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Long-term study on regeneration process of several tree species with special reference to mortality in a tropical rain forest of West Sumatra

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ABSTRACT

Regeneration process of several important tree species in a tropical rainforest, West Sumatra, was evaluated for seven tree species over 20 years period in 1-ha plot of tropical rain forest in Ulu Gadut, West Sumatra, Indonesia. Seven tree species were sampled in 1989, 1999 and 2009. The highest mortality rate of seedling was observed for *G. florida* and the lowest was observed for *S. schwenkii*. At the sapling stage (101–400 cm), the highest mortality rate was also observed for *G. florida* and the lowest one was observed for *H. dryobalanoides*. Furthermore, at the pole stage (401-1000 cm), the highest mortality rate was observed for *S. schwenkii* and the lowest one was observed for *C. glandulosus*. Species with high mortality rates were various between emergent, canopy and subcanopy tree. *G. florida* and *M. trichotoma* as subcanopy tree species have performance the higher mortality for seedling, sapling and pole stage. Whereas *G. forbesii* and *C. glandulosus* also as subcanopy tree species showed lower mortality for seedling, sapling and pole stage. Between canopy tree species *C. soulattri* showed the lowest in mortality rate for seedling, sapling and pole. Furthermore, *H. dryobalanoides* as canopy tee species performance low mortality at sapling and pole stage but higher at seedling stage. On contrary, *S. schwenkii* as emergent tree species have performance low mortality at seedling stage but high at sapling and pole stage.

Key Words : mortality, seedling, sapling, pole, Ulu Gadut, tropical rain forest.

INTRODUCTION

Regeneration is a key process for the existence of species in the community. It is also a critical part of forest management, because regeneration maintains desired species composition and stocking after biotic and abiotic disturbances. Various studies on regeneration of plants have been carried out in informally managed sacred groves. The process of seedling development and growth of forest trees largely depends on gaps/canopy openings in the forest created due to natural disturbance, thus influencing the regeneration and species composition of the forest. The rate of forest regeneration depends largely on the growth rates and

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survival of native species that are planted or arrive on their own (Clark *et al.*, 1998; Condit *et al.*, 1995; Pott *et al.*, 2002).

Non-pioneer trees in mature forests spend many years, even decades, as seedlings and small saplings in the understory. Evaluating the nature and extent of non-random effects on seedling survival is the basis for assessing the evolutionary and ecological processes important in structuring forest communities. Mortality of tropical tree seedlings is usually greatest in the first year, decreasing to a much lower, nearly constant mortality rate after several years (Clark *et al.*, 1998).

We have monitored the population of major juvenile tree species at 1-ha permanent plots of a foothill rain forest in Ulu Gadut, West Sumatra since 1980. Spatial distribution pattern of major species in this forest have been revealed and their regeneration mechanisms were discussed with demographic data (Suzuki and Kohyama, 1991; Mukhtar *et al.*, 1992, 1998, Mukhtar and Koike, 2008, 2009; Kohyama *et al.*, 1994).

MATERIALS AND METHODS

Study site

This study was carried out at 1-ha permanent plot, named Pinang-pinang plot in a foothill forest of Mt. Gadut (Lat. 0° 55' S, Long. 100° 30' E), 18 km east from Padang, West Sumatra, Indonesia. The elevation ranged from 490 m to 520 m in altitude. Details of stand descriptions could be referred to the previous papers (Kohyama *et al.*, 1989; Yoneda *et al.*, 1990; Mukhtar *et al.*, 1992; 1998; Mukhtar and Koike, 2008, 2009).

Tree species studies

Seven tree species were selected. The species were *Calophyllum soulattri* Burm (Guttiferae), *Cleistanthus glandulosus* Jabl. (Euphorbiaceae), *Mastixia trichotoma* Bl. (Cornaceae), *Swintonia schwenkii* T & B (Anacardiaceae), *Hopea dryobalanoides* Miq. (Dipterocarpaceae), *Grewia florida* Miq. (Tiliaceae) and *Gonystylus forbesii* Gilg. (Thymelaeceae).

