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Final Report to the Biodiversity Research and Training Programme

Seed rain in the abandoned grassland of lowland rain forest in Khao Pra Bang Kram Wildlife Sanctuary, Krabi, Thailand

(BRT R352123)

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การศึกษาการกระจายเมล็ดพืชในป่าที่ราบต่ำบริเวณเขตรักษาพันธุ์สัตว์ป่าเขาประ-บางคราม

บทคัดย่อ

เนื่องจากพื้นที่ป่าเขตร้อนได้มีการลดลงอย่างรวดเร็ว การปลูกป่าเป็นแนวทางหนึ่งที่ได้มีการนำมาใช้อย่างแพร่หลายเพื่อคืนสภาพป่า แต่พื้นที่เหล่านั้นมีเมล็ดในดินค่อนข้างน้อย จำเป็นต้องอาศัยสัตว์ในการนำเมล็ดจากภายนอก แต่การนำเมล็ดของสัตว์ขึ้นกับหลายปัจจัย ได้แก่ ความหลากหลายของพื้นที่ได้แก่ ใต้ต้นไม้ใหญ่ ใต้ไม้พุ่ม บริเวณทุ่งหญ้าโล่งๆ และระยะห่างจากขอบป่าซึ่งอาจเป็นแหล่งที่มาของเมล็ด เป็นต้น ดังนั้นการศึกษาถึง การกระจายเมล็ดในลักษณะพื้นที่ที่แตกต่างกันและระยะห่างจากป่าต่างๆในแปลงปลูกป่าจึงเป็นเรื่องสำคัญ การศึกษาในครั้งนี้มีวัตถุประสงค์ เพื่อเปรียบเทียบการกระจายของเมล็ดพืชในบริเวณทุ่งหญ้า ในบริเวณที่แตกต่างกัน คือ ใต้ต้นไม้ ไม้พุ่ม และกลางทุ่งหญ้า และ ระยะห่างต่างๆจากขอบป่า ศึกษาหาสัตว์ที่เป็นตัวกระจายเมล็ดในพื้นที่ที่ต่างกันบริเวณทุ่งหญ้า การศึกษาในครั้งนี้ทำการศึกษาบริเวณเขตรักษาพันธุ์สัตว์ป่าเขาประ – บางคราม ทำการศึกษาโดยวางกับดักเมล็ดบริเวณต่างๆในแปลงทุ่งหญ้า คือ ใต้ต้นไม้ ใต้ไม้พุ่ม และกลางทุ่งหญ้า บริเวณละ 30 กับดัก วัดระยะทางจากขอบป่าไปยังจุดที่ตั้งกับดัก จากนั้นเก็บข้อมูลความหลากหลายและความหนาแน่นของเมล็ด พร้อมทั้งแยกเมล็ดที่ถูกนำโดยนก ค้างคาว และลม วิเคราะห์หาความสัมพันธ์กับลักษณะพื้นที่ต่างๆและระยะห่างจากป่า รวมทั้งสำรวจสัตว์ที่เป็นตัวพาเมล็ด จากการศึกษาพบว่าพื้นที่มีผลต่อจำนวนเมล็ด โดยพบเมล็ดจำนวนมากที่สุดใต้ไม้พุ่ม รองลงมาคือ ใต้ต้นไม้ และกลางทุ่งหญ้า ส่วนระยะห่างจากขอบป่าพบว่ามีผลต่อจำนวนเมล็ดใต้ต้นไม้เท่านั้น และพบว่านกเป็นสัตว์พาหะสำคัญในการนำเมล็ดมายังบริเวณใต้ต้นไม้ ส่วนค้างคาวมีบทบาทสำคัญในการนำเมล็ดมายังทุ่งโล่ง จากการศึกษานี้พบว่าทั้งนกและค้างคาวมีส่วนสำคัญในการกระจายเมล็ดมายังพื้นที่ปลูกป่านี้

Seed rain in the abandoned grassland of lowland rain forest in Khao Pra Bang Kram Wildlife Sanctuary, Krabi, Thailand

Abstract

There are several factors that limit the rate of forest recovery, which the major one is lacking of seed dispersal. The mosaic habitat types (e.g. isolated tree, shrub, open grassland)in the reforested area and distance from the forest edge may result in the difference of seed rain abundance and diversity. In this study, we determined whether the diversity and abundance of seed rain in different mosaic habitats and distances from the forest edge from November 2009 to October 2010 in 20 ha grassland at Khoa Pra Bang Kram widelife sanctuary, which is surrounded by the secondary forest planted with seedling of forest trees. We set paired seed traps (night and day trap) in the different distances from the edge under shrubs, trees, and in open grassland (n=30 in each micro-habiat). The seed abundance and diversity between the each micro-habitat and distance from the forest edge was analyzed and discussed. The species and frequency of seed dispersers at each site were observed. The result showed that there was significant effect of treatment (different micro-habitats) on seed rain number (Kruskal wallis' test, $P< 0.001$). Seed rain was highest under the shrub and following by under tree and in open grassland. Distance from forest edge effect the number of seed rains in all treatments (GLM, $P <0.001$). The main seed dispersers under the shrubs and trees were bird; Bulbul, flowerpecker, etc, while bats play the important role of seed disperser in open grassland. From this study, birds and bats are the dominant seed dispersers, so planting mixture trees may attract more seed dispersers to this area.

Acknowledgements

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Chapter 1

Introduction

The early successional forests need the dispersal animals to introduce the seed from outside because the soil is deficient in seed bank (Duncan and Chapman, 1999, Slocum, 2001). There are several factors that limit the rate of forest recovery, including lack of soil nutrients, competition with aggressive grass, seasonal drought, low rates of seed colonization, and seed and seedling predation (Aide & Cavelier, 1994, Holl, 1999). However, the major factor that limits the forest recovery is lacking of seed dispersal (Holl, 1999).

The spatial pattern variation may influent the pattern of seed rain, which will be deposited to those areas. For instance, in the early succession forest, many fruits and seeds are dispersed to under the trees or shrubs that could be the nurse plant (Godinez et al., 2002, and Gomez-Aparicio et al, 2004). Nepstad et al. (1990) found that seed are more concentrated beneath shurb-like lianas and trees that produce fruit throughout the year. This pattern is similar with the study from Au et al. (2006) the mean seed rain was highest under the fruiting female isolated shrubs in the grass land. In addition, most of seeds deposited under shrub were the vertibrate-dispersed seeds, while the seeds in open areas are wind-dispersed seeds (Willson and Crome, 1989). The seed rain under the freshy fruit shrubs have the higher number of species and seed density than in open area or wind-dispersal seed tree because the shrubs provide the perches and food for vertebrates such as birds, bats which are the seed disperser (Willson and Crome, 1989, Nepstad et al. 1990, and Au et al 2006). However, there is no difference in the numbers of species or of seedling density beneath the canopy of wind-dispersed and freshy-fruited-dispersed trees (Toh et al., 1999). The former studies indicated that the spatial pattern of seed rain in the degraded grassland landscape is unique, which may be associated with seed dispersers or distance from the forest.

