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Diversity of Figs and Their Pollinators in Chiang Mai Province, Thailand

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ABSTRACT

A study of the diversity of fig trees (*Ficus* spp.) and their pollinators in parts of Chiang Mai Province in Thailand was conducted from June 2007 to May 2009. 13 monoecious and 13 dioecious species were recorded (twenty-nine taxa in total) representing all six subgenera. The largest group of 11 species belonged to subgenus *Urostigma* followed by *Sycomorus* with 8 species, *Ficus*, *Sycidium* and *Synoecia* each with 2 species and *Pharmacosycea* with 1 species.

Some fig trees such as *F. benjamina* L., *F. hispida* L.f. and *F. racemosa* L. were found commonly in both lower and upper areas (310-1,200 m asl.), while some were found in small populations and restricted to specific habitats, such as limestone areas (*F. anserina* Corner and *F. anastomosans* Wall.). The study revealed a large number of fig wasp species, but only one species functioned as the pollinator. Pollinators of 20 fig species were identified, with *Ceratosolen emarginatus* Mayr recorded in both *F. auriculata* Lour and *F. oligodon* Miq. In this study, pollinators of *F. anserina*, *F. curtipes*, *F. rumphii*, *F. pumila* and *F. maclellandii* could not be found.

Keywords; diversity, *Ficus*, fig wasps, pollinator, taxonomy.

1. INTRODUCTION

Ficus (fig trees) is one of the most important genera of plants in rain forest ecosystems. There are close to 1,000 different species found around the world and approximately 350 species in Asia [1, 2]. A large number of animals like pigeons, parrots, hornbills, toucans, monkeys, gibbons and fruit-eating bats, feed on fig fruits [3]. In addition, many parts of fig trees are benefit for humans, e.g. juvenile shoots and leaves

of *F. lacor* are used as vegetables and fruits of *F. carica* are edible. Latex of these plants is also used for many purposes such as *F. benjamina* latex for inhibiting the distribution of malarial mosquitoes, *F. variegata*, in Malaysia; used for godang wax in batic dye, and *F. dusenii* for trapping of birds. Some species can be used for fiber and as raw materials for papermaking. Also, some fig species are popular in gardening [4].

Each fig species is believed to have a unique pollinator and their interaction is typically thought as being one-to-one. Although, there are increasing number of known exceptions such as *Ceratosolen silvestrianus* and *C. arabicus*, and *Ficus sycomorus* [5]. Their pollinators are insects belonging to the family Agaonidae, in order Hymenoptera. The interaction is an obligatory mutualism [6].

In the syconium, not only the living of pollinators but also the habitat of other wasps present, those wasps function as competitor or parasite that called “non pollinators” for instance, *Sycophaga*, *Apocrypta* and *Philotrypesis* [7].

Until recently, *Ficus* was classified into 4 subgenera based primarily on floral characters; *Ficus*, *Urostigma*, *Pharmacosycea*, and *Sycomorus* [2]. Modifications were later made at the subgeneric level by giving more emphases to vegetative characters and *Ficus* is currently divided into six subgenera comprising subgenera *Ficus*, *Urostigma*, *Pharmacosycea*, *Sycomorus*, *Sycidium* and *Synoecia* [8].

For monoecious fig trees, a syconium contains many female flowers with variable style lengths and a few male flowers in active pollination. They produce seeds, wasps, and pollen within a single fig tree. Dioecious fig trees produce either seed and gall figs. ‘Seed fig’ refers to fig trees whose syconia have only female flowers with long styles, whereas, gall figs contain both male and short-styled female flowers [9].

2. MATERIALS AND METHODS

2.1 Fig Specimens

Plant specimens such as leaves, shoots and syconia were collected to the laboratory for identification work. Each sample was taken from many parts of the districts of Chiang Mai. The syconium specimens were very important for taxonomic study. The young syconium gave more information of male

flowers and difference of long and short style female flowers while the mature and ripe syconium were benefit for studying fruits and seeds morphology. The periods of flowering were observed by visiting each tree every month. To report condition of crops, synchrony and asynchrony, we observe the stage and size of figs in the same tree. Synchronous crops within tree means the difference stages both young and mature figs (syconium) represent in the same tree.

