

CHAPTER 6

DISCUSSION

Seedling establishment

Most seedlings that established in the studied plots were of animal-dispersed species (Table 2). A slightly larger proportion of these seedlings established beneath remnant trees (66.8%) than in control plots (60.6%). On the other hand, a slightly smaller proportion of wind-dispersed seedlings established beneath remnant trees (33.2%) than in control plots (39.4%), agree to Carrière *et al.*, (2002b). Therefore, animal-dispersed species were important for forest regeneration in this disturbed area.

Comparison between beneath tree sites and control sites

Duncan and Chapman (1999) concluded that the seed rain under trees was higher than in open areas. Therefore, it was expected that seedling recruitment beneath isolated trees would be greater than away from their crowns. However this study indicated that establishment of natural seedlings beneath remnant trees was not significantly higher than in control plots. This agrees with a previous study of Carrière *et al.* (2002b) but contrasts with Guevara *et al.* (1986). Seedling recruitment differed among the remnant tree species and the types of seed dispersal mechanism.

Remnant trees tended to slightly enhance seedling establishment beneath their crowns, but not significantly so compared with controls (Table 4). Only beneath *Schima wallichii* crowns was seedling density significantly higher than in the control

plots. Beneath *Eucalyptus camaldulensis* crowns the species richness of seedling was higher significantly than in the control plots. The significant differences that occurred with both tree species were strongly influenced by the abundance of animal-dispersed seedlings (Table 6).

Distribution of wind-dispersed seedlings varied among remnant trees species (Table 5). It was difficult to conclude that wind-dispersed seedlings were more abundant in the control plots or beneath the tree crowns. However, seedling establishment below *Erythrina stricta* and *Albizia chinensis* was higher significantly than in the control plots. Both species are legumes and their crowns produce little shade, which might create suitable conditions for wind-dispersed species. Some of the *Albizia chinensis* trees studied were located in a forest-planting area. Therefore, some seedlings might have been damaged by human activity, so seedling density under *Albizia chinensis* was lower than in control.

All of the remnant tree species tended to attract animals, which are seed dispensers. The establishment of animal-dispersed seedlings beneath the crowns of remnant trees was higher than away from the crowns, except beneath the crowns of *Erythrina stricta* (Table 6). Lower numbers of animal-dispersed seedlings beneath *Erythrina stricta* crowns might be because of low shade beneath their crowns. Animal-dispersed species are usually shade-tolerant (Whitmore, 1989). Accordingly, the abundance of animal-dispersed seedlings was low (Table 6), but the abundance of wind-dispersed seedlings was high (Table 5).

Furthermore, the species component of animal-dispersed seedlings beneath *Pinus kesiya* was higher than in control plots. It is therefore possible that forest

regeneration might be faster in *Pinus kesiya* plantations than in areas without plantations as suggested in a previous study by Oberhauser (1997).

Schima wallichii crowns had the greatest effect at increasing seedling recruitment, compared with the control plots, especially for seedling species dispersed by animals, a result also obtained by Kuarak and Hitchcock (1998). This result agrees with the bird-observation data, which showed that many birds visited these trees.

Although, the recruitment of animal-dispersed seedlings beneath remnant trees was higher than in control plots, the result was not statistically significant. It is possible that the influences of remnant trees alone might not be strong enough to enhance the seed rain. Differences of environmental condition between sites beneath and away from remnant trees could lead to variation in seedling establishment (Nepstad *et al.* 1996), including other effects, such as competition, seed-predation (Carrière *et al.*, 2002b), and herb cover (Adhikari, 1996).

Effects of the species of remnant tree on seedling establishment

The density and species richness of natural seedling recruits differed among the species of remnant tree. Variations in seedling establishment were strongly influenced by wind-dispersed tree seedlings, whereas animal-dispersed seedlings had a lesser effect. Moreover, analysis results of only bird-dispersed seedlings also not different as results of animal-dispersed seedlings.

The density and species richness of animal-dispersed seedlings was similar among the species of remnant trees, which agrees with previous studies. Toh *et al.* (1997) and Carrière *et al.* (2002b) concluded that all isolated tree species were equally

attractive as a focal point for seedling recruitment, regardless of whether they had fleshy fruits or dry fruits. *Callicarpa arborea* var. *arborea* is a fleshy-fruited tree, but seedling establishment of animal and bird-dispersed trees under its crowns was not different to the other trees studied. It is possible that this tree in addition attracting seed dispersers, might also attract seed and seedling predators.

