E-2.1 Diversity of Wildlife Species in the Tropical Forest Ecosystem

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Abstract
Post dispersal survival of *Dryobalanops aromatica* (Dipterocarpaceae, Malay name: kapur) was monitored in a ca. 60-year old kapur plantation and a mixed species (non-kapur) plantation at Kepong, Peninsular Malaysia. Ninety percent of Kapur seeds were predated by insects. One of the most important insects which attack Kapur seeds was a weevil belong to the genus Alcidodes. In both plantations, seeds and cotyledon-stage seedlings were predated by vertebrates such as rodents and wild pigs and less than 1% of the seeds survived to four-leaf stage seedlings. After reaching the four-leaf stage, the survival rate was increased due to reducing predation. Six-leaf stage seedlings showed very low mortality to make a sapling bank under the canopy. There were no practical differences in survivorship of Kapur seeds and seedlings between the two plantations. In the kapur plantation, natural regeneration can be expected, when sufficient seed supply in mast years compensates for the high mortality during the seed and seedling stage. On the other hand, seedling mortality of Pentaspadon motleyi (Pelong) at Pasoh forest reserve was not affected by the distance from nearest adult tree nor the density of seedlings, but related to the light environment of the habitat.

Key Words Biological diversity, Buried seeds, Herbivory, invertebrate community, Plant-animal interaction, Seed bank, Seedling establishment

1. Introduction

In many plant species, the period from seeds to seedlings is the most vulnerable stage in their life histories. Particularly in tropical forests, seeds and seedlings are consumed by animals and insects, attacked by fungi and other microorganisms, buried under litter, washed away by rain, and starved by lack of light, water and mineral nutrients.

It has been found that in several plant species in tropical regions, seedlings growing near their parents suffer high mortality, because density of natural enemies may be high around the mother tree. If this is the case, probabilities of seedlings surviving in a mono-dominant forest like plantations are expected to be lower than those in mixed-species forests such as typical lowland tropical forests. However, evidence reported from neotropical forests suggested that this situation does not always occur and very few evidence has been reported from southeast Asia.

In this study, we investigate post-dispersal survival of two canopy tree species in lowland tropical forests in Malaysia, Kapur (*Dryobalanops aromatica*) and Pelong (*Pentaspadon motleyi*) to obtain information on the process of regeneration of these species in a plantation forest (Kapur) and in a natural forest (Pelong).

2. Seedling establishment of Kapur

Dryobalanops aromatica Gaertn.f. (local name: Kapur) is a canopy tree species in lowland tropical rain forests in southeast Asia (Symington 1943). Its natural distribution is known from in Malay Peninsular, Sumatra and Borneo (Foxworthy 1932). Unlike many other canopy tree species in lowland tropical forests, Kapur is locally very abundant (Foxworthy, 1932).

Because Kapur seeds do not have dormancy (Yap 1981) and therefore cannot survive as a seed bank in the soil (Jensen 1971), regeneration of Kapur depends largely on the presence of sapling bank on the forest floor. Kapur seeds and seedlings are known to be predated by insects and mammals and the mortality is usually very high (Wyatt-Smith 1963). In our previous experiments in a Kapur plantation site, less than 1% of germinated seedlings survived to the four-leaf seedling stage, whereas the survival rate was much higher after reaching six-leaf stage (Kachi *et al.* submitted).

Like many other species of dipterocarp species, Kapur shows irregular fruiting with gregarious and sporadic years. In a gregarious year predation pressure may be higher than in a sporadic year, because gregarious fruiting could attract mammal and insect predators. This paper reports post-dispersal survival of Kapur in a Kapur and non-Kapur plantations in a sporadic fruiting year to obtain evidence for the above possibility.

