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Original article

Ecology of *Ficus Racemosa* Linn and *F. Hispida* Linn.F. With Their Interspecific Relationships with Fig Wasp in Namtok Samlan National Park, Saraburi Provine

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ABSTRACT

The purposes of this research were determine to the ecological distribution of figs along the altitudinal gradient; phenology of two fig species, namely *Ficus. racemosa* Linn. and *F. hispida* Linn; and interspecific relationships of fig and fig wasp mutualism. The research was carried out in two selected forest types, namely mixed deciduous forest (MDF) and dry evergreen forest (DEF) at Namtok Samlan National Park (NSNP) in Saraburi Province. It was conducted during January 2005 to January 2006. This study site covers the altitude from 100 to 300 meters above mean sea level. Quadrats were used for collecting and identifying the vegetation and the data were quantitatively analyzed.

The results showed that 83 species in 62 genera and 31 families were found. The top ten important value index (IVI)species were *Lagerstroemi calyculata* Kurz (24.13%), *Colona* sp. (21.00%), *Bombax anceps* Pierre.(15.96%), *Leucaena leucocephala* de Wit.(12.80%) *Vitex peduncularis* Pirerre. (10.44%), *Dialium cochinchinense* Pierre (8.41%), *Hymenodictylon excelsum* (Roxb) Wall (7.82%), *Parinari anamense* Hance (6.81%), *Adinanthera pavovina* Linn (6.69%) and *Memecylon* sp.(6.56%), including *F.hispida* L. (4.52%) and *F. racemosa* L. (3.63%) respectively. The plant communities at MDF could be classified into two groups, in both MDF and DEF. The amount of plant species and all individual species demonstrated inclination to decrease with increasing of elevations. The distribution patterns of both fig species were clumped and the fruiting periods were found all through the year. It can be seen that leaf production in *F.racemosa* L was, although present. The presence of fruit on the trees was in contrast very even throughout the year. The interspecific relationships of fig and fig wasp in monoecious figs (*F. racemosa* L.) and dioecious figs (*F. hispida* L.) observed, The number of fig species and their density decreased with increasing elevation. The existing fig wasp of *F. racemosa* L. and *F. hispida* L. were *Ceratosolen fusciceps* Mayr and *Ceratosolen solmsi marchali* Mayr respectively. The data can be applied to build up the new figs communities and to manage food plants for wildlife.

Keywords: Ecological distribution, Phenology, Interspecific relationships, Fig wasp

INTRODUCTION

Fig trees (Ficus, Moraceae) are considered to be keystone species in many tropical and subtropical ecosystems. While many other fruit trees have fruits only once a year, figs provide food for wild animals year round. There are now thought to be approximately 750 species of fig in the world (Berg, 1989) is pollinated by a single wasp species, and each wasp species usually reproduces only within the closed inflorescences (called syconia,or figs) of its host fig species and almost every species has its own pollinating species of fig wasp. The specificity of the fig-fig wasp mutualism, and the influence of parasitic wasps on fig trees, has been observed by many ecologists. The male flowers are degenerate and do not produce pollen. In male syconia the styles of female flowers are all short and the wasps can oviposit in all the ovaries. The male flowers also mature normally. These syconia, Therefore, produce wasps and pollen (Galil, 1973).

Throughout this paper the terms male and female will be used to refer to functionally male and female trees or syconia. (Figure 1).

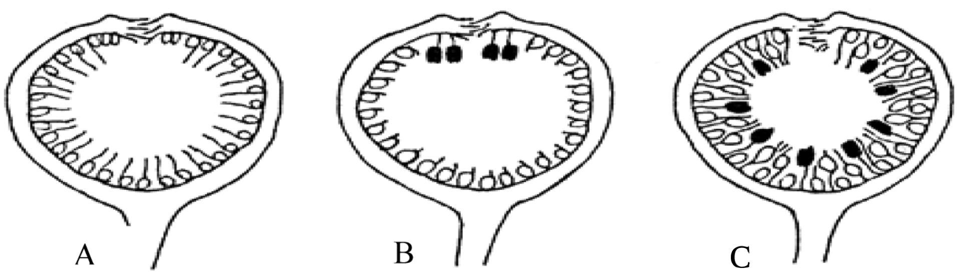

Figure 1. Dioecious fig, A: seed figs containing long-styled pistillate florets, B: gall figs containing short-styled pistillate florets and staminate florets. And Monoecious fig, C: species have a single type of fig containing pistillate florets with styles of varying length and staminate florets.