The common seed dispersers in old world tropical rain forest are birds, fruit bats and some small mammals (Primack and Corlett, 2005). There are some major differences between the roles of frugivorous bats and birds. For example, birds usually spend time longer at the fruiting trees and are more likely to defaecate under these trees than fruit bats or carry fruit to a perch before droping or defaecating the seeds while bat were much higher deposit seeds in clear-cut area than birds are (Bronstein and Hoffmann, 1987; Gorchov et al., 1993; Kalko et al., 1996; Corlett, 1998). This may lead to the different seed rain patterns in the mozaic habitats of forest restoration area. The seed rains in the grassland may be more likely to be deposited by the wind and fruit bats, while the seed rains under the shurbs or trees in grassland may be brought by birds.

The distance from the forest, which is the source of seed has the significant impact on the seed rain in grassland area. The previous studies found that the number of seeds and the seed diversity at the study sites near to the forest edge is much higher than the places that were far from the edge because the birds and bats, the main seed disperser, avoid the huge open area (Cubina and Aide, 2001, Ingle, 2002, Devlaeminck et al, 2005). In contrast, in some studies found no significant difference of the seed species between the near and far plots from the forest edge because seed deposited beneath the tree was not strongly dependent on the forest as the seed source at the distance (Willson and Crome, 1989, Guevara et al., 1992, Duncan and Chapman, 1999, and Duncan and Duncan, 2000).

The pattern of seed rain in different mosaic habitats and distances from the forest edge is distinct in each area. Moreover, most of reforestation techniques treat the remnant shrubs as competitors against newly planted tree seedlings; thus shrubs and weeds are cleared before tree plantation (Savill et al. 1997, and Elliott, et al. 2006), even the shrubs in grassland may attract seed disperser to that area. Thus in this study we will examine the seed rain in the forest restoration to answer the following questions:

1. Does pattern (abundance, species number) of seed rain differ among micro-habitat types?

   Predictions: abundance of seeds and species richness will be greater below shrubs & trees or artificial trees than open areas.

2. Do seed dispersers differ among micro-habitat types?

a) Seed rain under shrubs, and trees will be mainly deposited by the birds, while the majority of the seed rain in the open grassland will be dropped by the wind and bats.

b) The species of bird dispersers are likely to change with microhabitat type and distance from forest. The number of seed dispersing birds is likely to be similar with different distance from forest but the proportion of bulbuls will increase with increasing distance from forest. Is there the difference in species of bird using tree and shrub? Is there edge effect on Bulbul?

3. Does distance from forest edge affect the pattern of seed rain?

   Prediction: amount of seed rain should decline as distances increase away from forest edge

Chapter 2

Materials and methods

Study site

This study was carried out from November 2009 to October 2010 in Khao Pra Bang Khram Wildlife Sanctuary, Krabi Province, southern Thailand (8° 10' N, 98° 80' E, figure 1.) at an elevation of 100 m. Krabi Province has a distinct dry season from December to March with rain lesser than 150mm and temperature range from 31 to 35 °C. The actual rainy season start in the mid of April and peaking in September (419 mm). The annual rainfall in 2010 is >2000 mm (Krabi meteorological station). On everage, the warmest month is March (33 °C), and the coolest month is January (31 ° C).

The Khao Pra Bang Khram Wildlife Sanctuary covers remnants of lowland rain forests which largely disappeared from peninsular Thailand. Oil palm and rubber plantation has been the major causes of forest loss in this area. After the area has established as a wildlife sanctuary in 25 patches of rubber and oil palm plantations inside the forest were clear, and become grasslands (Figure 2). The present study carried out in 20 ha grassland which is relatively flat. The study site is surrounded mostly by primary lowland evergreen forest. The permanent streams run at the West edge of this grassland. Generally, the common flora in this forest are *Hedyotis pachycarpa*, *Phsychotria curviflora* (Rubiaceae), *Clausnea excavata* (Rutaceae), *Enicosanthum fuscum* (Annonaceae), *Schima wallichii* (Theaceae), *Chaetocarpus castanocarpus* (Euphorbiaceae). In early successional stage in cleared areas or large gaps, the vegetation is characterized by herbaceous weeds: *Ageratum conyzoides* and *Eupatorium odoratum* (Compositae), woody species: *Ziziphus oenoplia* (Rhamnaceae), and *Melastoma malabathricum* (Melastomataceae)(Figure 3, Maxwell, 2009).

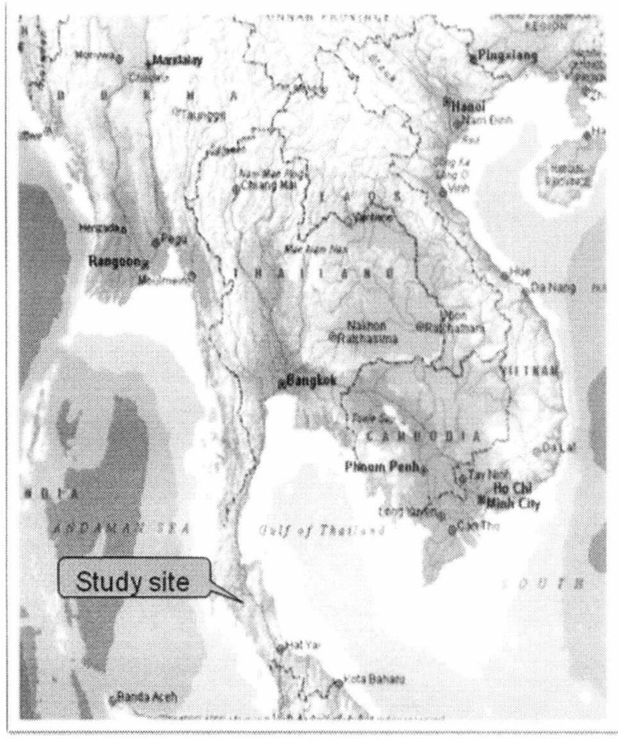


Figure 1. The map of study site at Khao Pra Bang Khram Wildlife Sanctuary, Krabi Province, southern Thailand