The site

In the Forest Reserve of Forest Research Institute of Malaysia (FRIM) in Kepong, Peninsular Malaysia (101° 37' E, 3°13' N), there is a plantation of Kapur (*Dryobalanops aromatica*). The plantation was established during late 1920's and early 1930's (Appanah & Weinland 1993). The canopy is purely dominated by Kapur with heights of around 40 m. Near the Kapur plantation, there is a mixed species (non-Kapur) plantation of similar ages to the Kapur plantation, where *Shorea bracteolata, Dipterocarpus baudii, D. semivestitus, Gymnacranthera forbesii* (Myristicaceae), *Scorodocarpus borneensis* (Olacaceae), and *Albiziz falcataria* (Leguminosae) are codominant, but no Kapur is growing in the plantation. The canopy height is 30-35 m and the density of canopy trees is comparable to that of the Kapur plantation.

Transplant experiments

A series of transplant experiments was conducted to determine the survivorship and causes of mortality of seeds and seedlings of Kapur. The year 1992 was a sporadic fruiting year and flowering was very localised and no flowering was observed in the Kapur plantation for the experiments. In Kanching Forest Reserve (*ca.* 10 km NE of FRIM) there is another Kapur plantation, where two neighboring Kapur trees produced fruits in July- August in 1992. Naturally fallen fresh seeds were collected from these two trees for transplant experiments. In all experiments, only visually undamaged seeds, which were expected to be germinable, were used.

Six 1 m x 1 m plots were established in Kapur and non-Kapur plantations. Immediately after seed collection, 18-20 seeds were transplanted to each plot on 5 September 1992. Thereafter, seed survival and causes of mortality were monitored at 2-5 day intervals for 21 days until 26 September 1992.

Two sets of transplant experiments were carried out to assess seedling survivorship; starting from cotyledon and from four-leaf stages. Germinating seeds and cotyledon stage seedlings were collected from Kanching Forest Reserve and put in a black plastic pot in 10 cm diameter containing B-layer soil of the Kapur plantation and grown outdoors in a shade condition (3-4% as the relative photon flux density) in a nursery until transplanting. Twelve cotyledon stage seedlings were transplanted to each plot on 23 September 1992 and their survival was monitored at 2-11 day intervals until 4 December 1992. In the other set of experiment, 12 four-leaf stage seedlings were transplanted to each plot on 25 September 1992 and their survival was monitored at 7-14 day intervals until 5 December 1992.

Results

Survivorship of seeds

In all plots, majority of Kapur seeds germinated within three days after transplanting if not predated. In both plantations, Kapur seeds and germinating seedlings suffered from heavy predation and all but one died by the 21st day (Fig. 1). Seed mortality was higher in non-Kapur plantation than in Kapur plantation (Mann-Whitney U-test, $P < 0.001$): the average longevity of seeds was 4.9 days in Kapur plantation and 9.8 days in non-Kapur plantation.

In both plantations, ca. 70% of seed mortality was due to mammal predation including wild pigs (*Sus scrofa*) and small rodents of which *Maxomys rajah* and *Callosciurus notatus* are dominant (Nor Azman Hussein, personal communication). Another 30% of the mortality was caused by the predation of a termite (*Longipeditermis longipes* Haviland, Nasutitermitinae). The termite consumed seeds and cotyledons and/or cut the base of the hypocotyl of seedlings.