However, little has been published about the biology and ecology of fig species. in Thailand. This paper presents the results of the study on ecology of *Ficus racemosa* Linn (monoecious fig) and *F. hispida* L.forst. (dioecious fig) and their relationships with fig wasps in mixed deciduous forest (MDF) and dry evergreen forest (DEF) at Namtok Samlan National Park (NSNP). *F. racemosa* L. is trees, 25-30 m tall, diameter at breast height (d.b.h.) 60-90 cm; monoecious. Bark grayish brown, smooth. Branchlets, young leaf blades, and fruits with bent hairs or densely covered with white soft pubescence (Ju, 2004). But *F. hispida* L.f. is shrubs or small trees, dioecious. Stipules usually 4 and decussate on leafless fruiting branchlets, ovate-lanceolate (Dui, 2004).

The results may contribute to our understanding of figs insect interactions, coevolution, and effects of environmental factor on the fig-fig wasp mutualism and perhaps provide constructive suggestions for the conservation of biodiversity in Thailand's forests.

MATERIALS AND METHODS

The study was carried out at Namtok Samlan National Park (NSNP), Saraburi Province, Thailand (lattitude 14º 31´ 43", longitude 100º 54´ 35"). Areas ranging from temporary roadside creeks to waterfalls were selected for intensive data collection. The topography is mountainous with the elevations ranging from 100-300 meters. In addition, environmental variables were recorded at each site and Global Positioning System (GPS) was used to record the Universal Transverse

Mercator (UTM). All taxa were collected during the study and samples were sorted and identified to genus or species level. One transect line was established in each of two selected study area in Namtok Samlan National Park. The transect lines were selected as follows:

1. Sam Lan Waterfall : Dry Evergreen Forest :DEF

2. Pho Hin Dad Waterfall : Mixed Deciduous Forest :MDF

Ecological Distribution of Figs along Altitudinal Gradients

Twenty main plots (each 50 x 20 m) were established along each transect line. Interval between main plots were approximately 100 m. Elevation above mean sea level was measured at each main plot by pocket altimeter. At the corner of each main plot, a small plot of 4x4 m. was also established. The main plot was used to study all tree species, that had diameter at breast hight (DBH) greater than 3 cm and the small plot was used to study seedlings of figs. Distribution pattern of dominant plant species were calculated by the Blackman method (Blackman, 1942). Each main plot was characterized by calculating the following statistics: relative frequency, relative density, relative dominance, and importance value index (IVI; McCune and Mefford ,1995).

Phenology of *F. racemosa* L. and *F. hispida* L.

A phenological census of the two figs (*F. racemosa* L. and *F. hispida* L) were conducted at the site from January 2005 to January 2006. Monthly sampling was sufficient to observe each stage of the life cycle; however, it was necessary to conduct more frequent censuses to understand the duration of each stages and the transition from one stage to the next. The census included observation of leaf and fruit characteristics. The proportion of leaves on the tree (1 = 25%, 2 =50%, 3= 75%, and 4 =100%) and the proportion of buds, new leaves, old leaves and senile leaves were recorded. The presence of syconia and the proportion (same scale as leaves characteristics) at different stages (immature, receptive, interfloral, male or fruiting) was recorded (Galil, 1973). The same labels for the different stages were used for both male and female for simplicity, even though they were not entirely appropriate. Male syconia, of course never 'fruited' and female syconia were never 'male' (Harrison, 1999).

Interspecific Relationships between Figs and Fig Wasps

Male late interfloral syconia were sampled from *F. racemosa* and *F. hispida*. Wasps were collected by piercing the ostiole and placing the syconia in a seal container. While this method was effectiveness for collection and identification of fig wasps. Wasp traps were set in mature fig trees. Once the species of fig wasp were identified, it was relatively easy to identify them by eye or using a hand lens. The number of each species was recorded and the wasps were picked from the traps. The traps were cleaned and sticky material re-applied as necessary. Syconia were sampled to observe the internal phenology, pollination behavior, emergence, and other aspects such as parasite damage. Interfloral syconia were collected more frequently to examine the number of seeds or wasps. Initially the samples were preserved in 70% alcohol but this proved to be unsatisfactory and later Fomalin-Acetic Acid (FAA) was used. Measurements of the flowers in *F. racemosa* and *F. hispida* were made using a light microscope with eyepiece graticule (Harrison, 1999).