Erythrina stricta crowns seemed to create suitable conditions for seedling recruitment of wind-dispersed species. Most wind-dispersed seedlings are pioneer species that like to establish in gaps (Whitmore, 1989). The low shade and long leafless period of *Erythrina stricta* might provide for germination and recruitment of wind-dispersed seedlings.

While seedling density and species richness were low under the canopy of *Eucalyptus camaldulensis* (an exotic species), these parameters were not significantly different compared with the other tree species studied. Such a result agrees with the previous study of Pommerenke (2000) which was also inconclusive on impact of eucalyptus on forest vegetation composition.

In control areas, away from the crowns of studied trees the seedling density did not differ among the control sites of each species studied. But, the species richness of seedlings, especially animal-dispersed species was significantly different among the control sites. An unusual peak of animal-dispersed species in the control sites near *Erythrina stricta* tree caused a significant difference in seedling richness, among the control sites. Without this, the species richness among the control sites would not have differed significantly if *Erythrina stricta*' control sites had been removed from the analysis. Small mammals dispersed thirteen species of tree

seedlings, from a total of 15 animal-dispersed species. It is possible that small mammals dropped tree seeds in the *Erythrina stricta* control sites before arrival this tree species.

Effects of remnant tree size on seedling establishment

There was no relationship between remnant tree size and the density of tree seedlings, established beneath their crowns. A similar result was obtained by Toh *et al.* (1999). However, the results showed some variation when each parameter of tree size, dispersal mechanism, and remnant tree species were considered.

The parameters of tree size, tree height, GBH, and width of crown showed different results. There was no relationship between tree height of any of the remnant tree species with seedling density, but there was a relationship between GBH and crown width. Therefore, tree height might not influence seedling establishment beneath their crown, whereas crown width and GBH might have more influence.

Crown width determines shade and influences soil moisture content (Verdú and García-Fayos, 1996). Such factors may then influence the density and distribution of tree seedlings (Maguire and Forman, 1983). Increasing the width of *Albizia chinensis* crowns increased seedling density, especially of animal-dispersed species. In general, animal-dispersed seedlings are often climax species, which like to establish in shade, whereas wind-dispersed seedlings are often pioneer species, which are shade-intolerant (Whitmore, 1989). Pathogens are another cause of most seedling mortality (Augsburger, 1983). Animal-dispersed species seem to resist pathogens

better than wind-dispersed species (Schupp *et al.*, 1989). Consequently, low shade under *Albizia chinensis* might provide suitable conditions for seedling establishment.

However, the dense evergreen crown of *Castanopsis diversifolia* shaded out weeds and natural seedlings, especially of animal-dispersed species that constitute a large proportion of the seedlings. Most animal-dispersed seedlings might be killed by predators or be disturbed by some mammals that dig soil to forage for food under tree canopies.

Surprisingly, seedling density below *Eucalyptus camaldulensis* crowns decreased with increasing GBH, but there was no significant relationship with crown width. RFD (1997) reported that *Eucalyptus camaldulensis* competed efficiently for soil moisture content and that chemical substances (1,8 - cineole and α - pinene) in Eucalyptus oil from the leaves (terpenes) can inhibit seed germination and plant growth. It is possible that larger trees have a higher efficiency to compete for soil nutrients, and drop more leaves, which inhibit seedling establishment.

Species richness beneath remnant tree crowns increased with all parameters of tree size, height, GBH, and crown width. But species richness per unit area decreased with increasing tree size, which agrees with the results of Toh *et al.* (1999). However, the results showed some variation depending on each parameter of tree size, dispersal mechanism, and remnant tree species considered.

There was no relationship between tree height and species richness per unit area, but there was an inverse relationship with GBH and crown width. Increasing width of *Castanopsis diversifolia* and *Schima wallichii* crowns was associated with a

decline in species richness of natural seedlings. Declining seedling density beneath *Castanopsis diversifolia* might cause declining species richness of seedlings. Species richness of establishing tree seedlings declined with increasing GBH and crown width of *Schima wallichii*. This may have been due to the creation of a more homogenous environment beneath the larger *Schima wallichii* trees.

Increasing girth at breast height of *Schima wallichii* was related with decreasing of the species component of animal-dispersed species, as the width of crown, because the GBH of *Schima wallichii* related with the width of their crown ($P < 0.05$).

A previous study indicated that plant diversity beneath a *Eucalyptus* plantation was inversely related to canopy cover (Bone *et al.*, 1997). However, this study did not find such a relationship. Soil properties and micro climatic conditions under *Eucalyptus* might provide unsuitable conditions for many tree seedling species. Consequently, there were only 15 seedling species found under *Eucalyptus* crowns, the lowest species richness compared with the other tree species.