Observation for juvenile tree dynamics

The seven tree species were measured and marked. In September 1989, we were carried out first census of individuals for representative tree species in the 1-

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ha plot permanent. The area was re-sampled on September 1999 and on September 2009 in a second and the third census, respectively. In this paper we distinguishes plants with their height (H) as follows : seedlings (H= 0-100 cm), sapling (H= 101-400 cm) and poles sizes (H= 401-1000 cm).

Calculation of Mortality Rate

Mortality rate was calculated in two different census intervals, 1989-1999 and 1999-2009, and in three size classes, < 100 cm height, 101-400 cm height and > 400 cm height.

Mortality (*M*) rates were calculated (Sheil and May, 1996) as follows:

$$M = \{1 - [(N_o - m)/N_o]^{1/\Delta t}\} \times 100$$

where N_o = population count at the beginning of the measurement interval, m = number of deaths among the initial population, following the between-census period (Δt), Δt = measurement interval between census ($t_1 - t_0$).

RESULTS

Vertical structure

Figure 1 is shown the height distributions of seven tree species in Pinang-pinang plot. The result shows a time trend of the population number during 20 years since 1989. The population was decreased gradually as the height class increased. The distributions patterns were founded majority (six species) in **L-shaped** except for *Gonystylus forbesii* was in **Bell-shaped** at the first census interval. The numbers of population were dominant at seedling stage (H=0-100 cm) except for *Gonystylus forbesii*. The distribution pattern for *Hopea dryobalanoides* and *Cleistanthus glandulosus* were changed to **Bell-shaped** at the second and third census measurement and *Grewia florida* at the third census measurements. These results suggested that later three species have reached regeneration process at sapling stage (H=101-400 cm).

Mortality

Seedling survival differed among seven tree species as shown in Figure 2. In the combined census interval (1989-2009), the result showed that mortality rate was decreased as the height class increased except for *Swintonia schwenkii*. The mortality rate was ranged from 2.71 %/yr to 18.47 %/yr in all three height classes.

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The mortality rate was observed majority higher in the seedling than sapling and pole size. The highest mortality rate was observed for *Grewia florida*. The higher mortality was also observed for *Mastixia trichotoma*. The intermediate mortality rates were observed for *Hopea dryobalanoides*, *Calophyllum soulattri*, *Gonystylus forbesii* and *Cleistanthus glandulosus* in the seedling size. The lowest mortality rate was observed for *Calophylllum soulattri* in the pole stage.