RESULTS AND DISCUSSION

Ecological Distribution of Figs along Altitudinal Gradients

Eighty-three species of plants in 62 genera and 31 families were found in the Mixed Decidous Forest (MDF) and Dry Evergreen Forest (DEF) respectively. The ten species with highest importance value index (IVI) were *Lagerstroemia calyculata* Kurz (24.13%), *Colona* sp. (21.00%), *Bombax anceps* Pierre (15.96%), *Leucaena leucocephala* de Wit (12.80%), *Vitex peduncularis* Pirerre (10.44%), *Dialium cochinchinense* Piere (8.41%), *Hymenodietylon excelsum* (Roxb)

Wall (7.82%), *Parinari anamense* Hance (6.81%), *Adinanthera pavovina Linn* (6.69%) and *Memecylon* sp (6.56%). Considering the ability of these plants to establish, survive and grow in the two forest types, *L. calyculata* Kurz, *Colona* sp and *F. hispida* L were the most successful tree, shrub and seedling species respectively. If a revegetation program is proposed for these sites, species of Leguminosae, Lythaceae, Tiliaceae, Verbenaceae and Rubiaceae would be planted (Figure 2).

Saplings and seedlings are important components of the forest in Namtok Samlan National Park, both as undergrowth and for their potential to grow to mature trees. *L. leucocephala*, *V. peduncularis* and *D. cochinchinense*. were the three most dominant species in term of IVI value. *F.hispida* and *F.racemosa* were also abundant especially at the moist areas.

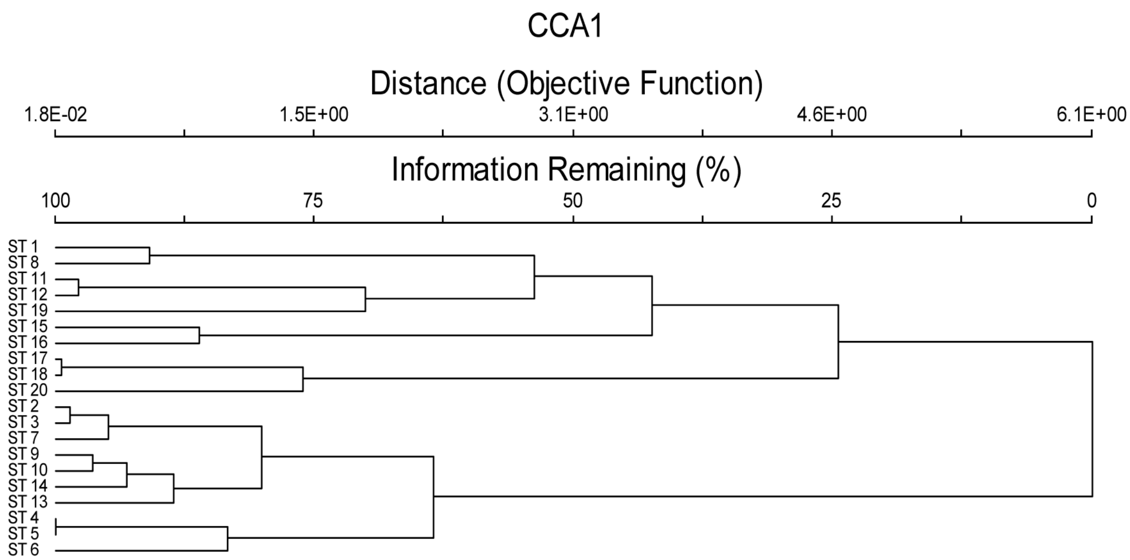

Figure 2. Cluster analysis illustrating the grouping of 20 stands based on dominant tree species in dry evergreen forest (DEF) and mixed deciduous forest (MDF).

Dominant seedlings were *L. leucocephala*, *A. pavovina*, *S. pinnata* and *S. cumini*. Not all dominant seedlings were likely to become dominant trees, and there were many factors affecting the survival of seedlings. Microclimate, soil moisture, amount of deposit, tolerance of shading, and wind exposure were important factors. Nevertheless, some seedlings such as *F. hispida* and *Colona sp*. become established as mature trees.

Cluster analysis demonstrated that the 20 forest stands in Namtok Samlan National Park could be classified into three forest groups along the altitudinal gradient by using an arbitrary Sorensen's distance of 4.60 (Figure 1). Each group was named by the species with highest IVI; brief descriptions are as follows:

Group I: *Dipterocarpus sp., Memecylon sp., D. cochinchinense*. This group included DEF stands (St 1, 8, 11, 12, 15, 16 and 19) located at 100 m asl. *Dipterocarpus sp.* was the dominant species in this group. Stands 1, 8 and 11 included other co-dominant species such as *S. cumini* (L.) Skeels, *Peltophorum dasyrachis* Kurz, *D. cochinchinense* Pierre, *Memecylon sp.*, *Hopea odorata* Roxb. In stands St 19 figs are represented by *F. hispida* L.