2.2 Fig Wasps

The fig wasps were taken collected by harvesting the early ripe figs (before ostiole turn loose). Then put each fig in the bottle with thin cloth covering. The fig wasps, both pollinators and non pollinators, emerged in the next day.

The fig trees were identified using the *Checklist of Ficus in Asia and Australasia with keys to identification* [2], *Flora of China*, vol.5. [10], *Thai plants names* [11], *Flora Malesiana, series 1, volume 17* [12], and *Precursory taxonomic studies on Ficus (Moraceae) for the Flora of Thailand* [13].

The fig wasps were verified using *Australasian Chalcidoidea (Hymenoptera): A biosystematic revision of genera of fourteen families, with a reclassification of species* [14], *The Indo-Australian Agaoninae (pollinators of figs)* [15], *Classification of fig wasps* [16], and *Notes on Families: Agaonidae* [17].

2.3 Research and Location

The specimens were collected from different locations as follows; the sampling of upper areas and moist and evergreen forest, the specimens were taken from Inthanon Research Station of Royal Project Foundation (Chom Tong district) at 800-1,200 m asl., beside the road of Mae Tang-Pa Pae at 700-1,000 m asl.,

The upper areas with evergreen and mixed deciduous forest, the specimens were

taken from beside the road of Mae Rim-Sameng and Queen Sirikit Botanic Garden at 700-950 m asl., Chiang Dao at 550-900 m asl. The samples of lower areas were taken from Sansai, Hang Dong and Muang districts

(from 310 m to 500 m asl, Figure 1). The study areas were sampled under the condition of difference kind of ecology and not too difficult to collect and study on fig wasps.