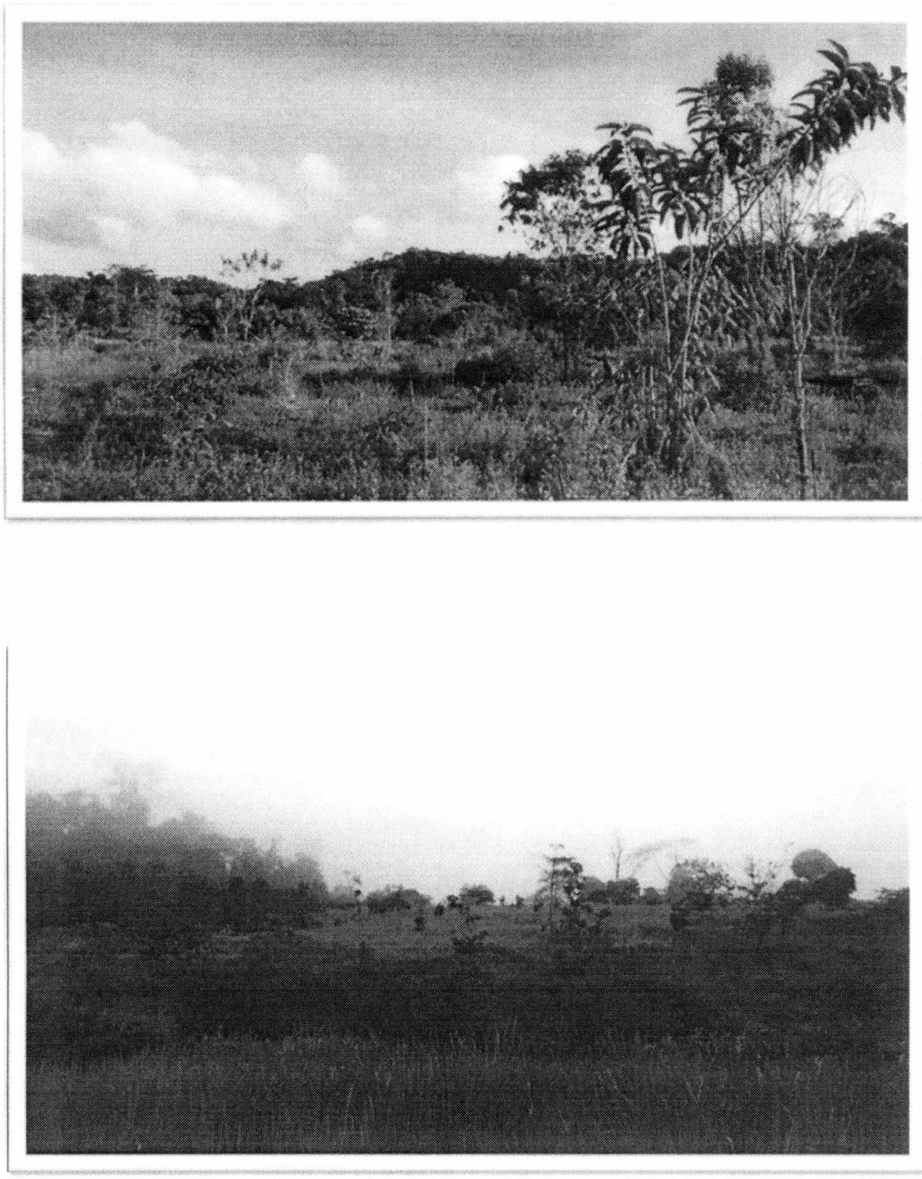


Figure 2. Open grassland where forest restoration has been established.

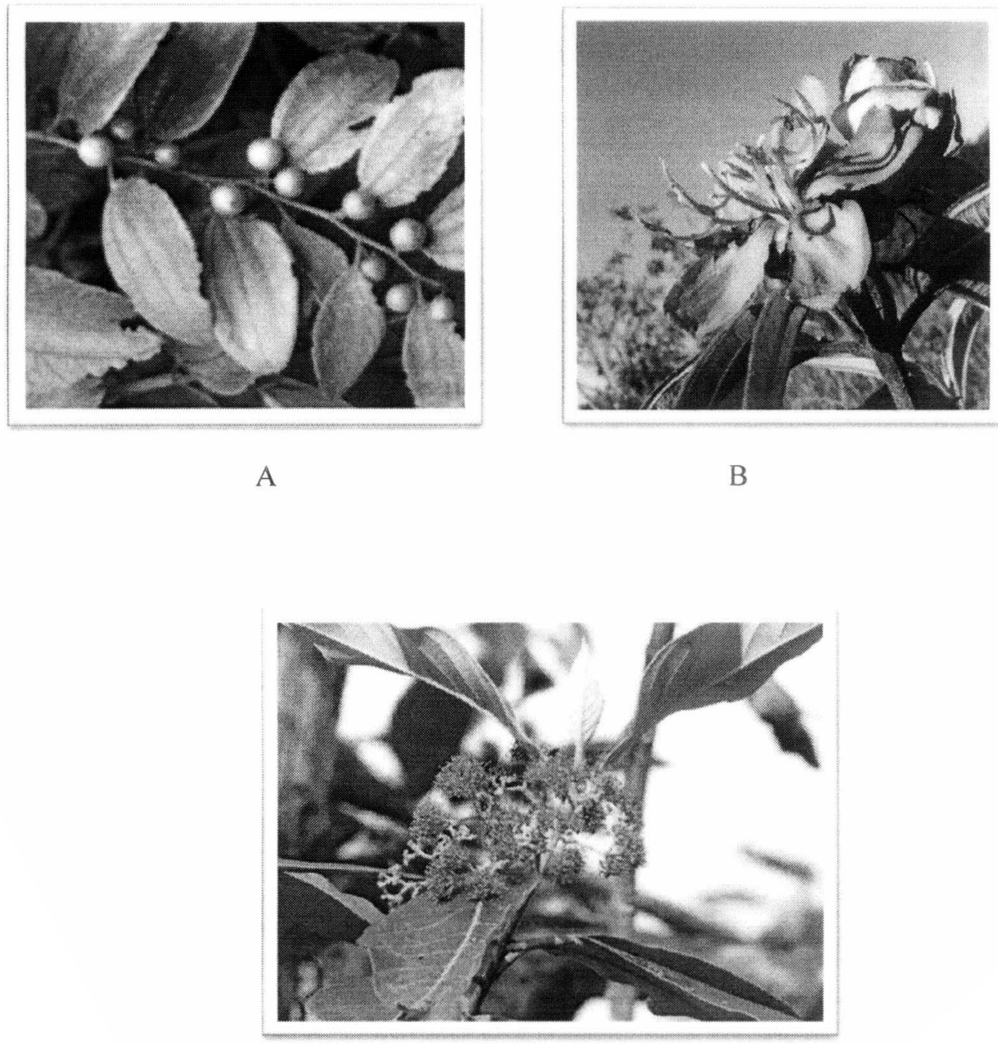


Figure 3. The generally flora in grassland are (A) *Ziziphus,*(B) *Melastoma*, and (C) *Callicapa*