GroupII: F. *racemosa* L., *F. hispida* L., *Colona* sp., This group represented a transition between DEF and MDF and included stands (St 17, 18 and 20) located between 100 and 150 m asl *F.hispida* was the dominant species in this group. and St 17 and 18 included co-dominant species such as *Alstonia scholaris* (L.) R.Br, *Oroxylum indicum* (L.) Vent. *Thysostachys siamensis* Gamble., *Garuga* *pinnata* Roxb., *Erythrina subumbrans* (Hassk).Merr., *Dalbergia cochinchinensis* Pierre, Spondias pinnata (L.f.) Kurz, *Adenanthera pavovina* Linn, *Parinari anamense* Hance. and *Hymenodictyon excelsum* (Roxb.) Wall.. In stands St 20 figs are represented by *F. hispida* and *F. racemosa*.

GroupIII: *Lagerstroemia calyculata* Kurz, *Pterocarpus macrocarpus* Kurz, *Adenanthera pavovina* Linn., *Afzelia xylocarpa* Roxb., *Wrightia tomentosa* Roem. and *Xylia xylocarpa* Taub., *Bombax anceps* Pierre. Ten stands of MDF were clustered in this group including St 2, 3, 4, 5, 6, 7, 9, 10, 13, and 14 located between 200 and 300 m msl. This group was further divided into two sub-groups, one with *Lagerstroemia calyculata* Kurz, *Bombax anceps* Pierre and *Adenanthera pavovina* Linn. as the dominant species, the other group without these species. The canopy of this forest included a mixed of deciduous tree species, lacking any single dominant species. One of the sub-groups (St 4, 5, and 6) featured *Tectona grandis* and *Xylia kerrii* as the dominant tree species, mixed with other species such as *Dalbergia oliveri* and *Grewia* sp. The other sub-group (St 2, 3, 7, 9, 10, 13 and 14) was characterized by the absence of *Tectona grandis*. The dominant species, *Lagerstroemia calyculata* and *Pterocarpus macrocarpus* were mixed with other species such as *Dalbergia dongnaiensis*, *Afzelia xylocarpa* Roxb., *Dialium cochinchinense* Pierre, *Wrightia tomentosa* Roem. and *Xylia xylocarpa* Taub., *Syzegium cumini* (L.)Skeels, *Peltophorum dasyrachis* Kurz . Bamboo was found every stand in this group.

The vegetation surveyed in the 20 stands was used to illustrate plant communities in the mountains of NSNP. Data was summarized by using IVI value those only two major groups of the top vegetation current in this area (Figure 3).

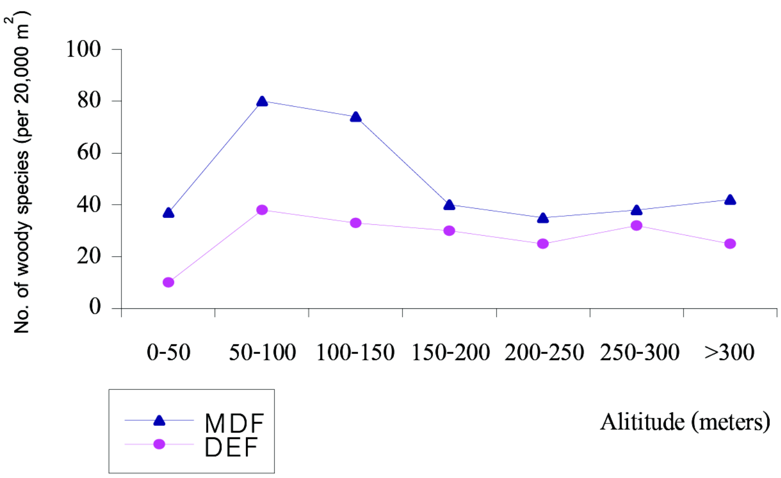

Figure 3. Number of woody species found in DEF and MDF at different elevations.

Given the mountainous terrain of Namtok Samlan National Park,altitude was an obvious factor to relate to the changing of plant community. However, many other enviromental factors (e.g.,temperature, rainfall) were correlated with elevation. Thus, a change in altitude implied a change in several environmental variables, and this complicated analyses. Number of individual of all species was clearly negatively correlation with altitude (Figure 4-5).