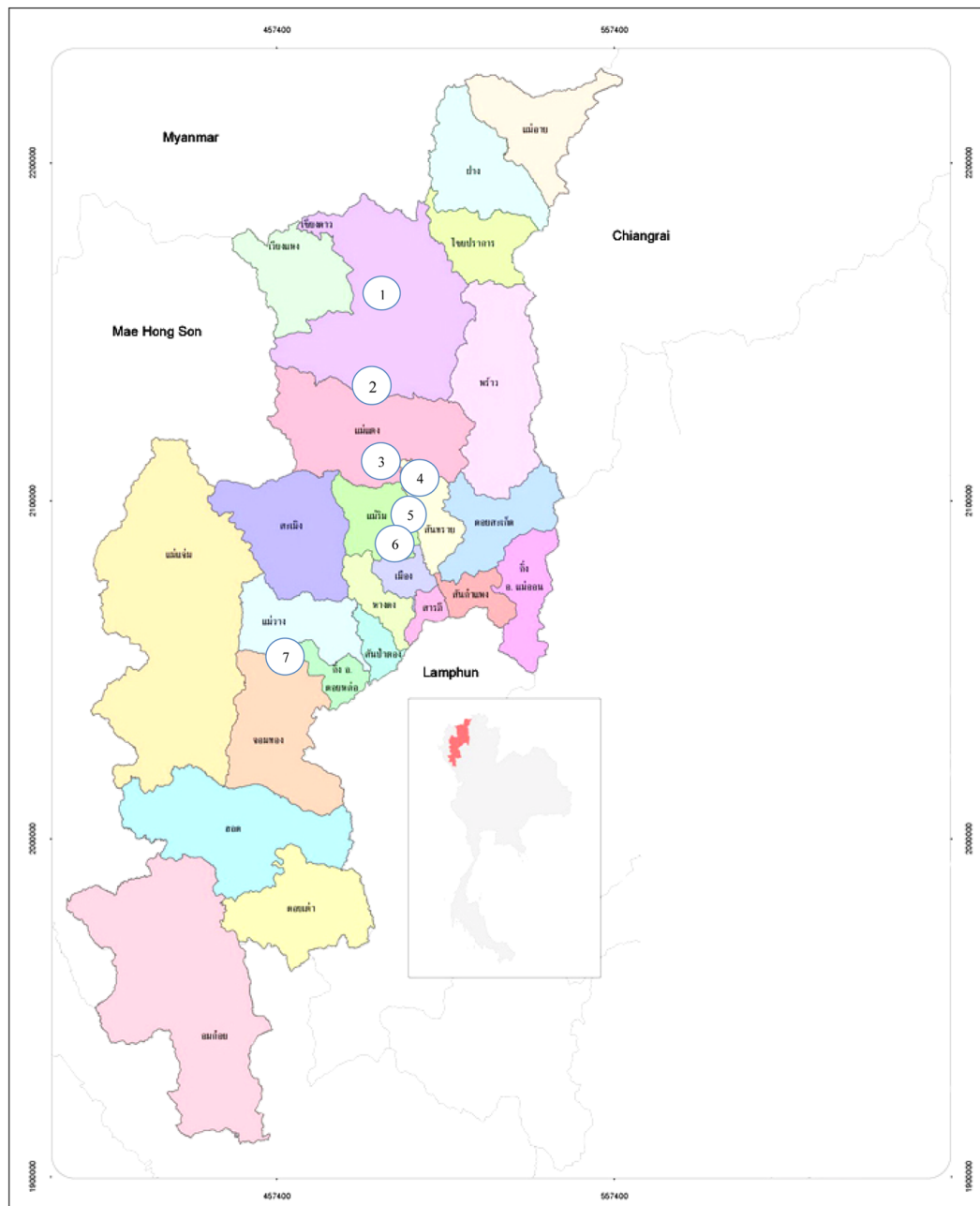


Figure 1. The study sites of *Ficus* and fig wasps in Chiang Mai; 1. Chiang Dao, 2. Mae Tang, 3. Mae Rim, 4. Sansai, 5. Muang, 6. Hang Dong, 7. Chom Tong.

3. RESULTS AND DISCUSSION

3.1 Taxonomic study

Twenty-nine taxa in 26 fig species were collected, representing 13 monoecious and 13 dioecious species from all six subgenera. The largest group was 11 species of subgenus *Urostigma*. The second largest group consisted of 8 species of *Sycomorus*. *Ficus*, *Sygidium* and *Synoecia* each had 2 species and *Pharmacosycea* 1 species (Table 1).

Two varieties of *F. benjamina* L. were found; *F. benjamina* var. *benjamina* and *F. benjamina* var. *nuda* (Miq.) Barrett. The former had small-sized glabrous figs (0.8-1.5 cm in diameter), and the latter larger pubescent figs (1.8-2 cm in diameter). Their pollinator was the same species, *Eupristina emeryi* Grandi and non-pollinators were insects in the genera *Philotrypesis* and *Ormyrus* (Table 1).

Another monoecious species was *F. racemosa* L. with *F. racemosa* var. *racemosa* L. and *F. racemosa* var. *miquell* (King) Corner. The former had figs with bent hairs, whereas the latter had dense white pubescence. Their pollinator was *Ceratosolen fusciceps* Mayr. Five other fig wasps from the genera *Apocrypta* and *Apocryptophagus* were found inside the figs.

Amongst the dioecious trees, *F. hispida* L. was the most universally distributed. There were two varieties; *F. hispida* var. *hispida* L.f. and *F. hispida* var. *badiostriosa* Corner. This fig tree was distributed in open areas, sometimes near streams and rivers. Both varieties occasionally appeared as pioneer species in deforested areas and their specific pollinator was *Ceratosolen solmsi* Mayr. The ripe fruits attracted animals, for example squirrels, bats and also insect-eating birds such as bulbul family.

Overall, seven genera of pollinators were found consisted of *Blastophaga*, *Ceratosolen*, *Dolichoris*, *Eupristina*, *Liporrhopalum*, *Platyscapa* and *Pleistodontes*. Non-pollinator fig wasps were *Acophila*, *Apocrypta*, *Apocryptophagus*,

Camarothorax, *Ormyrus*, *Otitesella*, *Philotrypesis*, and *Sycoapter* (Table 1).