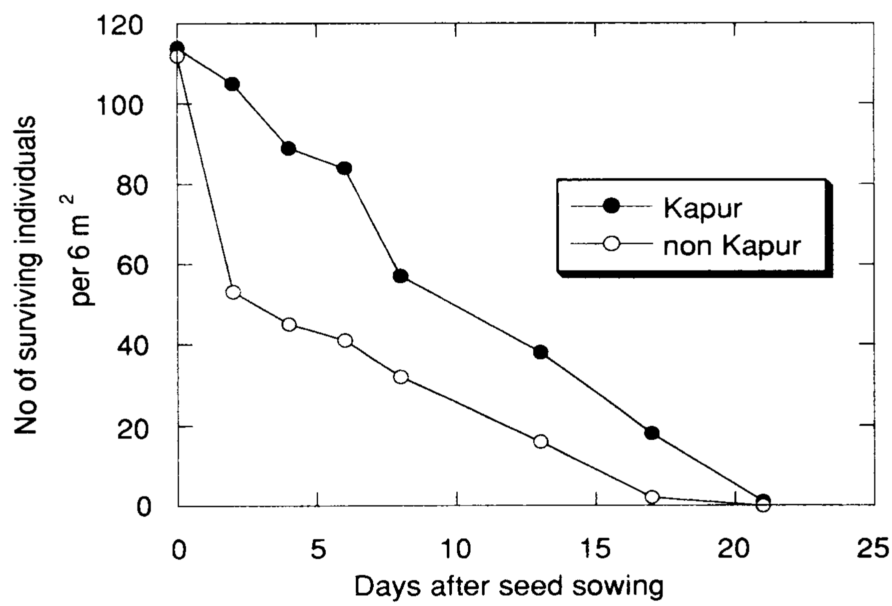

Fig. 1. Survivorship of seeds of Kapur (*Dryobalanops aromatica*) transplanted in Kapur (closed circle) and non-Kapur (open circle) plantations in Forest Research Institute of Malaysia.

Survivorship of cotyledon stage seedlings

In the Kapur and non-Kapur plantations, the survival of cotyledon stage seedlings was approximately linear in a semi-logarithmic plot (Fig. 2). Average specific mortality rates were -0.027 per day in Kapur plantation and -0.038 in non-Kapur plantation. On the 72nd day after transplanting, 10% and 6% of seedlings were still surviving in Kapur and non-Kapur plantations, respectively.

The main cause of mortality during the above period was predation by termites (*Longipeditermis longipes*) and mammals (rodents and wild pigs); contribution to the total mortality was 65% and 61% in Kapur and non-Kapur plantations. Another mortality factor was wilting of shoot and/or damage of shoot apex. Water stress, attack by microorganisms including fungi, insect attack to the shoot apex were possible agents for the wilting of seedlings.

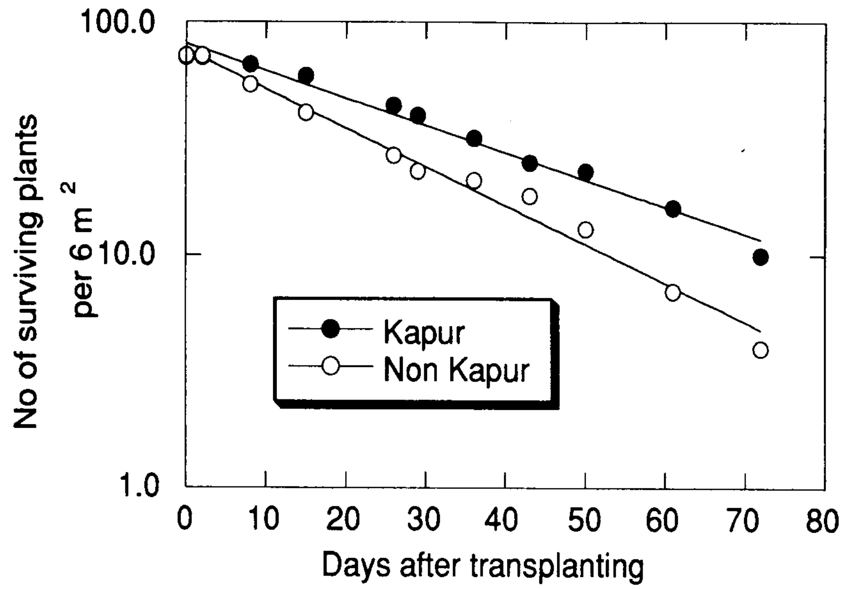

Fig. 2. Survivorship of cotyledon-stage seedlings of Kapur (*Dryobalanops aromatica*) transplanted in Kapur (closed circle) and non-Kapur (open circle) plantations in Forest Research Institute of Malaysia. The vertical axis is in a logarithmic scale.

Survivorship of four-leaf stage seedlings

The mortality rates obtained in Kapur and non-Kapur plantations were insignificantly different ($P > 0.05$) and the average specific mortality was -0.062 per day (Fig. 3). This rate was about one-fifth of the mortality rates obtained for cotyledon stage seedlings. On the 72nd day after transplanting, 62% (in Kapur plantation) and 56% (in non-Kapur plantation) were still surviving. During this period 23% and 21% of seedlings in Kapur and non-Kapur plantations were dead due to wilting caused by various agents. Proportions of seedlings which were predated by mammals were 14% and 23% in respective plantations. No mortality due to termites was observed.