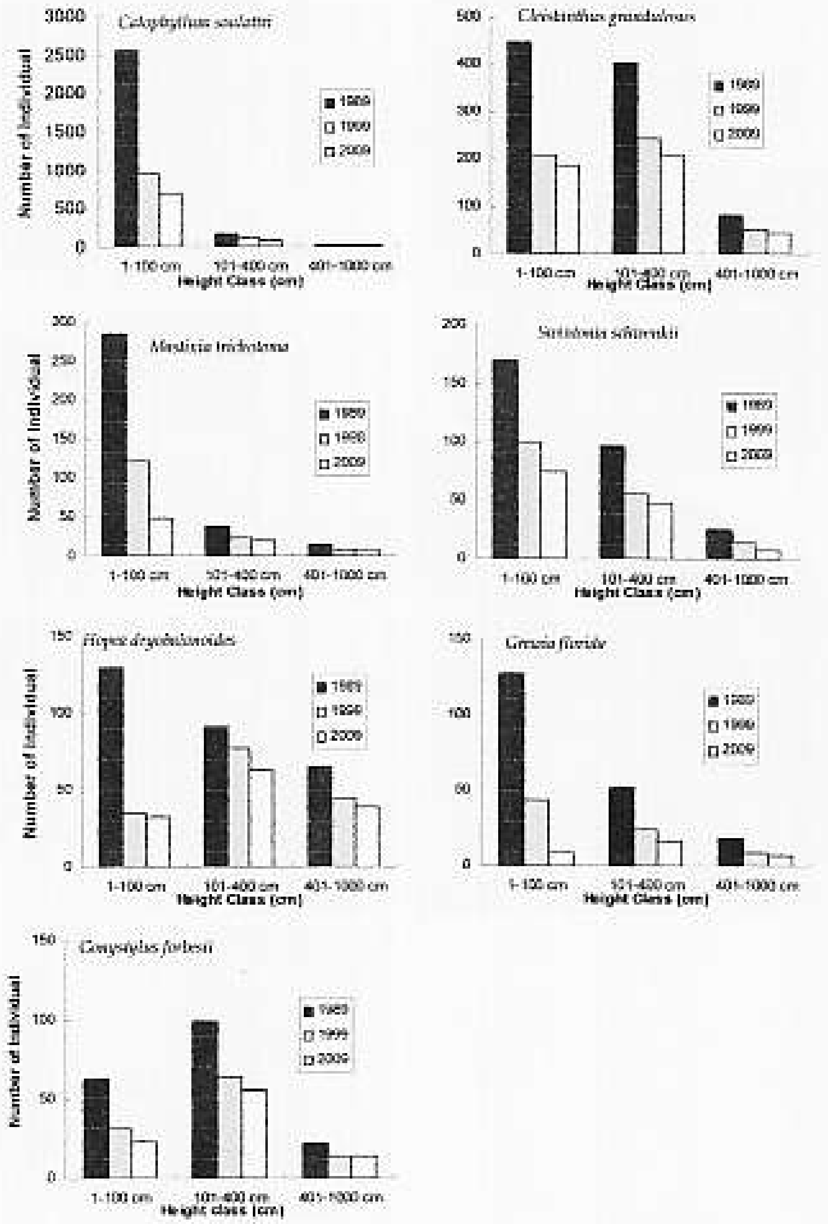

Figure 1. The height class distribution of seven tree species based on seedling stage (H=0-100 cm), sapling stage (H=101-400 cm) and pole stage (H=400-1000 cm)

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Mean mortality rates were higher during 1989-1999 than during 1999-2009. For each height class separately, the difference in mean mortality was much more pronounced in seedling than sapling stage. Four tree species had higher mortality in the early census interval, but their percentage was lower in second census interval. In contrast, two species (*Swintonia schwenkii* and *Grewia trichotoma*) had significantly higher mortality during the later census interval. Whereas *Mastixia trichotoma* was showed slightly higher mortality rate at the second census interval.