3.2 Ecology and distribution

The native and cultivated plants occurred in different habitats. Some species thrived in unique habitats, whereas others could thrive everywhere. However, most of the fig trees were common in moist areas such as waterfalls, streams and river banks. Some figs were found at upper areas, about 800-1,200 m, for example *F. auriculata*, *F. semicordata*, *F. fistulosa*, *F. subincisa*, *F. oligodon* and *F. anserina*. The others were mainly distributed at lower altitudes, e.g. *F. altissima*, *F. drupacea*, *F. benjamina*, *F. elastica*, *F. lacor*, *F. microcarpa* and *F. religiosa*. They were represented throughout the forest and urban areas. Meanwhile, some species, e.g. *F. racemosa*, *F. hispida*, *F. squamosa*, were distributed in both the lower and upper areas (Table 2).

F. squamosa and *F. ischnopoda* are species of rheophytic shrubs found in rocky beds of quick running streams. They are low bushy shrubs with creeping stem. *F. squamosa* grows on rocks or ground near the streams and has figs that originate on branches near to the water level or even below. Their fruits have brushy long hairy stigmas which persist when the figs are ripe. This is an adaptation for growing in running streams [12]. *F. ischnopoda* grows both on the ground of river banks and on rocks in the water as well.

F. anserina is a lithophyte growing from cracks in rocks. It is a woody climber in moist forests occurring on limestone mountains and has a narrow range in Thailand [12, 13]. More than 50 percent of its figs from several crops failed to be pollinated.

Several growth habits were represented: shrubs, climbers, trees, and stranglers. Most members of subgenus *Urostigma* started growing as epiphytes, then reached the ground and became stranglers when mature. Eight species were found growing naturally and as

Table 1. Checklist of *Ficus* and their fig wasps in Chiang Mai (June 2007-May 2009).

No	Subgenus	Sexual System	<i>Ficus</i> species	Pollinators	Non pollinator fig wasps	Crops sampling (times)	Synchrony/Asynchrony
1	<i>Urostigma</i>	monoecious	<i>Ficus altissima</i> Bl.	<i>Eupristina altissima</i> Balakrishnan & Abdurahiman	Not seen	2	Asyn
2		monoecious	<i>F. benjamina</i> var. <i>benjamina</i> L.	<i>Eupristina emeryi</i> Grandi	<i>Philotrypes</i> sp. <i>Ormyrus</i> sp.	2	Asyn
3		monoecious	<i>F. benjamina</i> var. <i>nuda</i> (Miq.) Barrett.	<i>Eupristina emeryi</i> Grandi	<i>Philotrypes</i> sp. <i>Ormyrus</i> sp.	1	Asyn
4		monoecious	<i>F. curtipes</i> Corner	Not seen	Not seen	2	Asyn
5		monoecious	<i>F. drupacea</i> Thunb	<i>Eupristina belgaumensis</i> Joseph	Not seen	1	Asyn
6		monoecious	<i>F. elastica</i> Roxb.	<i>Pleistodontes claviger</i> Mayr	Not seen	2	Asyn
7		monoecious	<i>F. lacor</i> Ham.	<i>Platycaapa</i> sp.	Not seen	3	Asyn
8		monoecious	<i>F. maclellandii</i> King	Not seen	Not seen	3	Asyn
9		monoecious	<i>F. microcarpa</i> L. f.	<i>Eupristina verticillata</i> Waterston	Not seen	2	Asyn
10		monoecious	<i>F. religiosa</i> L.	<i>Platycaapa quadriceps</i> (Mayr)	Not seen	2	Asyn
11		monoecious	<i>F. rumphii</i> Bl.	Not seen	Not seen	1	Asyn
12		monoecious	<i>F. superba</i> Miq. var. <i>japonica</i> Miq.	<i>Blastophaga constabularis</i> Joseph	<i>Acophila</i> sp. <i>Camarothorax</i> sp. <i>Otitivella</i> sp. <i>Philotrypes</i> sp. <i>Syocapter</i> sp.	2	Asyn
13	<i>Pharmacosyceae</i>	monoecious	<i>F. callosa</i> Willd	<i>Dolichoris malabarensis</i> Abdurahiman & Joseph	Not seen	4	Asyn
14	<i>Sycomorus</i>	monoecious	<i>F. racemosa</i> var. <i>racemosa</i> L.	<i>Ceratosten fusciceps</i> Mayr	<i>Apocrypta</i> sp.1 <i>Apocrypta</i> sp.2 <i>Apocrypta</i> sp.3 <i>Apocryptophagus</i> sp.1 <i>Apocryptophagus</i> sp.2	3	Syn