Discussion

Termite as a mortality factor

The experimental results showed that even in a sporadic fruiting year when there are locally very few or no fruiting trees, artificially introduced seeds encountered considerable predation pressure (Fig. 1). However, relative importance of mortality due to mammal predation was less compared with that in a more gregarious year (1991) when majority of predation was caused by mammals like rodents and wild pigs (Kachi et al. in press). Other than mammal predation, a termite (*Longipeditermis longipes*) was also an important agent of mortality of seeds and cotyledon stage seedlings, although termites have not been recognised as a pest of Kapur plantation. *Longipeditermis longipes* is widely distributed throughout Malaysia and common in lowland dipterocarp forests (Tho 1992). A termite (*Microcerotermis dubius*) could attack living trees of numerous indigenous species including Dipterocarpaceae in natural forests (Tho 1982). Several exotic pine species are also known to be susceptible to attack by subterranean termites when they were planted experimentally in Peninsular Malaysia (Dhanarajan 1969; Tho 1974).

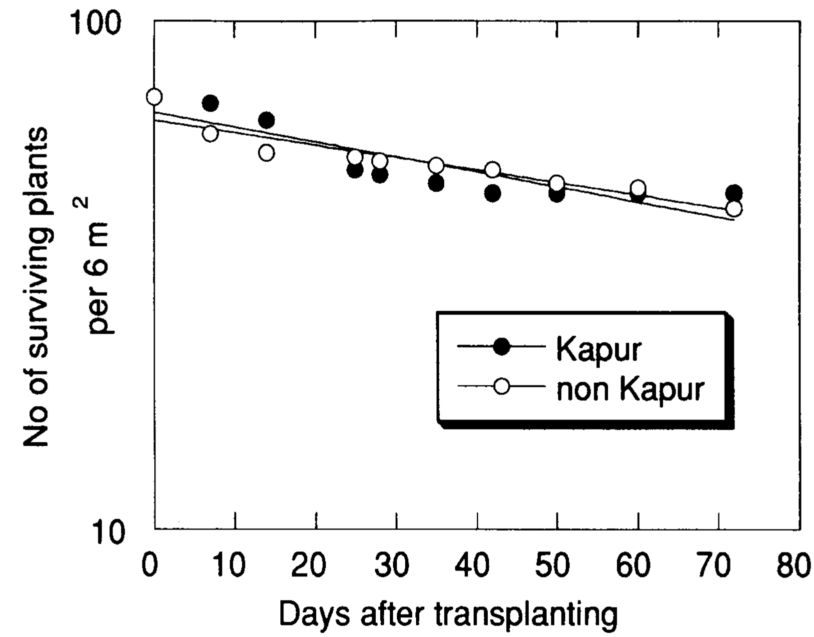

Fig. 3. Survivorship of 4 leaf-stage seedlings of Kapur (*Dryobalanops aromatica*) transplanted in Kapur (closed circle) and non-Kapur (open circle) plantations in Forest Research Institute of Malaysia. The vertical axis is in a logarithmic scale.

Comparisons between gregarious and sporadic fruiting years

Compared with survivorship of seeds and seedlings in more gregarious year in 1991 (Kachi et al. submitted), the survival rates in sporadic fruiting year in 1992 was more than twice higher (Figs. 2 & 3). Lower predation pressure by mammals was attributable to the lower mortality, which suggests lower activity of mammal predators in a sporadic fruiting year. It is well expected that mammals were not attracted to the plantation, because there was no attractive fruiting in 1992.

3. Interactions between Dipterocarp trees and seed predators

We investigated the composition of insects emerging from seeds of the dipterocarp tree Kapur (*D. aromatica*) and the germination success in relation to the seed size. We randomly collected fresh seeds which were found on the ground in planted stands of the tree within FRIM campus on 15 and 17 July 1991. Size of each seed was measured by its wet weight using a balance accurate to 0.1 g. Keeping each seed in a transparent plastic cup, then we waited for insect emergence for 37 days when seed germination and insect emergence were ceased. Insect emergence and seed germination were checked once every week.