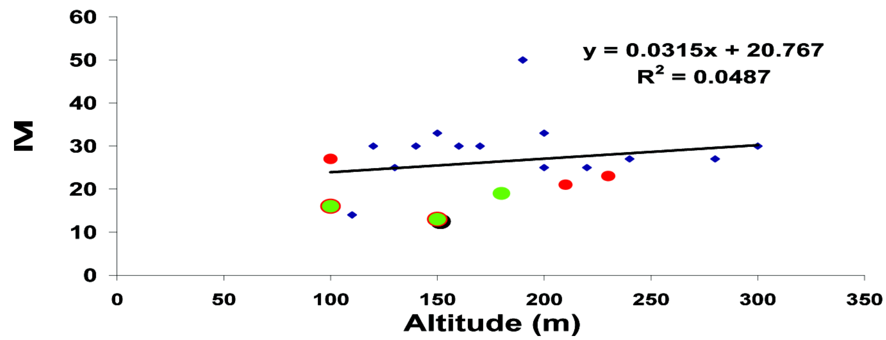

Figure 4. Changing important value index: IVI of *F.hispida* L:● and *F.racemosa* L:● with different altitudes, in DEF and MDF.

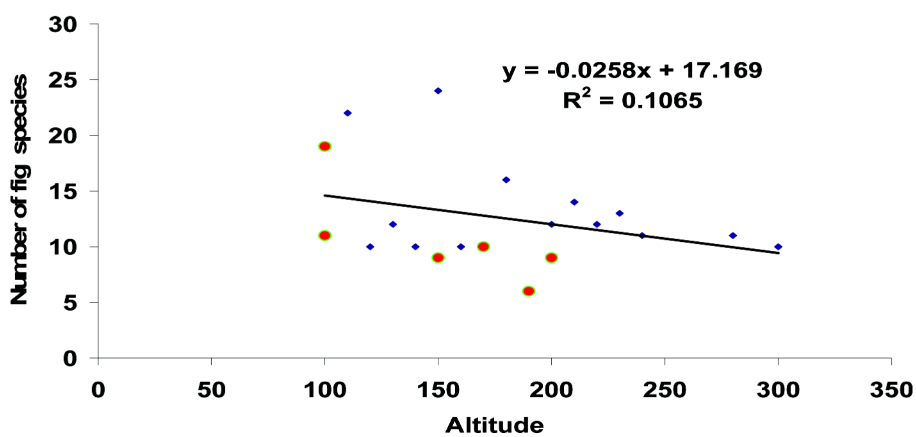

Figure 5. Changing number of fig species:● with different altitudes, at DEF and MDF.

Species density, number of families and number of species in group I were lower than group II, but basal area was higher. This is because the canopy was more open and more than 80% covered by *Lagerstroemia calyculata* group, Colona sp. group and *Bombax anceps* group. *F. hispida* was found in both MDF (St 13) and DEF (St 1, 15, 19, 20). *F. racemosa* L. was also found in both MDF (St 9) and DEF (St 19, 20).

Phenology of *F. racemosa* L. and *F. hispida* L.

F. racemosa **L.** is a monoecious species, and male flowers and female flowers mature asynchronously inside the same syconium. Pollination of *F. racemosa* can only succeed through its fig wasp and the pollinating wasp depends on the fig for habitat to lay eggs and complete their life cycle. Because of this obligate mutual relationship, it may be necessary for *F. racemosa* to regulate its phenology and syconium growth to fit the life cycle of its pollinating wasp, as discovered in other "fig-fig wasp" mutualisms. However, little is known about the basic ecology and life history of this fig species. Based on the visual observation of 10 individuals of *F. racemosa*, leaffall and flushing occurred twice a year: once during the dry season (January to March) and again during the rainy season (July to September).

The green mature leaf stage of the first leaf production was much longer than that of the second. The pattern of syconium diameter increment indicated that the syconia growth process of *F. racemosa* has a close relationship with parasitic wasps (and its pollinator), because the increase rate was remarkably higher in phase A than phase C when wasps had already invaded the syconia. This was likely the result of resource competition between wasps and the inflorescence itself (Ju, 2004).