Table 1. Checklist of *Ficus* and their fig wasps in Chiang Mai (June 2007-May 2009). (continued)

No	Subgenus	Sexual System	<i>Ficus</i> species	Pollinators	Non pollinator fig wasps	Crops sampling (times)	Synchrony/Asynchrony
15		monoecious	<i>F. racemosa</i> var. <i>miquelli</i> (King) Corner.	<i>Ceratosolen fusciceps</i> Mayr	<i>Apoerypta</i> sp.1 <i>Apoerypta</i> sp.2 <i>Apoerypta</i> sp.3 <i>Apoeryptophagus</i> sp.1 <i>Apoeryptophagus</i> sp.2	4	Syn
16		dioecious	<i>F. auriculata</i> Lour.	<i>Ceratosolen emarginatus</i> Mayr	<i>Philotrypesis longicaudata</i> Mayr <i>Platyneura</i> sp.	4	Syn
17		dioecious	<i>F. fistulosa</i> Reinw ex. Bl.	<i>Ceratosolen constrictus</i> Mayr	Not seen	2	Syn
18		dioecious	<i>F. hispida</i> var. <i>hispida</i> L.f.	<i>Ceratosolen solmsi</i> Mayr	<i>Apoerypta</i> sp. <i>Philotrypesis</i> sp.	3	Syn
19		dioecious	<i>F. hispida</i> var. <i>badiostriosa</i> Corner	<i>Ceratosolen solmsi</i> Mayr	<i>Apoerypta</i> sp. <i>Philotrypesis</i> sp.	3	Syn
20		dioecious	<i>F. oligodon</i> Miq.	<i>Ceratosolen emarginatus</i> Mayr	<i>Apoerypta</i> sp.	1	Syn
21		dioecious	<i>F. semicordata</i> Buch-Ham. ex. J. E. Sm.	<i>Ceratosolen grevebyi</i> Grandi	<i>Philotrypesis dmia</i> Joseph	2	Syn
22		dioecious	<i>F. squamosa</i> Roxb.	<i>Ceratosolen</i> sp.	Not seen	2	Syn
23		dioecious	<i>F. variegata</i> Bl.	<i>Ceratosolen appendiculatus</i> Mayr	Not seen	2	Syn
24	Ficus	dioecious	<i>F. ischnopoda</i> Miq.	<i>Blastophaga</i> sp.	Not seen	2	Syn
25		dioecious	<i>F. hirta</i> Vahl	<i>Blastophaga javana</i> Mayr	<i>Philotrypesis</i> sp. <i>Syocapter</i> sp.	2	Syn
26	Synocia	dioecious	<i>F. anserina</i> Corner	Not seen	Not seen	3	Asyn
27		dioecious	<i>F. pumila</i> L.	Not seen	Not seen	2	Asyn
28	Sycidium	dioecious	<i>F. anastomosans</i> (Corner) Berg	<i>Liporhopalium</i> sp.	<i>Philotrypesis</i> sp. <i>Syocapter</i> sp.	3	Syn
29		dioecious	<i>F. subincisa</i> Buch.-Ham. ex. Smith	<i>Liporhopalium</i> sp.	Not seen	3	Syn

Table 2 Diversity and distribution of *Ficus* species in Chiang Mai, Thailand (June 2007-May 2009).