Growth rate of natural seedlings

Trema orientalis (L.) Bl. (Ulmaceae) grew very fast compared with other natural tree seedlings (Table 19). This species is a pioneer tree in open, disturbed areas, and secondary growth forest (Maxwell, 2001). Its seeds are dispersed by birds. Moreover, it has been suggested for planting for restoring forest in degraded areas in southern Vietnam (So, 2000). In Thailand, FORRU studied seed germination of this tree in their nursery and reported that the germination rate was low. Before using this

species as a framework species, we need to know how to increase the germination rate for seedling production.

This study did not find a clear difference in growth rate of natural seedlings below tree crowns compared with open areas. Tree crowns had no significant effects on RGR. This may have been because the trees were not large enough to permanently shade establishing seedlings. Moreover, other effects such as weed competition and soil conditions might have more influence on the growth rate of natural seedlings.

The role of birds in forest regeneration

Observations of birds visiting isolated trees indicated that very few bird species are able to increase the seed rain in disturbed areas, and the most important species are bulbuls.

Schima wallichii was the most attractive remnant tree species to birds. Although, a large proportion of the birds visiting this species were insectivores, such as *Pericrocotus cinnamomeus* (Small Minivet) and *Phylloscopus inornatus* (Inornate Warbler), this species also greatly attracted *Pycnonotus aurigaster* (Sooty-headed Bulbul) and *Pycnonotus flavescens* (Flavescent Bulbul), which might be the most important birds that enhance seed deposition below their crowns. These results correspond with seedling data in this study. Consequently, planting *Schima wallichii* as a framework species could probably greatly increase the seed rain in deforested areas and accelerate forest regeneration.

During the observation period, *Callicarpa arborea* var. *arborea* produced fleshy fruits which attracted more frugivorous birds than the other trees studied,

except for *Schima wallichii*. Willson and Crome (1989) suggested that although the seed rain of animal-dispersed tended to be higher under fruiting trees than non-fruiting trees, the effect of fruit resources also depends greatly on the social, foraging and digestive behavior of frugivorous involved.

Once problem of this study was bird observation visiting to the remnant trees studied only a few months, March to May. Season had strongly influence on trees providing flower/fruits, which attracted birds. Then, the timing of bird observation will affect birds seen.

Comparing bird observations with a previous study (Scott *et al.*, 2000) in the same area, only bulbuls (Sooty-headed Bulbul and Red-whiskered Bulbul) were observed visiting both artificial perches and the trees in this study. This suggests that differences between artificial perches and natural perches have a strong influence on the species of birds visiting. Artificial perches might be attractive to birds, which are not usually shy and like to perch in low places. While complexity of natural perches, such as tree branches might useful to attract many birds visited.

Although isolated trees in deforested areas clearly attract birds and increase the seed rain, however a large proportion of seeds fail to develop into seedlings (McClanahan and Wolfe, 1993; Toh *et al.*, 1999; Hardwick *et al.*, 2000b). Thus, further research is needed to find out how to increase seedling recruitment.

Observations of fruiting trees indicated that the commonest birds which fed on fleshy fruits, were bulbuls. This agrees with Kuarak and Hitchcock (1998) and Sanitjan (2001). Lambert (1989) demonstrated that bulbuls (*Pycnonotus* spp.) can

disperse seeds over several kilometers and can retain seeds in their digestive tracts for up to 40 minutes.