A great number of wasp larvae (usually several hundred to over one thousand) need large amount of nutrients for their development. The corresponding enlargement of syconium diameter and receptacle cavity indicated that the fig-fig wasp interaction is highly evolved. Along the development process of a syconium, two peaks of diameter increase were observed around the critical time for the fig-fig wasp interaction, phase B, plant pollination and wasp oviposition, and phase D, where insects mate and pollen were dispersed by the female wasps. A relatively large cavity at phase B may increase the female fitness of the fig and pollinating wasp. A large cavity at phase D may enhance the male fitness of the fig through more active and sufficient pollen collection by female pollinating wasps, and also offers adequate space for wasps to mate, increasing fecundity. The development of syconia is divided into five phases see in (Appendix).

***F. hispida* L** is a dioecious species, "male" trees produced more syconia in the dry and rainy seasons than in winter season. In this specie, male and female trees abscised more unpollinated, young inflorescences than pollinated inflorescences, but abscission appeared to be more likely due to resource rather than pollinator limitation. The phenology of *F. hispida* requires that male inflorescences wait in the receptive phase for scarce pollinators to arrive. As expected, male inflorescences of this species had a longer receptive phase than female inflorescences. In *F. hispida*, where pollinators were rarely scarce, duration of receptive phase was the same for both sexes. Duration of developing phase was longer in female syconia of this specie than in male syconia, most likely because they need a longer period of investment in a freshy fruit (Dui, 2004).

Flowering or fruiting of fig species at NSNP was observed for one year, and the results were shown in Tables 1-2. There were many flowerings during the dry season, between January and May. *F. racemosa*, a species endemic to NSNP, had flowers during March to September, but the most pronounced period was March to June. *F. hispida*, the most privalent species in this study area, had fruit continually, but it was occasioned during February to May. Although fruits were numerous, especially of *F. racemosa*, seedlings were rather scarce. Growth of seedlings may be limited by difficult conditions of sandy soils and steep slopes.

Table 1. Duration and characteristics of syconium development of *F. racemosa* L.

Syconium development Phase	Duration (days)		
	Dry (N=10)	Rainy (N=10)	Winter (N=10)
A = pre female	23.2 ± 11.4	17.9 ± 5.2	19.5 ± 6.0
B = female	5.1 ± 1.0	2.2 ± 0.0	8.7 ± 3.2
C = interfloral	29 ± 6.1	21.9 ± 4.3	44.7 ± 17.3
D = male	2.4 ± 0.0	1.6 ± 0.0	5.2 ± 0.8
E = postfloral	5.2 ± 0.9	4.1 ± 0.0	7.0 ± 2.0

Table 2. Duration and characteristics of syconium development of *F. hispida* L

Syconium development Phase	Duration (days)		
	Dry (N=10)	Rainy (N=10)	Winter (N=10)
A = pre female	47.2 ± 11.0	26.9 ± 5.2	29.5 ± 7.0
B = female	52.5 ± 0.8	56.0 ± 1.3	58.7 ± 3.2
C = interfloral	29.0 ± 5.1	31.9 ± 4.0	44.0 ± 1.2
D = male	37.1 ± 0.7	37.1 ± 0.6	39.9 ± 0.8
E = postfloral	5.0 ± 0.5	4.0 ± 0.0	7.0 ± 5.0

(Figure 6) showed that fruiting periods by the two fig species was scattered throughout the year. Although small sample sizes made statistical analysis impossible, the species specific patterns are important if we wish to consider the different guilds of dispersers specializing on a small number of species. At the species level, the figure also illustrates that the area covered by a population of fig trees sufficient to maintain its fig wasp population must be very large indeed and that the wasp must be able to disperse effectively over these large areas, given that so few figs are apparently aborted though a lack of pollinators.