No	<i>Ficus</i> species	Habit	Habitat	Ecology & distribution	Status of species		Flowering/ year	Synchrony/ Asynchrony
					Chiang Mai	Thailand		
1	<i>Ficus altissima</i> Bl.	T	Tr	generally occur in lowland, open area and deciduous forest, 310-1,000 m asl.	Co	Co	1-2	Asyn
2	<i>F. benjamina</i> var. <i>benjamina</i> L.	T	Tr, St	widespread, moist mixed forest and in the city, 310-800 m asl.	Co	Co	2-3	Asyn
3	<i>F. benjamina</i> var. <i>nuda</i> (Miq.) Barrett.	T	Tr, St	widespread, moist mixed forest, and in the city, 310-800 m asl.	Co	Co	2-3	Asyn
4	<i>F. carripes</i> Corner	T	Tr	moist mixed deciduous, near the stream, 350-850 m asl.	Co	Co	1	Asyn
5	<i>F. drupacea</i> Thunb.	T	Tr	open area, near the stream, deciduous forest, 320-700 m asl.	Co	Co	1	Asyn
6	<i>F. elastica</i> Roxb.	T	Tr	planted in town, cultivated, 310-500 m asl.	Co	Co	1	Asyn
7	<i>F. lacor</i> Ham.	T	Tr	open area, in the village, for landscaping, 310-600 m asl.	Co	Co	1	Asyn
8	<i>F. macclandii</i> King	T	Tr	open area, growing in the city, 310-400 m, asl.	Co	Co	1-2	Asyn
9	<i>F. microcarpa</i> L. f.	T	Tr	open area, near the river, often cultivated in the city, 310-700 m asl.	Co	Co	1-2	Asyn
10	<i>F. religiosa</i> L.	T	Tr, St	open area, in village and city especially in temple, 310-450 m asl.	Co	Co	1-2	Asyn
11	<i>F. rumphii</i> Bl.	T	Tr, St	open area, in village, 310-450 m asl.	Co	Co	1-2	Asyn
12	<i>F. superba</i> Miq. var. <i>japonica</i> Miq.	T	Tr	deciduous forest and in the village, 320-500 m asl.	R	Co	1	Asyn
13	<i>F. callosa</i> Willd	T	Tr	open area, cultivated in town, 310-500 m asl.	Co	Co	1-2	Asyn
14	<i>F. racemosa</i> var. <i>racemosa</i> L.	T	Tr	riverside, along the stream, moist forest, 310-1,200 m asl.	Co	Co	5-6	Syn
15	<i>F. racemosa</i> var. <i>miquelii</i> (King) Corner	T	Tr	riverside, along the stream, moist forest, 310-1,200 m asl.	Co	Co	5-6	Syn

Table 2 Diversity and distribution of *Ficus* species in Chiang Mai, Thailand (June 2007–May 2009). (continued)

No	<i>Ficus</i> species	Habit	Habitat	Ecology & distribution	Status of species		Flowering/ year	Synchrony/ Asynchrony
					Chiang Mai	Thailand		
16	<i>F. auriculata</i> Lour.	T	Tr	upper area, forests in moist valleys, 600-1,200 m asl.	Co	Co	1-2	Syn
17	<i>F. fistulosa</i> Reinw. ex. Bl.	T	Tr	forests along streams, 310-1,200 m asl.	R	R	1-2	Syn
18	<i>F. hispida</i> var. <i>hispida</i> L.f.	T	Tr	along streams, or moist areas, 310-1,200 m asl.	Co	Co	5-6	Syn
19	<i>F. hispida</i> var. <i>badiostriosa</i> Corner	T	Tr	along streams, or moist areas, 310-1,200 m asl.	Co	Co	5-6	Syn
20	<i>F. oligodon</i> Miquel	T	Tr	upper areas, valleys, along streams or moist areas, 500-1,200 m asl.	R	Co	1-2	Syn
21	<i>F. semicordata</i> Buch-Ham. ex J. E. Sm.	T	Tr	forest margins, valleys, along trails, 600-1,200 m asl.	Co	Co	2-3	Syn
22	<i>F. squamosa</i> Roxb.	S	R	moist forests, near the stream or on the rock in stream and falls, 700-1,200 m asl.	Co	Co	2-3	Syn
23	<i>F. variegata</i> Corner	T	Tr	valleys or moist open areas, 600-1,000 m asl.	Co	Co	1-2	Syn
24	<i>Ficus ischnopoda</i> Miq.	S	R	riverside, on the crack rock in the stream or falls, 500-1,200 m asl.	Co	Co	2-3	Syn
25	<i>Ficus hirta</i> Vahl	S	Tr	forests, forest margins, open areas; low elevations, 500-1,000 m asl.	Co	Co	2-3	Syn
26	<i>Ficus anserina</i> Corner	C	L	rain forests, forests, mountain slopes, limestone areas, 400-1,200 m asl.	R	R	1-2	Asyn
27	<i>Ficus pumila</i> L.	C	E	cultivated and ornamental plant, 310-600 m asl.	Co	Co	2-3	Asyn
28	<i>Ficus anastomosans</i> Wall.	S	Tr	limestone mountain, crack of the rock, open and dry areas, 500-900 m asl.	R	R	2-3	Syn
29	<i>Ficus subinvisia</i> Buch.-Ham. ex. Smith	S	Tr	moist forests, along streams, valleys, 400-1,200 m asl.	R	R	2-3	Syn