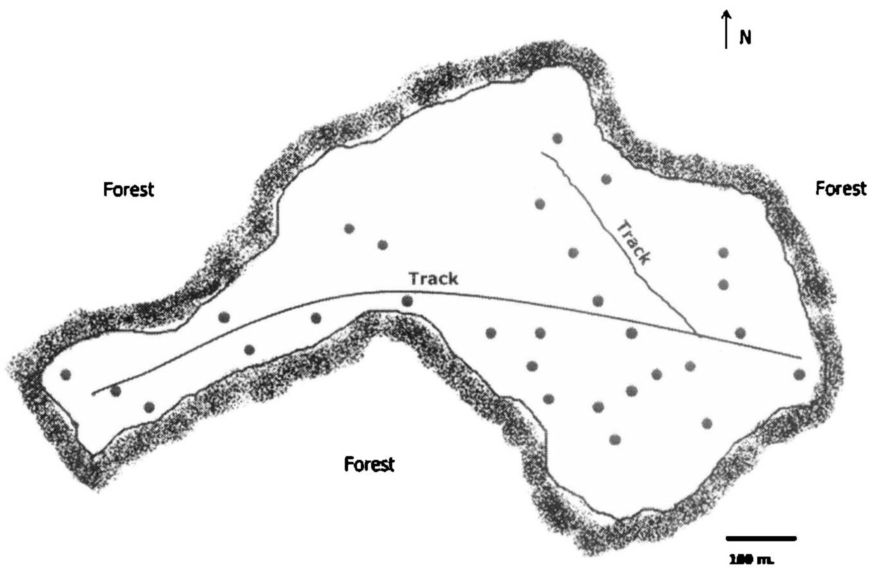


Figure 4. Map represents the study site in Kao Pra Bang Kram, Krabi. Seed rains samples were taken from 30 trios (black dot) in the open grassland.

The study grassland was also the forest restoration site lead by the Forest Restoration Unit, Chiang Mai University which was started in 2009. In this program, restoration plantings consisted of several native species such as *Garcinia merguensis, Vatica odorata, Eugenia grandis, Madhuca malaccensis* were planted (at a height of 0.5-1.0 m at a density of 3,000 trees per hectare over an area of 0.32 ha on the eastern edge of the grassland. The remaining grassland area was replanted with a mixture of exotic (*Acacia mangium, Acacia auriculiformis*) and native species (*Parkia speciosa*) by the wildlife sanctuary. However, most (>80%) of planted seedling was died during the long drought period of 2010

Seed rain

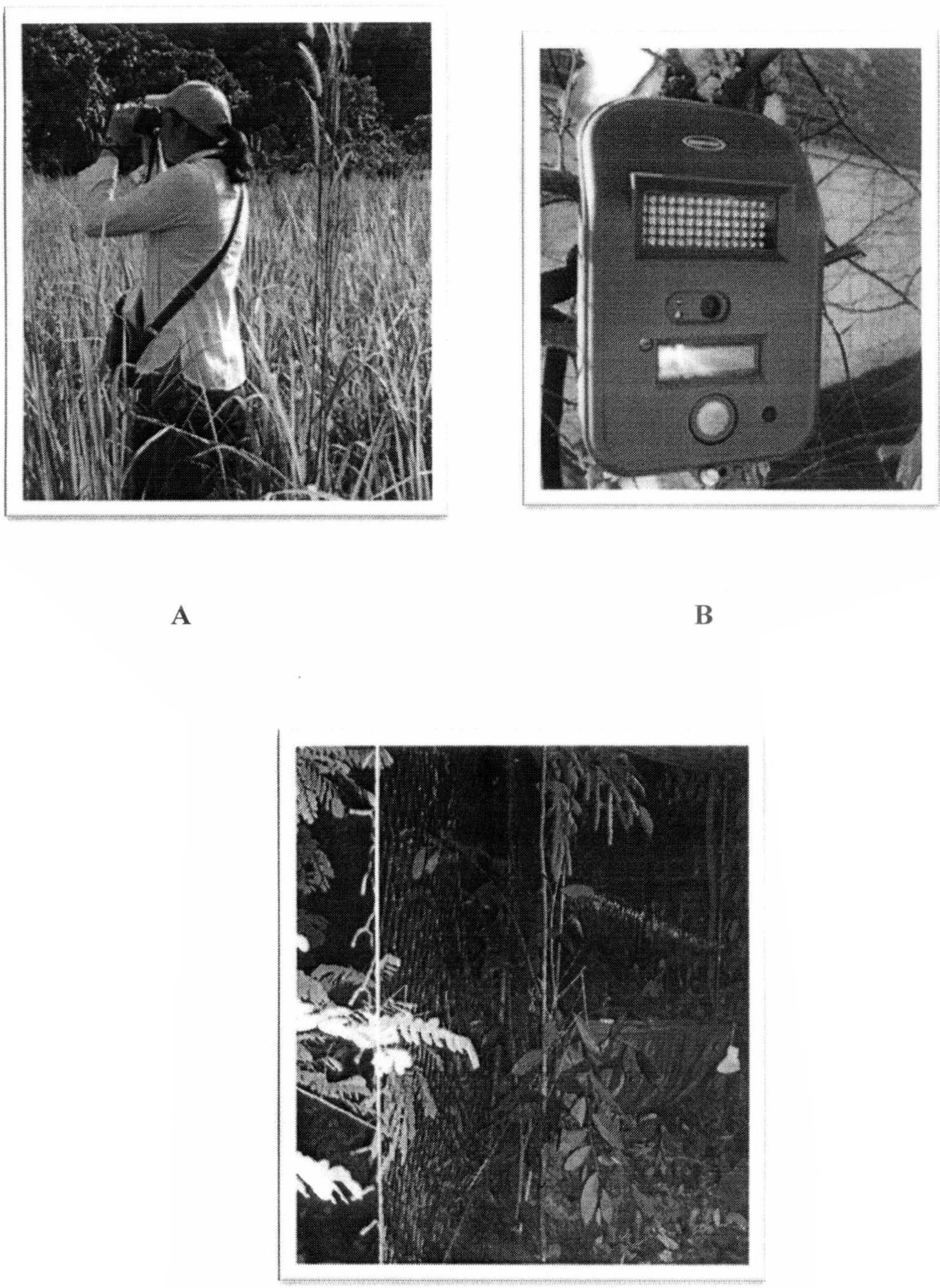
Seed rain were collected with 1 m^2 seed traps (Figure 5) set along or within 200 m of an approximately 2 km rough car track within the grassland. Seed trap were made of wooden flame covered with black plastic sheets which is supported by wooden legs set over the ground for 0.5 m. Strings attached at each corners of plastic sheet were tied with each leg to hold it against wind or rain. Plastic sheets were pierced for draining and covered with polyester cloth at the bottom. All seed traps were placed in trios (traps < 10 m apart in each trio), with two traps in each trio set in open grassland, two set under a fruiting *Callicarpa arborea* and two set under *Melastoma malabathricum* shrub, totaling 30 trios (Figure 4). We collected seed rain both in the morning and evening in the first month of study to gain the capability to identify bird and bat seed dispersal. Then, trapped seeds were collected and cleaned every morning for 10-15 days each month (10.83 $\pm$ 1.94 days). Traps were cleaned prior to the start of the monthly trials. All fecal seeds and pulp lacking seeds were classified as being dispersed by bird, bat, or small mammals. The pulpy seeds were assumed to be fallen from trees over seed traps. The visible seed samples were identified by comparing with the reference collection of a plant phenology research carried out in the area nearby, and also from PSU herbarium. Most seeds were identified into species, but some seeds could be indentified only to genus namely *Ficus, Ixora.* The small seeds such as *Ficus* or animal feces, which could not be identified from seeds, were planted in nursery house. The seedlings were record as species present but were not analyzed quantitatively. At each tree, we measured the distance from the forest edge, and number of trees within 10 m radius from traps.