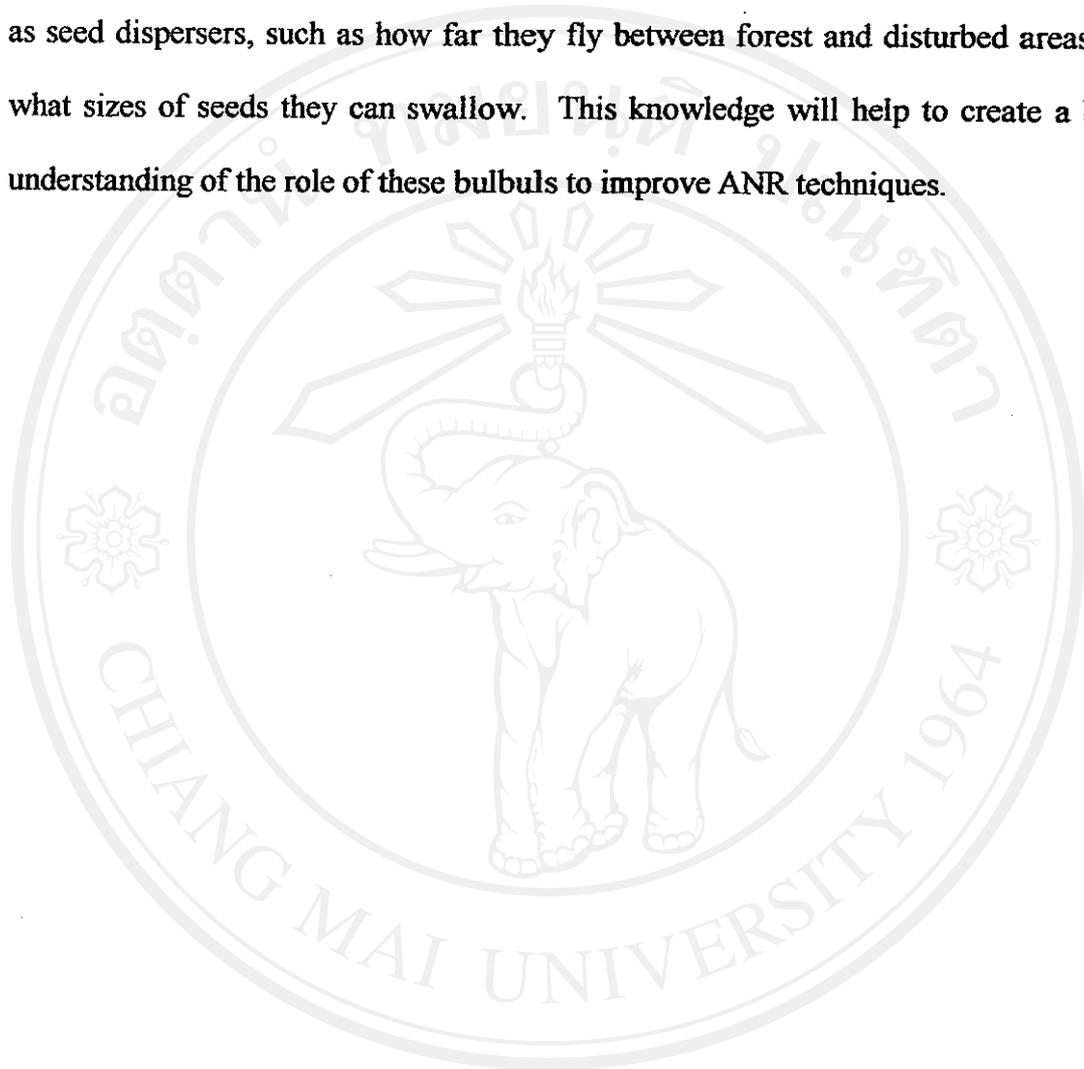
Bischofia javanica was very attractive to many birds. This might have been because this tree was located far from human activity and produces a favorite fruit for many bird species. Sanitjan (2001) noted that many birds were observed on fruiting trees, which have fleshy, small, ripe fruits and big crowns.

It was surprise that few birds visited fruiting trees of *Debregeasia longifolia* and *Heynea trijuga*. Both of these fruiting trees were located near a dirt road and human activity. I observed, birds would fly out every time a human came near, so disturbance may have reduced the species observed. The birds observed were often those tolerant of human activity, e.g. *Pycnonotus jocosus* (Red-whiskered Bulbul). These bird species can adapt their behavior and invade man made habitats (Portigo, 1994).

For trees with abundant fruits, e.g. *Bischofia javanica* large bird flocks would visit and break up into smaller groups, whereas trees offering limited food supplies, e.g. *Debregeasia longifolia* and *Heynea trijuga* tended to attract on individuals or very small groups of bird which entered and left in rapid succession. Such behavior reduces competition for food and perch places (Singhakan, 1986).

Three bulbul species, *Pycnonotus aurigaster* (Sooty-headed Bulbul), *P. flavescens* (Flavescent Bulbul), and *P. jocosus* (Red-whiskered Bulbul) were observed at both deforested areas and intact forest. These bulbuls help to accelerate forest regeneration in disturbed areas by consuming seeds in the forests and depositing them

under perch trees. However, more needs to be known about what limit these bulbuls as seed dispersers, such as how far they fly between forest and disturbed areas, and what sizes of seeds they can swallow. This knowledge will help to create a better understanding of the role of these bulbuls to improve ANR techniques.



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