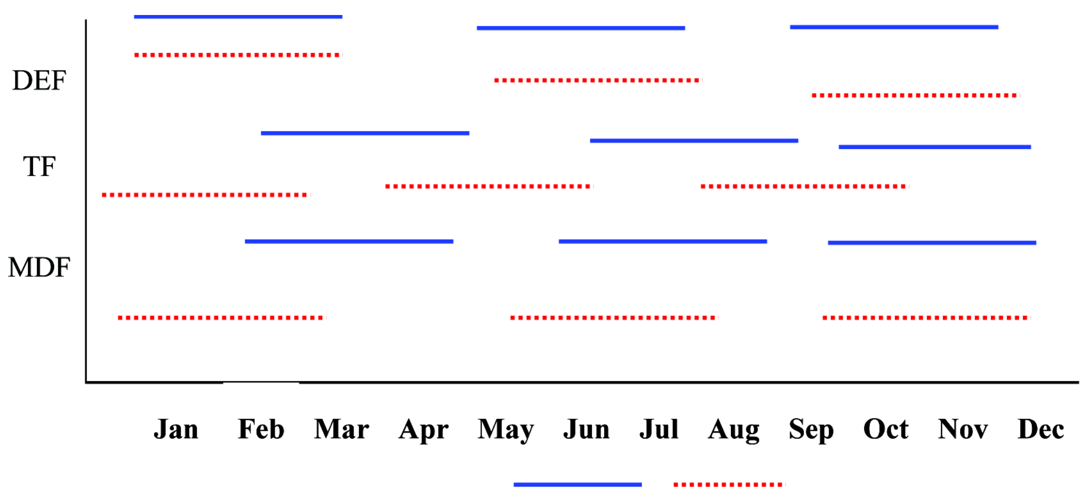

Figure 6 Fruiting periods of two figs (*F. racemosa* , *F. hispida*) in three plant communities at Namtok Samlan National Park.

Interspecific Relationships between Fig and Fig Wasp

Correlations between the leaf production, syconia initiation, including time lack correlations of up to 50 days, were investigated. And they occurred again during the rainy season (July to September).The duration of a syconium growth cycles of *F. racemosa* and *F. hispida* were much longer in the winter season than in the rainy season. The key development stage in fig-fig wasp symbioses is phase B = (female) when the two partners had interacted. There were several long phase B periods distributed throughout the year (Figure 7).

The development of syconia is divided into five phases. (Appendix)

Two species of fig wasp were caught by plastic bag on the *F.racemosa* and *F.hipida* *trees*. They were *Ceratosolen fusciceps* Mayr. and *Ceratosolen solmsi marchali* Mayr respectively (Figure 8). The wasps were identified using to genus level (Weibes, 1994).

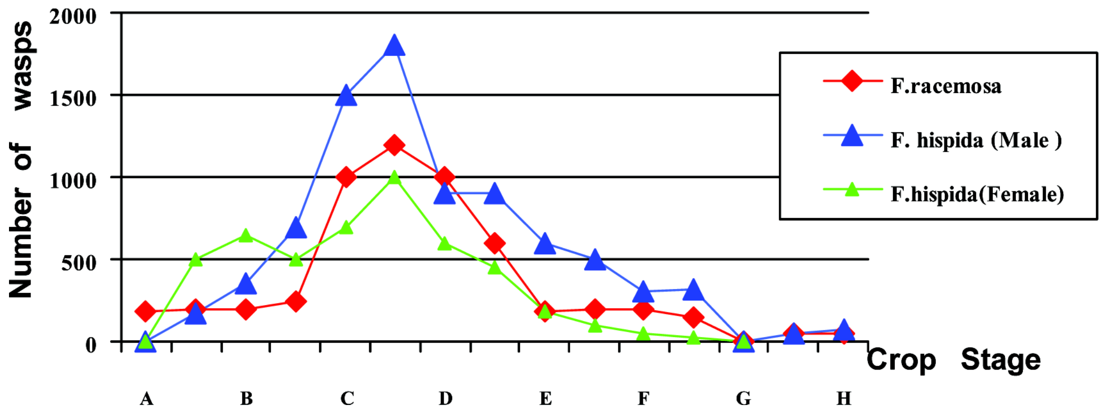

Figure 7. Total results of flower from two fig on *F.racemosa* L.(Male + Female Trees) and *F.hispida* L. (Male,Female Trees) by crop stage (A & H = 10 days, Other = 5 days).