Figure 5. One square meter of seed trap for seed rain collecting, made from plastic.

Animals observation.

Bird surveys were conducted along the track and among the isolated trees in the grassland (Figure 4). Surveys were conducted 10-15 days per month from 7:30-10:00 (total of 360 hour) on the same days that seeds were collected. We counted and compared the frequency of observed seed dispersing birds focusing primarily on those using trees and shrubs, however those using herbaceous vegetation were also noted.

Bats were netted in both wet and dry season (Figure 6(C)). The mist nets were set in various locations in early evening of 10 nights between May and August 2010 for a total of 150 net hours. Bats were identified following Francis (2008). To observe the terrestrial mammals, the camera traps were set near tracks. We set 3 camera traps a total of 180 trap nights.



A B

C

Figure 6. Animal observation; A) using binocular for bird observation, B) using camera trap for small mammals, C) using mist net for trapping bat.

Statistical analyses

Seed rain abundance data were not normal distribution so square root data transformation was applied. A one-way analysis of covariance was conducted to evaluate the effects of treatment, distance from forest edge, and interaction between them on the number of seed rain and species number of seed rain (normal distribution). Multiple comparisons (LSD test) were conducted to test for differences between group means.

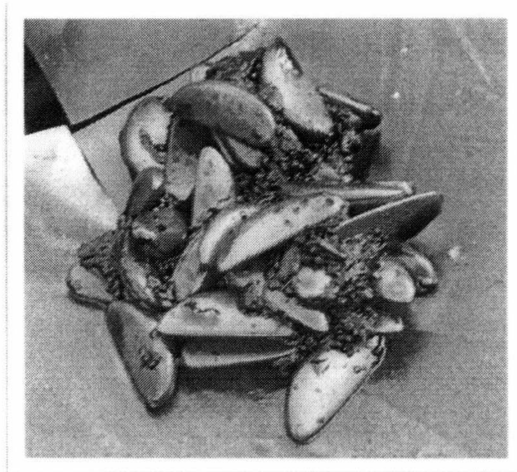
Chapter 3

Results

Seed rain

A total of 66,305 seed of 40 plant taxa (Table 1) were recorded in one year from 180 1 m^2 seed traps (total trap effort 561,600 hour). Most seed rains (77%) were collected from June to November with a peak during August to October (Figure 8). In terms of species richness, a majority of seed rain species were dispersed by bird (27 taxa) while a minor were from wind (7 taxa), bat (5 taxa) and civet (1 taxa) shown in figure 7.

A



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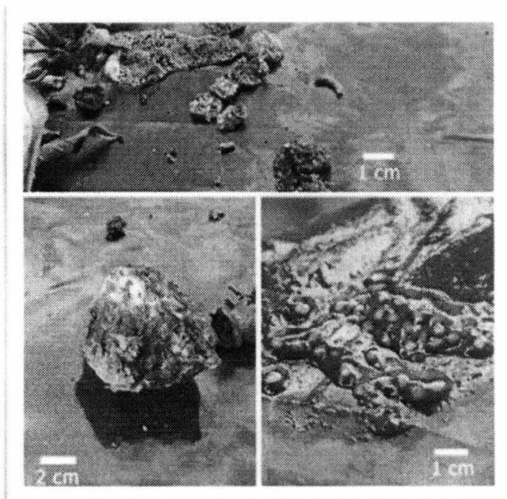


C

Figure 7. Seed rain from seed trap dispersed by; A) Bird, B) Civet, and C) Bat

Table 1 Species that were found in seed rain. Seed dispersal animal were identified from all fecal seeds. SQ = squirrel; BD = bird; WD = wind; BT = bat; CV = civet.

Family	Species	Dispersal agents
Arecaceae	*Elaeis guineensis*	SQ
Annonaceae	*Uvaria hahnii*	BD
Bignoniaceae	*Oroxylum indicum*	WD
Bignoniaceae	*Pajanelia longifolia*	WD
Chrysobalananaceae	*Parinari anamense*	BD
Compositae	*eupatorium odoratum*	WD
Dipterocarpacaea	*Hopea odorata*	WD
Dipterocarpacaea	*Shorea gratissima*	WD
Euphorbiaceae	*Antidesma ghaesembilla*	BD
Flagellariaceae	*Flagellaria indica*	BD
Labiateae	*Callicarpa arborea*	BD
Leeaceae	*Leea indica*	BD
Lythraceae	*Lagerstroemia floribunda*	WD
Melastomataceae	*melastoma malabathricum*	BD, CV
Melastomataceae	*memecylon corticosum*	BD
Moraceae	*Ficus* sp1	BD, BT
Moraceae	*Ficus* sp2	BD, BT
Moraceae	*Streblus ilicifolius*	BD
Myrtaceae	*Eugenia grata*	BD
Myrtaceae	*Eugenia* sp.	BD
Myrtaceae	*Eugenia tumida*	BD

Myrtaceae	*Psidium guajava*	BD
Myrtaceae	*Rhodomyrtus tomentosa*	BD
Palmaceae	*Calamus javensis*	BD
Passifloraceae	*Passiflora foetida*	BD
Rhamnaceae	*Ziziphus oenoplia*	BD
Rubiaceae	*Ixora cibdela*	BD
Rubiaceae	*Lasianthus kurzii*	BD
Rubiaceae	*Morinda elliptica*	BD
Rubiaceae	*psychotria angulata*	BD
Rubiaceae	*Rennellia speciosa*	WD
Rutaceae	*Acronychia pedunculata*	BT
Sapindaceae	*Allophyllus cobbe*	BD
Sapotaceae	*Madhuca malaccensis*	BT, CV
Solanaceae	*Capsicum frutescens*	BD
Solanaceae	*Solanum torvum*	BT
Tiliaceae	*Microcos paniculata*	BD
Ulmaceae	*Trema orientalis*	BD
Verbenaceae	*Vitex* sp.	BD
Zingiberaceae	*Sostus speciosus*	BD