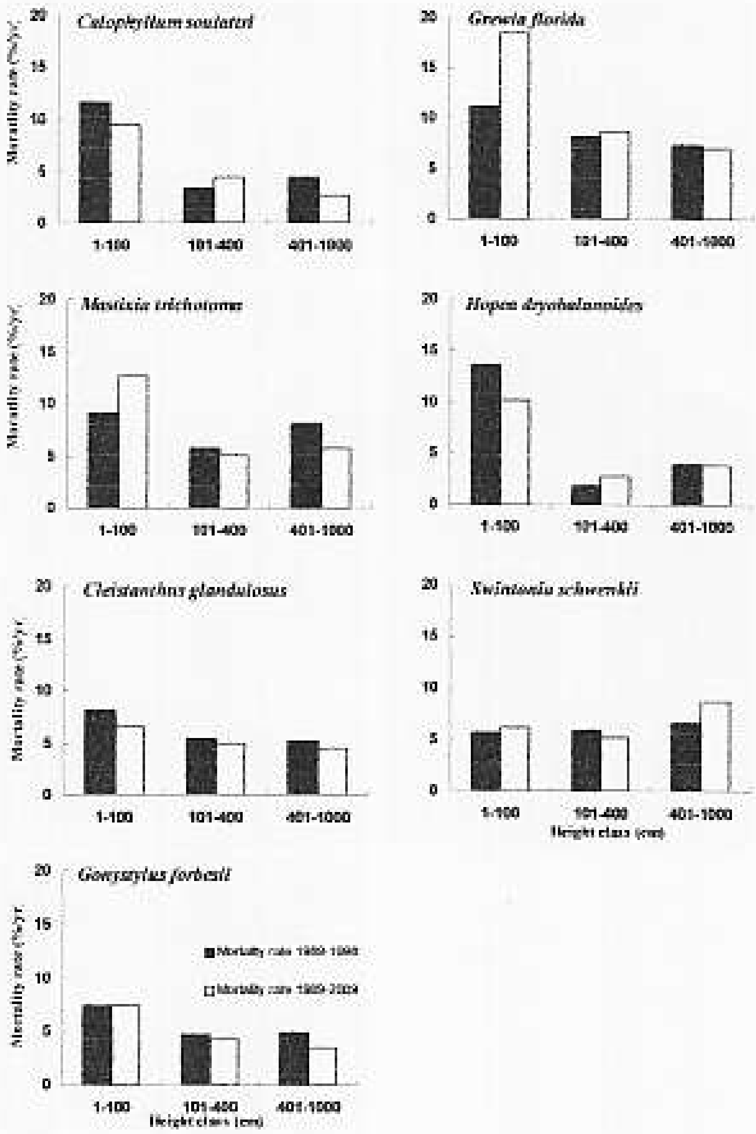

Figure 2. Frequency distribution of mortality rates for seven tree species in two different census interval.

The highest mortality in the first census interval was observed for *Hopea dryobalanoides* (13.57 %/yr) in the seedling whereas the highest rate in the second census interval was observed for *Grewia trichotoma* in the sapling (16.17 %/yr). On contrary, the lowest mortality in the first census interval was observed for *Hopea dryobalanoides* (1.84 %/yr) in the sapling and the lowestin the second census was observed for *Gonystylus forbesii*, *Mastixia trichotoma* and *Calophyllum soulattri* that all of them were in the pole.

With all tree size combined, mean mortality rate was significantly higher in the smaller size class than in the larger during both census intervals. This overall trend, however, mask a sharp difference between size classes. In pole sizes, the difference was highly significant during both intervals except for *Hopea dryobalanoides*. Two extreme illustrate the variation in how mortality changed with size. In 1989-1999, *Swintonia schwenkii* (Anacardiaceae) had 6.65 %/yr mortality in the pole size class in the first census interval but become 13.0 %/yr in the second census interval. Conversely, *Hopea dryobalanoides*, *Cleistanthus glandulosus* and *Calophyllum soulattri* in 1989-1999 had higher mortality at the seedling in the first census but the rate was observed in the pole in the second census interval.

DISCUSSION

The regeneration behaviour of each tree species is controlled by many factors such as distance from the mother tree, topography and their statue in the forest stand. In our plot we have found clear relationship between mortality and distance from the mother tree of *C. soulattri* (Mukhtar *et al.*, 1998). We also found that *Swintonia schwenkii* micro-environment in the area around mother tree seemed not to be suitable for the survival of the seedlings (Suzuki and Kohyama, 1991).

Most tropical rain forest tree species have strongly aggregated spatial distribution pattern. The species distributions are also strongly aggregated with respect to variation in soil nutrient status (Clark *et al.*, 1998). Palmiotto *et al.*, (2004) in Lambir, Borneo founded that *Swintonia schwenkii* naturally aggregated on low-fertility humult ultisol and *Hopea dryobalanoides* on moderate-fertility udult ultisols. *Hopea dryobalanoides* had significantly higher survival rates in udult than in humult soils in gaps area. Whereas for *Swintonia schwenkii* had no significant differences in survival rates between soils or light level. They result concluded that habitat-mediated differences in seedling performance strongly influence the spatial distribution of tropical trees and therefore likely to play a key role in structuring tropical rain forest communities.

Various pattern of mortality rate were found between emergent, canopy and subcanopy tree species. *Grewia florida* and *Mastixia trichotoma* as subcanopy tree species have performance the higher mortality for seedling, sapling and pole stage as shown in Figure 2. Both of two species were recognized to be more sensitive to gap dynamics than *Hopea, Gonystylus* and *Cleistanthus* (Kohyama *et al.*, 1994). Whereas *G. forbesii* and *C. glandulosus* also as subcanopy tree species showed lower mortality for seedling, sapling and pole stage. Between canopy tree species *Calophyllum soulattri* showed the lowest in mortality rate for seedling, sapling and pole. Furthermore, *Hopea dryobalanoides* as canopy tee species performance low mortality at sapling and pole stage but higher at seedling stage. On contrary, *Swintonia schwenkii* as canopy tree species have performance low mortality at seedling stage but high at sapling and pole stage.

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