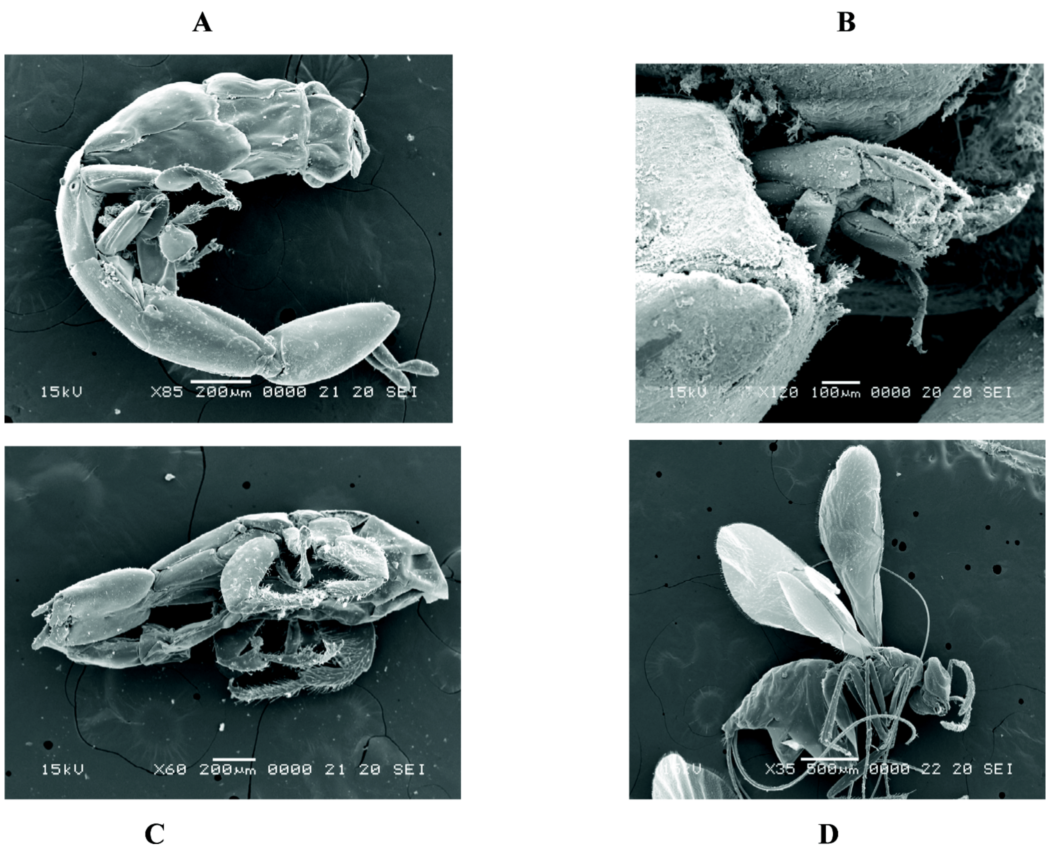

Figure 8. Fig wasp in the syconium of figs were made using a light microscope, A: male of fig wasp. B: showing male into gall flower of *F. racemosa* L., C: juvelnile male pollinator and D: adult female pollinator of *F. hipida* L.

CONCLUSION AND RECOMMENDATION

CONCLUSION

The results from this study can be summarized as follows:

1. The flora in study area: DEF and MDF at Namtok Samlan National Park was composed of 83 trees species in 62 genera and 31 families. There were five fig species; *Ficus racemosa* L., *Ficus hispida* L, *Ficus superba* Miq., *Ficus drupacea* Thunb.and *Ficus religiosa* Linn.

2. The top five Important Value Index (IVI) fig species were *F. hispida* L. (4.52%) and *F. racemosa* L. (3.63%), *F. religiosa* L. (1.37%), *F. drupacea* Thumb. (1.32%) and *F. superba* Miq. (0.4%) respectively. Dominant of shrub and herbaceous species was *F. hispida* L, Dominant seedling species was *F. religiosa* L. Tree biggest families with high number of individuals were Leguminosae, Lythraceae, Moraceae (*F. racemosa* L.), Verbenaceae and Rubiaceae

3. The vegetation changed with altitude of mountains. The number of plant species and the number of individuals of all species showed trends to decrease with increasing of elevations, *F. racemosa* L. and *F. hispida* L. were found at low elevations of MDF and DEF, especially moist areas of the transitionale forest.

4. The dioecious figs (*F. hispida* L) produce fruit crops much more frequently than the monoecious figs(*F. racemosa* L). They are, therefore, a much more reliable resource and dispersers may be much more dependent on them.

5. Based on the fig wasp life cycle that they have to servive in the fig fruit for about 50 days. The two plant communities (DEF and MDF) cannot support ig wasp life cycle but the transition zone community provide fig fruit all year round, therefore fig wasps can maintain their species in this plant community. Each species of fig n each community cannot support fig wasp life cycle. Especially *F. hispida* L in the three communities has a short time lack for fig wasp life cycle.

RECOMMENDATION

This study will provide some useful basic knowledge for forestry work in Thailand. The knowledges of phenology, ecology and mutualism of fig and the interspecific relationships of fig wasp to their environmental complex can be applied for managing natural stands, and maintaining and enhancing bio-diversity, as well as restoring habitats and conservation values according to the objectives of the park. More important, the results from this study are useful for estimating basal area, species density and it is an important value index of species distributed along altitudes.

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