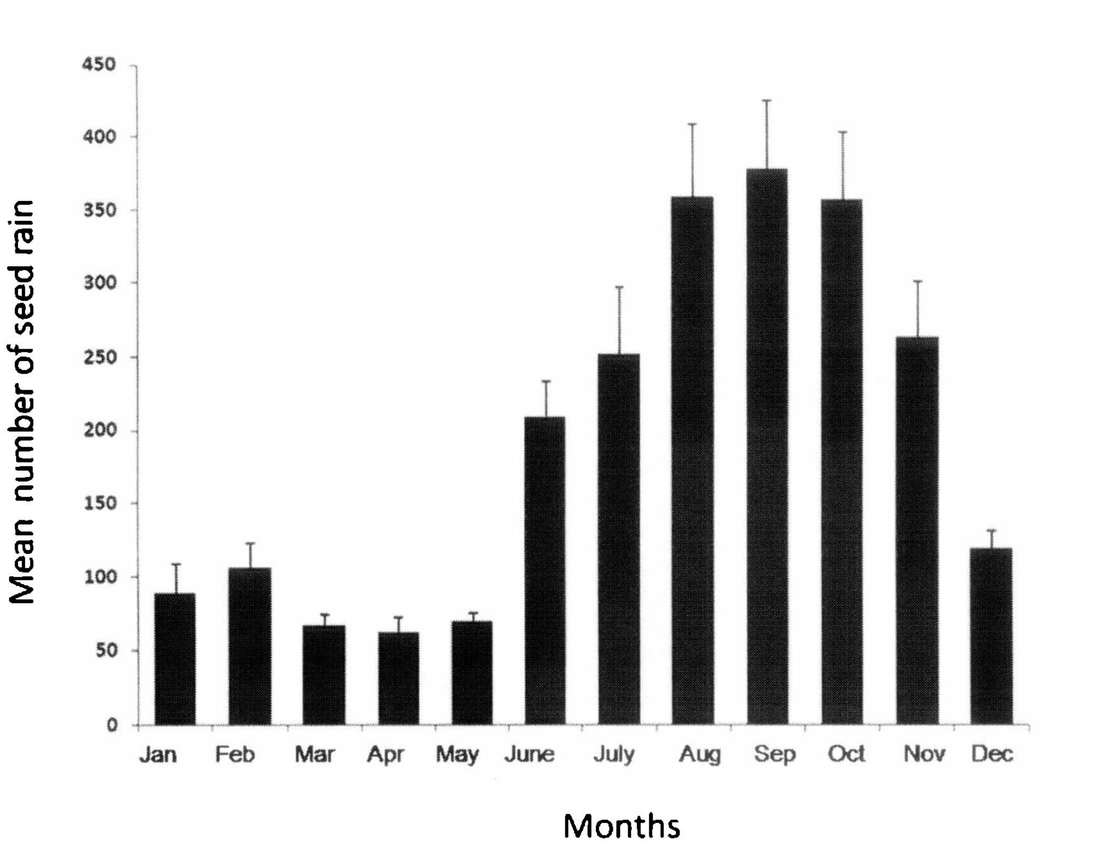


Figure 8. Pattern of seed rain in lowland rain forest in Thailand from November 2009 to October 2010

For species number from ANCOVA analysis, treatment and distance from forest edge had non significant interaction. Species number was not affected by treatments ($F_{2,87}$ = 2.697, P = 0.073). For the number of seed rain, seed number was significantly different between treatments (Table 2, Figure 9). Seed number was highest under shrub (mean $\pm$ SD = 1,237.6 $\pm$ 175.09, N = 30) and followed by under tree (mean $\pm$ SD = 806.24 $\pm$ 154.81, N = 30) and in open grassland (mean $\pm$ SD = 163.78 $\pm$ 140.26, N = 30). The significant interaction between treatment and distance from forest suggests that the relationship between seed number and distance from forest edge varied among treatment (Fig 10). Under tree treatment showed a sigificant negative regression of distance from forest on the number of seed rain (r^2 = 0.61, P <0.001, N = 29). Under shrub treatment (r^2 = 0.35, P = 0.84, N = 29) and in open grassland treatment (r^2 = 0.109, P = 0.076, N = 29) the regression were not significant.

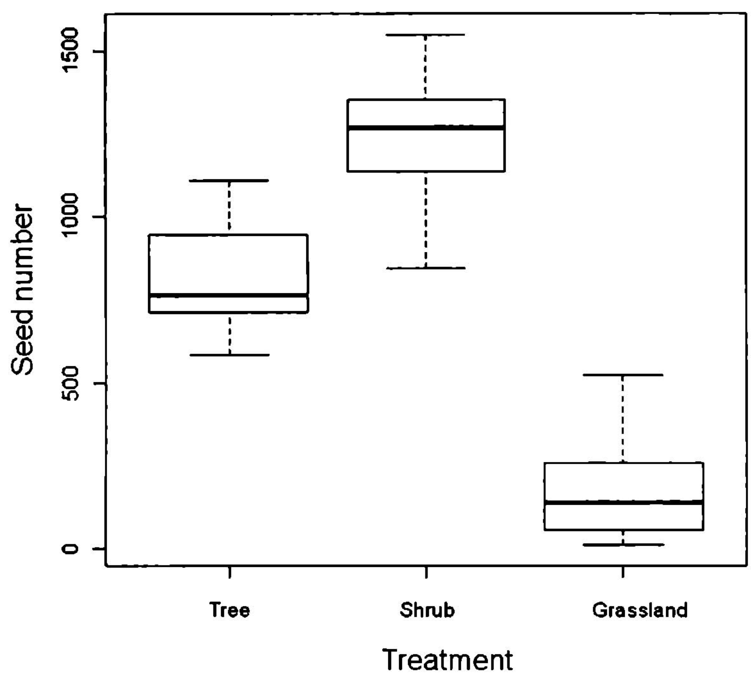


Figure 9. Number of seeds in each treatment; tree, shrub, and grassland

Table 2 Summary of Analysis of covariance to detect significant differences among treatment (under shrub, tree, and in open grassland), and distance from the forest edge with respect to the mean of seed number of seed rain.