Habit: T= Tree, Tr= Terrestrial, S= Shrub, E= Epiphyte, H= Herb, C= Climber, St= Strangler
Habitat: Tr= Terrestrial, E= Epiphyte, R= Rheophyte, L= Lithophytes
Status of species: R= rare, Co= Common **Syn**= Synchrony, **Asyn**= Asynchrony

cultivated plants: *Ficus altissima*, *F. benjamina*, *F. lacor*, *F. microcarpa*, *F. religiosa*, *F. superba* var. *japonica*, *F. callosa* and *F. hispida*.

Pollinators of five fig species were not found; composed of four introduced species; *F. curtipes*, *F. rumphii*, *F. pumila* and *F. maclellandii*, and one local species of *F. anserina*, rare fruiting samples in site study.

The most common monoecious species were *F. benjamina*, *F. lacor*, *F. religiosa* and *F. racemosa*. They were strangling plants that were mainly bird-dispersed, except *F. racemosa*, which has fruits usually eaten by small mammals such as squirrels and fruit eating bats.

The numbers of flowering periods and fruiting times were diverse among the fig trees. Figs might be present just once a year or could be produced 5-6 times in some species. Both monoecious and dioecious species such as *F. racemosa*, *F. fistulosa* and *F. hispida* have figs at different stages of development within the same crop (Table 2). The situation called 'synchrony' that we found in both within tree and among trees in each species.

4. CONCLUSION

Twenty-six fig species were represented in the study sites around Chiang Mai. Most had their own specific pollinators, but *F. auriculata* and *F. oligodon* shared the same species of pollinator (*Ceratosolen emarginatus*). The pollinators of *F. curtipes*, *F. rumphii*, *F. pumila*, *F. maclellandii* and *F. anserina* could not be found.

The widespread fig species usually possessed a large number of individuals of pollinators. However, the number varied in each season [18, our observation]. There were many syconia of some figs without pollination e.g. *F. ischnopoda* and *F. subincisa*. Almost figs dropped in a few weeks. Perhaps there was small population of pollinators in nature. In dioecious fig tree, male tree bear fig wasp

offspring in its syconium. If there is less male tree population in the area, fig wasps cannot survive without syconium. Thus the status of synchronous crops both within tree and among tree can solve this problem. Fig wasps can immerge the new receptive fig in the same tree or other tree. In the study, synchronous crops was usually occur in dioecious fig except a big syconium monoecious fig as *F. racemosa*. It bears lots of syconium and fig wasps, sometime the new generation pollinators immerge to the same tree again.

The ripe fruits of *F. racemosa* served many kind of animals as food, so they distributed lots of seeds. Number and size of figs in each crop was one of the reasons to promote them such as *F. benjamina*, *F. microcarpa* and *F. lacor*, although produced small figs but their big crop attracted many kind of birds, which help them planting new generation. Future studies on the details of interactions between figs and fig wasps should be of valuable works. It would be support knowledge of fig diversity and distribution and also the conservation of natural ecosystems.

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