time. Shade area indicated the period of seed germination of each mother tree. Monthly variation of rainfall obtained from radar station of the Royal Thai Air Force summit in 2,565 m altitude were shown during the study periods between June 1998 and May 2000. na means data not available.

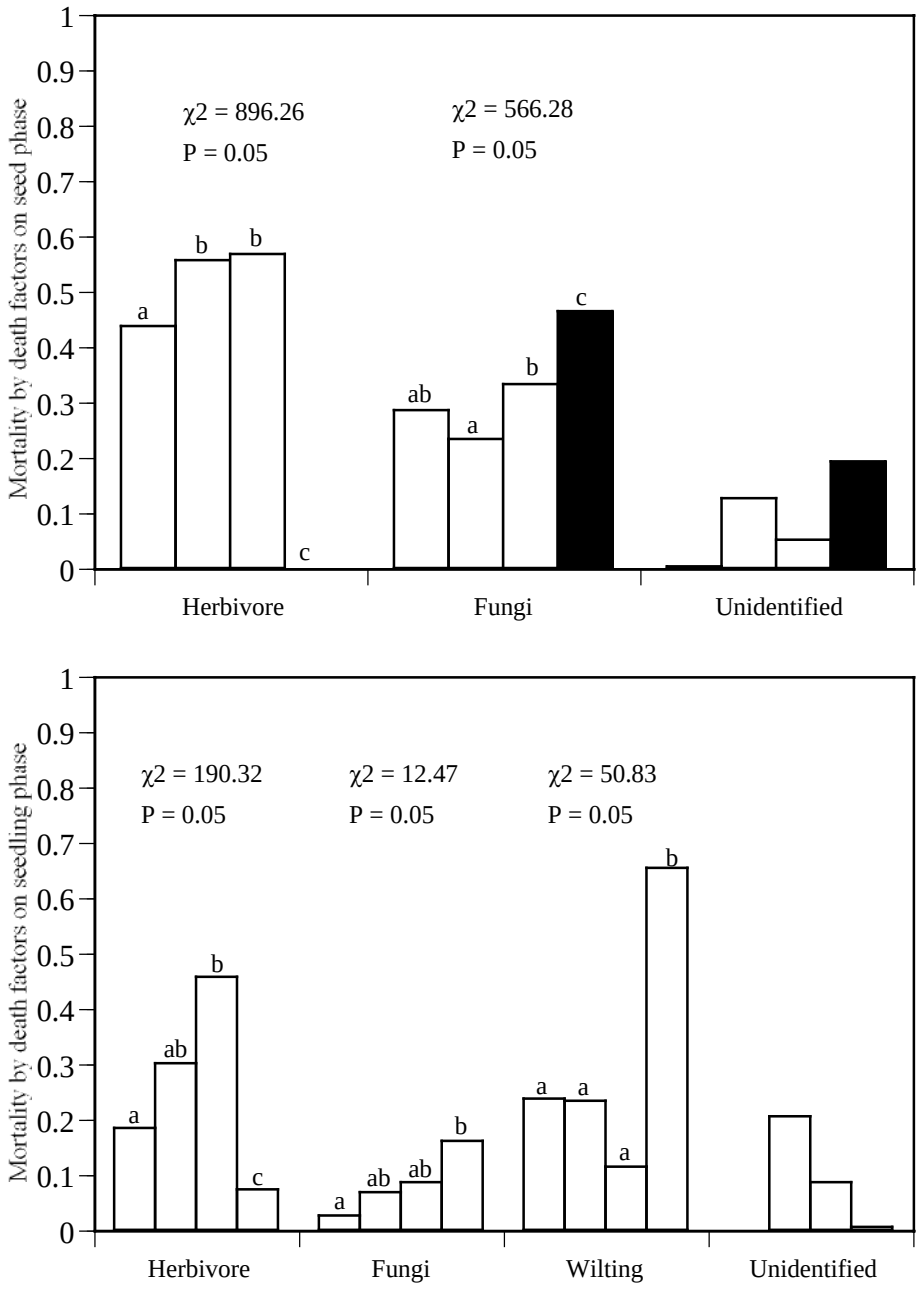

Figure 5 Mortality percentage by death factors on seed and seedling phase for 17 months after seed dispersal of *Cryptocarya densiflora* and *Cinnamomum soegengii* . Three mother trees were sampled for *Cryptocarya densiflora* (□) and one mother tree for *Cinnamomum soegengii* (■). Different letters indicate significantly different at P=0.05 according to χ^2-test

CONCLUSION AND REOMMENDATION

Seed and seedling of two climax Lauraceae species; *Cinnamomum soegengii* and *Cryptocarya densiflora* show the different both germination and mortality factor aspects. *Cinnamomum soegengii* germinate within one month after dispersion but simultaneously germinated for *Cryptocarya densiflora*. During seed phase herbivore was the majority factors for *Cryptocarya densiflora*. In contrast, fungal pathogens were a major mortality factor for *Cinnamomum soegengii*. On seedling phase, the major cause of mortality appeared to be herbivore and wilting (drought) for *Cryptocarya densiflora* and *Cinamomum soegengii*, respectively. We need more mother trees in order to confirm the result of this study. Regarding to seedfall of *Cinamomum soegengii,* dispersd on rainy season and fungal pathogen was the key factors of the mortality. Therefore, seed collection should be immediately collected after disperse to forest floor for any purposes such as producing seedling for forest plantation.

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