Source	**df**	**Mean of Square**	***F* - ratio**	***P* – value**	**Partial R^2**
Seed number					
Treatments	2	1381.857	105.817	.000	.85
FD	1	2.944	.225	.636	.050
Treatment x FD	2	111.438	8.533	.000	.163
Model	5	1749.153	133.942	.000	.885

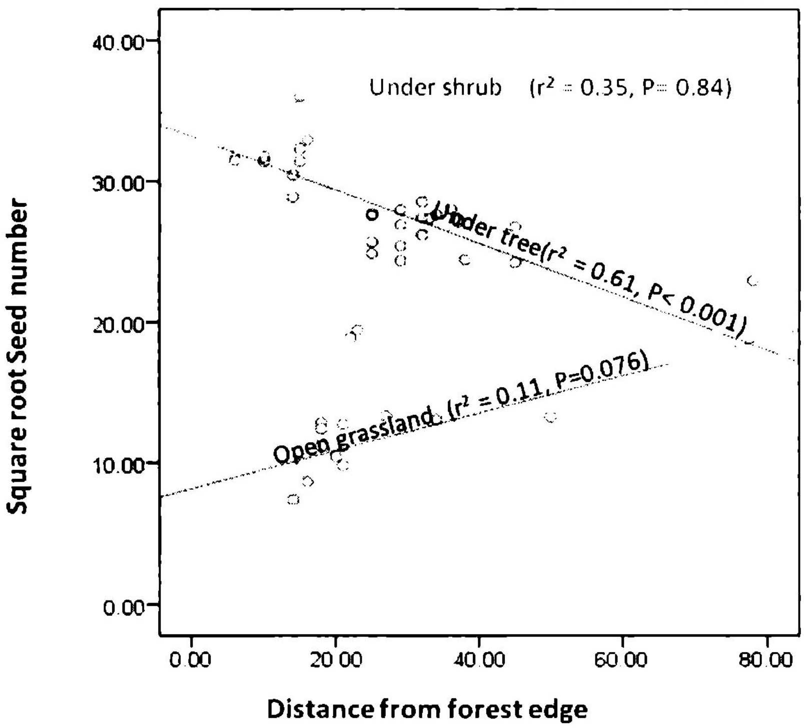


Figure 10 Seed number plotted against distance from forest edge for three treatments. Each point represents an individual place that seed trap was set.

Seed dispersers

Twenty three species of bird from 13 families were observed. The most common species are *Pycnonotus goiavier, P. atriceps, P. blanfordi* . The majority groups of bird were Bulbul, flower pecker, and Barbet (table 3, figure 11). The groups of bird dispersers are likely to change with microhabitat type. Bulbul and Barbet were observed in the larger number at tree than at shrub, while we found flower pecker at shrub more than at tree (Table 3). The frequency of Bulbul observed under tree were significantly different from under shrub (chi-square = 3.83, $p < 0.001$, df =1). This pattern also showed in Barbet (chi-square = 26.47, $p < 0.001$, df =1), Flowerpecker (chi-square = 20.00, $p < 0.001$, df =1). The frequency of Bulbul at tree was likely to decrease with different distance from forest (Fig 5, $r^2 = 0.04$, P = 0.34, N = 29, Figure 12). For other seed dispersers observed during the present study, two species of bat, *Cynopterus sphinx*, and *Megaerops ecaudatus* were netted, and *Viverra zibetha* were recorded from camera traps (Figure 13).

A

C

Figure 11 The most three common species of bird found in study area, which are A) Yellow vented Bulbul, B) Black headed Bulbul, C) Scarlet back flower pecker.

Table 3 Groups of bird found at shrub and tree, and proportion of each bird group.

	Barbet	Bulbul	flowerpecker	pigeon	White eye	Lesser green Leaf bird	Vernal Hanging Parrot	Asian Brown flycatcher	Black naped Oriole	Black naped monarch	Common Iora	Babbler	Green Broadbill
tree	32	2569	20	12	4	2	4	7	3	3	9	4	1
shrub	2	1345	60	9	1	0	5	3	0	0	12	1	0
proportion	**0.0083**	**0.9558**	0.0195	0.0021	0.0012	0.0005	0.0022	0.0024	0.0007	0.0007	0.0051	0.0012	0.0003

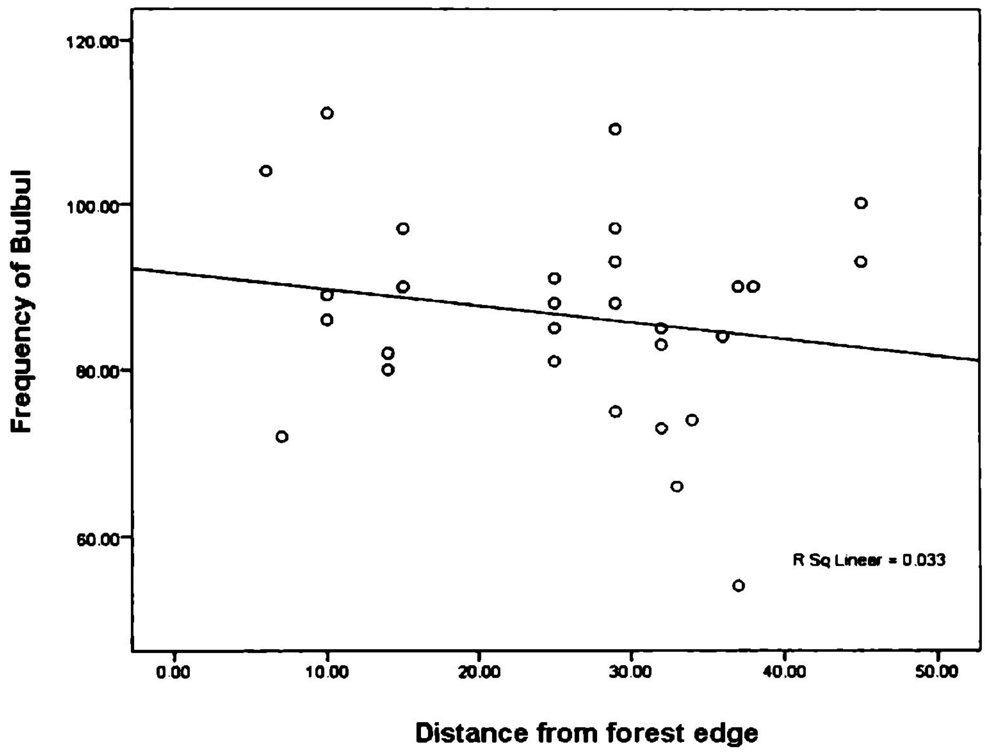
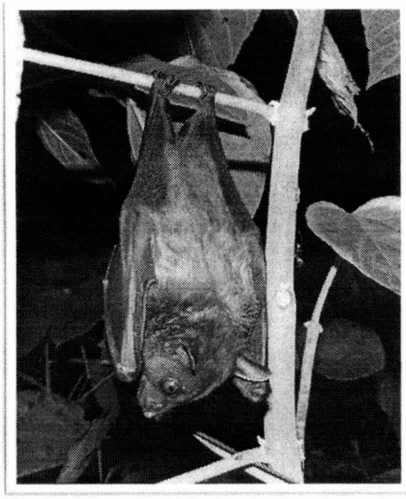
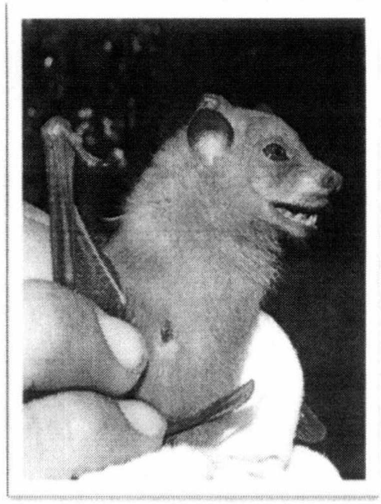


Figure 12 Number of Bulbul observed at tree plotted against distance from forest edge.



