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Decomposition of wood blocks in *Acacia* plantations and natural forests in Bintulu, Malaysia

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Abstract We conducted a field experiment to reveal the effect of environmental factors on the decomposition process of woody debris in Bintulu from July 2013 to November 2014. Forest type (*Acacia* plantation or natural forest) and canopy openness were selected as predictor variables of the decomposition rates for *Xylopia ferruginea* and *Dryobalanops beccarii*. The results suggest that land use change affects the decomposition process of woody debris. Further studies on effects of landscape structure on colonization processes of decomposers are needed.

Keywords *Dryobalanops beccarii*, Termite, White rot fungi, *Xylopia ferruginea*

Introduction

The high biodiversity in natural tropical rainforests provides many types of ecosystem function. On the other hand, natural tropical rainforests are rapidly decreasing in area and are being modified into other land use types, such as plantations, crop lands, and so on. Such modifications in land use cause changes in biodiversity and the composition of biological communities and result in changes in ecosystem functions (Steffan-Dewenter et al. 2007).

The decomposition is one of the most important functions in material circulation in forest ecosystems, because most primary products flow directly into the decomposition (Cebrian 1999). Many factors, such as temperature, humidity, and decomposer communities, play important roles in the decomposition process (Harmon et al. 1986). Variation in these factors among forest stands is expected to cause large differences in the decomposition process.

Fungi and termites are two major decomposers of wood in tropical areas (e.g., Matsumoto 1976; Lodge 1993; Liu et al. 2015). *Acacia* plantations are a major land use type in Southeast Asia. Because the community structure of wood-decaying fungi in *Acacia* plantations is different from that in primary forests (Yamashita et al., unpublished data), it is reasonable to hypothesize

that the decomposition processes differ between the two forest types. In the Southeast Asian tropics, however, the decomposition process in *Acacia* plantations has not been compared with that in primary forests.

To test the hypothesis that the decomposition process in *Acacia* plantations would be different from that in natural forests, we analyzed the relationships between the decomposition rate of woody debris and environmental factors, such as forest type, canopy openness, soil temperature, and soil hardness.

Materials and Methods

To quantify the decomposition rate, we conducted a field experiment by placing artificial woody debris in natural forests and *Acacia* plantations in Bintulu, Sarawak, Malaysia.

Before starting the field experiment, we prepared blocks (3 cm × 3 cm × 5 cm) of wood of two tree species, *Xylopia ferruginea* (Ako) and *Dryobalanops beccarii* (Kapur). The timbers for making the blocks of wood were brought from a natural forest in Sampadi, Kuching, in April 2013. All the wood blocks were dried at 60 °C in an electric oven for more than 48 hours in May 2013. After drying, the dry weight of each wood block was measured.

We conducted field surveys in two types of vegetation in the land owned by Sarawak Planted Forest SDN BHD, Bintulu, from July 2013 to November 2014. Fifteen plots were set up in *Acacia* plantations and five plots were set up in natural forests. In each plot (ca 3 m × ca 3 m), we placed 49 blocks of *X. ferruginea* wood and 49 blocks of *D. beccarii* wood in June 2013. We collected 7 of the wood blocks of each species in each plot seven times: in July, September, and November of 2013, and in May, July, early September, and late October of 2014. The dry weight of each of the collected wood blocks was measured after drying at 60 °C in an electric oven for more than 48 hours.

For each plot, we recorded the forest type (*Acacia* or natural forest), canopy openness, soil temperature at 30-cm depth, and soil hardness as environmental factors. Canopy openness was estimated by using a spherical densiometer in November 2014. Soil temperature was measured in late October 2014. Soil hardness was measured by using a soil hardness tester in late July 2013. Forest type did not change during our field study.

Decomposition rate was calculated for each study site in this study. A single exponential model was used to estimate the decomposition rate. In the model, decomposition rate (k) was obtained as follows:

$$k = -\ln (W_t/W_0)/t,$$

where W_t is the dry weight at time t, W_0 is the initial dry weight, and t is the time elapsed since the experiment began. Relationships between the decomposition rate and environmental factors (forest type, canopy openness, soil temperature, and soil hardness) were analyzed with generalized linear models by using the R version 3.2.1 software (R core team 2015).

Results and Discussion

We observed that some wood blocks were attacked by white rot fungi or termites (Fig. 1). For *X. ferruginea*, the mean decomposition rate (k) was 0.4 year^{-1} (n = 15) in the *Acacia* plantations and 0.5 year^{-1} (n = 5) in the natural forest. For *D. beccarii*, on the other hand, the mean decomposition rate was 0.1 (n = 15) in the *Acacia* plantations and 0.1 (n = 5) in the natural forest. In our study area, soil temperature at 30 cm depth ranged from 25 °C to 27 °C, soil hardness ranged from 6 to

Fig. 1 Wood blocks attacked by white rot fungi (left) and termites (right) during the field experiment.

142 kg/cm^2, and canopy openness ranged from 4 to 31 %. Canopy openness in the *Acacia* plantations was higher than that in the natural forest. In the generalized linear model analysis, forest type was identified as a predictor variable for the decomposition rate of *X. ferruginea*, whereas canopy openness was identified as a predictor variable for the decomposition rate of *D. beccarii*. These results suggest that the change of land use from natural forest to *Acacia* plantation causes a decrease in the decomposition rate of *X. ferruginea*.

Temperature, moisture, and decomposer organisms in a forest stand are possible factors controlling the decomposition process (Harmon et al. 1986). In our study, soil temperature and canopy openness were weakly correlated with each other (R^2 = 0.3), suggesting that increasing canopy openness creates a high-temperature environment in plantations. In addition, high temperatures promote desiccation of the forest floor. In Sarawak, Sabah, Thailand, and Vietnam, the fungal community structure in *Acacia* plantations seems to be quite different from that in natural forests (S. Yamashita, personal observation). At our study site, the average number of termite species did not differ significantly between the *Acacia* plantation and natural forest (S. Yamashita, personal observation). On the other hand, it seems that wood blocks were attacked by white rot more frequently in the natural forests than in the *Acacia* plantations. Although further analyses of the effect of decomposers in the *Acacia* plantations are needed, we expect that the re-colonization of *Acacia* plantations by decomposers will play an important role in decomposition processes by affecting the community structures of fungi and other decomposers.

Apart from the traits of the study sites, the quality and size of the wooden blocks may possibly affect the decomposition process. In our experimental study, the size effect was controlled before starting the experiment, and the effect of the quality of substrate was largely randomized by using both heartwood and sapwood for each stand in the experiment. In the case of *X. ferruginea*, it is difficult to visually distinguish between heartwood and sapwood (Sarawak Timber Industry Development Corporation 2007).

Our study clearly showed that the decomposition rate differed between *X. ferruginea* and *D. beccarii*. The density of *D. beccarii* wood is about twice that of *X. ferruginea.* In contrast to *X. ferruginea*, *D. beccarii* has clearly distinguishable heartwood. Differences in wood density and chemical components might account for the difference in decomposition rates between these two

types of wood. Although the decomposition rate differed between *X. ferruginea* and *D. beccarii*, the decomposition rates of *X. ferruginea* and *D. beccarii* were highly correlated with each other. This suggests that the same environmental factors controlled the decomposition rate of these two different tree species.

In our study, the decomposition processes clearly differed in the *Acacia* plantations compared to the natural forest. Because wood decomposers must colonize *Acacia* plantations from the surrounding natural forest, the ability of decomposers to gain access from natural forests to *Acacia* plantations might be an important factor affecting decomposition processes, in addition to the environmental factors at each study site. Further study of this matter is needed.

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