In total, we collected 591 seeds. Seed weight ranged between 0.3 and 9.9 g, and the average weight was 2.97 ± 2.0 (S.D.). Most of seeds were between 1 g and 3 g in weight; very small and very large seeds were few in number. When the seed weight was log transformed, the distribution could be approximated by a log normal distribution model. Germination occurred in 63 among 591 seeds; 528 seeds did not germinated. The average size of seeds which germinated was 7.18 ± 1.60 (S.D.), and that of ones which did not germinate was 2.46 ± 1.34 (S.D.), indicating that germination occurs only in large seeds.

From 232 among 591 seeds collected, at least one insect came out. Only three seeds germinated in spite that they were attacked by insects. Therefore, we can conclude that most of seeds attacked by any insects do not germinate. The number of insects which came out from one seed ranged from 1 to 20. They were adult insects and larvae. Taxonomic groups of the larvae were not yet examined, but every adult insect was found to belong to one of four orders: Coleoptera, Lepidoptera, Hymenoptera and Diptera. One of the most important insects which attack Kapur seeds was a weevil belong to the genus Alcidodes. The average weight of seeds with insects of any species was 2.61 ± 1.05 (S.D.), indicating that insects emerge from seeds of small and middle sizes. There may be two possible reasons for this phenomenon. First, insect may discriminate between seed size and attack smaller seeds. Second, insects attack seeds when seeds are at young stage, and injured seeds do not grow well as healthy seeds. Observation of oviposition behavior of the weevil is needed to determine which explanation is reasonable.

4. Seedling establishment of Pelong

Pelong, which belongs to Anacardeacea, widely distributes in lowland forests on the Malay Peninsula. In Pasoh forest reserve, which is the study site for this study, mature trees of 30-40 cm of diameter at breast height (DBH) are frequently observed. In the central part of the forest reserve, there is a large permanent plot (50 ha) provided by Smithsonian Institute of America and FRIM. DBH of all the plant individuals of more than 1 cm, which appear in the study area, are measured and recorded and their locations are also recorded. As a preliminary investigation, we analyzed the effects of the size (DBH) of the adult trees on the density of the saplings of the same species (whose diameter is 1-2.5 cm) appearing in the study area. It was found that within the area 6 m in diameter surrounding a large adult tree of more than 40 cm in DBH, there exist no saplings. In order to clarify if this is due to what Janzen (1970) calls, a saplings' escape from parents, monitoring of survivorship of seedlings growing around parents started in August, 1991 in the Pasoh forest reserve (a 1 ha plot). In this monitoring, 22 plots were placed within 0-20 m from the closest adult tree and all of the seedlings which appeared in the plots were marked and their survivorship and heights were recorded every month.

Results and Discussion

In the 1 ha plot, survival rate of the seedling becomes almost linear on logarithmic graph and no significant difference was found in the linear gradient among the quadrats whose distances from the closest parent tree are different. This implies that seedling survival rate is not subject to the distance from a parent tree. In addition, it was found that there was no influence of seedling density on its survival rate in either case. From this, it can be estimated that the phenomena observed at the 50 ha plot where no saplings (1 - 2.5 cm) were found directly under parent trees, is due to 1) saplings underneath of the crown die out during the period when they grow to a tree of 1 cm DBH from a tree of the size which was selected for our study. Namely, seedling located close to parent trees die out not during the period from immediately after budding to seedling fixing period when saplings are rather weak but in the period when seedlings have grown to some extent, and they die in large number only in the area close to the parent trees; 2) Pelong seedlings are dependent on a forest crown gap. The fact that parent tree existences are shown on the plot map for the 50 ha area, at least indicates that a gap was not formed in a certain area (crown projected area) centering the 50 ha area. This is confirmed by the fact that seedlings grown in a nursery after being dug up from the forest can grow faster (based on height) than seedlings growing in the forest by 80 - 100 percent.

5. Acknowledgments

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