A



B

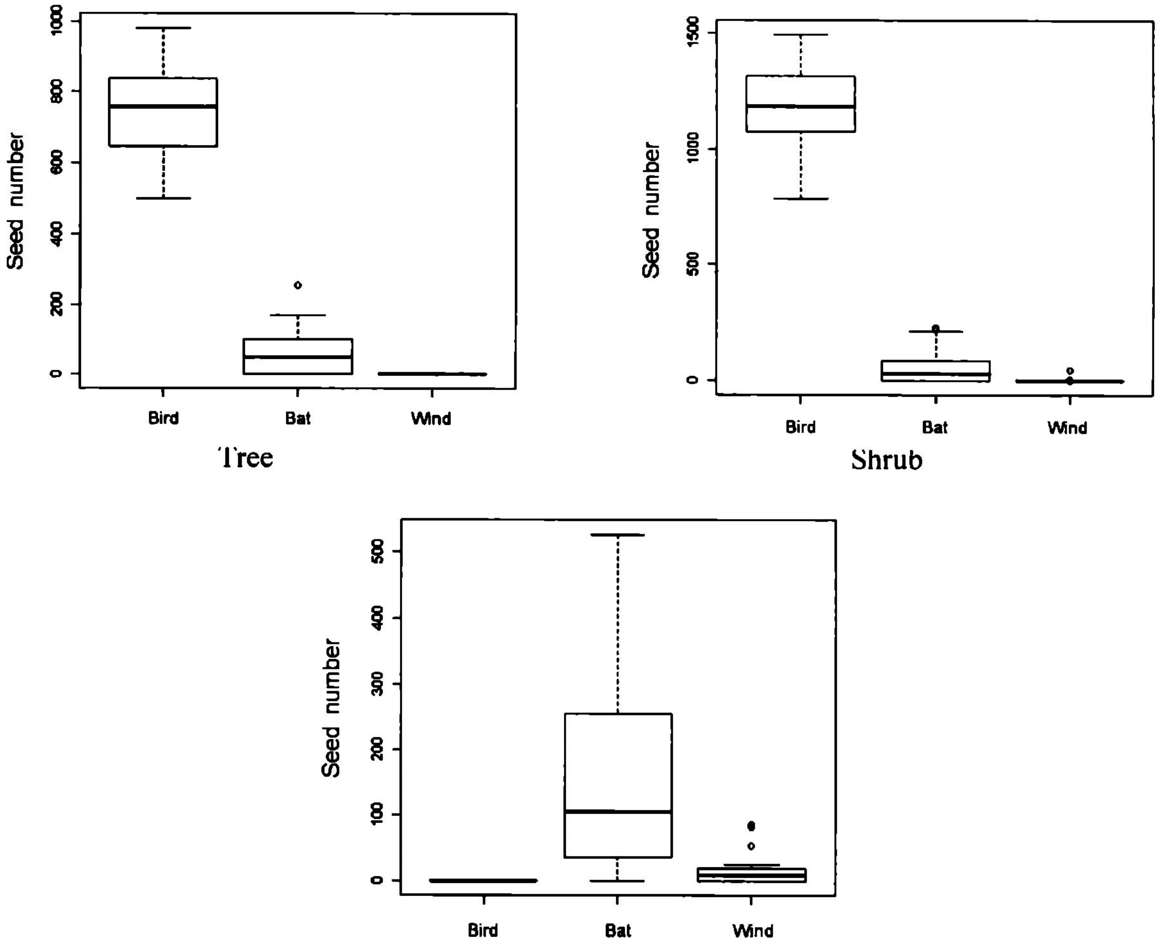
C

Figure 13. Fruit bat species and civet found in open grassland; A) *Cynopterus sphinx*, B) *megarops ecaudatus*, C) *Viverra zibetha*

According to seed dispersers from seed rain, We found that under shrubs and trees were mainly deposited by the birds, following by bat and wind, whereas, in open grassland the majority of seeds were dispersed by bat following by wind (Table 4, figure 14). Seed dispersed by bat in open grassland were significantly higher than under shrub and tree (U(59) = 608.5, Z = -2.42,0.012).

Table 4 Mean ± SD of number of seeds dispersed by bird, bat, and wind under tree, shrub, and open grassland.

	Mean ± SD of seed number		
	Bird	Bat	Wind
tree&shrub	935.59 ± 269.14	79.37 ± 87.42	30.12 ± 36.22
open grassland	0	155.33 ± 143.51	31.4 ± 37.28



Open grassland

Figure 14 Seed number of seeds dispersed by bird, bat, and wind in each treatment.

Chapter4

Discussion

Pattern of seed rain, particularly seed number under shrub and trees, were significantly higher than in open grassland. This is similar to the result of Au et al. (2006) study in upland plant communities in Hong Kong. Many other studies have shown that isolated shrubs and trees play the major role in effectiveness of perches in grassland (Toh et al. 1999; Guevara et al 2004)

Bird-dispersed seeds were the dominance in the seed rain under trees and shrubs, whereas bat dispersed seeds predominated over bird-dispersed seed in open grassland. Gorchov et al. (1993) found the similar pattern in Perunian lowland forest. This different seed rain pattern can be explained by different defecated behavior since bat and bird differ in that bats defecate during flight (Charles-Dominique, 1986; Corlett, 1998, 2006; Whittaker and Jones, 1994), whereas birds defecate seed while perched (Charles-Dominique, 1986; Corlett, 2006)

Under tree, in which most seed was dispersed by birds, amount of seed rain changes negatively with distance from forest edge, however, this relationship in open grassland the amount of seed rain which was dispersed by bats was not significant. Similarly, from study of Gorchov et al. (1993) in Amazonian rainforest, seed rain dispersed by bird show more decline with distance from forest edge than bat-dispersed seeds. In contrast, in the study from rainforest in Philippines, the negative relationship with distance for dispersal of forest seeds into the successional area was stronger for bats than for birds (Ingle, 2003). This reflects a failure of bird to disperse seeds to the big successional area.

Regarding to forest restoration, birds likely have a larger impact in areas that have already started to recover (e.g. some shrubs and trees present) whereas bats are potentially more influential seed dispersers for wide-open areas. Moreover birds and bats disperse different plant taxa. Both birds and bat are important for habitat restoration thus we need to emphasize more about the importance of their conservation.

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