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REPRODUCTIVE PHENOLOGY AND GROWTH OF RIPARIAN SPECIES ALONG PHRA PRONG RIVER, SA KAEO PROVINCE, EASTERN THAILAND

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ABSTRACT

The objective of this study was to investigate the duration of flowering and fruiting and the growth of riparian species in the natural forest along Phra Prong River, Watthana Nakhon District, Sa Kaeo province. The occurrence of flowering and fruiting was recorded every month from February 2015 to January 2016 (12 months) along a 7km distance of the riversides. Sixty six species belonging to 36 families were seen flowering and fruiting in this study. They were observed during February – April. The peak of flowering and fruiting occurred in March (early summer). *Hydnocarpus anthelminthicus*, *Uvaria rufa*, and *Combretum latifolium* had a long lasting flowering and fruiting period. *Oxystelma esculentum*, *Capparis micracantha*, *Connarus cochinchinensis*, *Derris scandens*, and *Ficus racemosa* produced flowers and fruits more than once a year. Those species may play an important role in availability of food resources for animals in the riparian forest. The appropriate time to collect seeds in Phra Prong riparian forest starts from February and lasts until August. The germination test indicated that *Xanthophyllum lanceatum* and *Crateva magna* had a high germination rate, about 70%. Growth of some riparian species, including *Cinnamomum iners*, *Dipterocarpus alatus*, *Hydnocarpus anthelminthicus* and *Hopea odorata* was monitored every three months from July 2015 to June 2016. Diameter growth of *D. alatus* was significantly higher during the wet season (Jul-Sep) than other seasons. In contrast, the rest of the species showed no significant differences among monitoring periods. Height growth rate of *C. iners* was significantly highest late in the dry period (Jan-Mar).

Keywords: reproductive phenology, flowering, fruiting, growth, riparian species, Phra Prong River, Sa Kaeo, Thailand

INTRODUCTION

Riparian forests occurring along streams, lakes, and rivers provide a natural buffer that can protect the freshwater environment from disturbances by human activities on the adjacent land. Many studies have revealed that a riparian buffer is beneficial to both aquatic and terrestrial ecosystems (Broadmeadow & Nisbet, 2004; Saint-Laurent *et al*., 2010; Bongard & Wyatt, 2010; Gunderson *et al*., 2010). The specific functions are considered to be regulation of sediment and nutrients transported from upslope areas (Merritt & Cooper, 2000; Luke *et* *al*., 2007; Mayer *et al*., 2007), reduction of soil erosion and stabilization of stream banks (USDA National Agroforestry Center, 1997), protection of water quality by filtering the heavy metals from the agricultural land (Zhang *et al*., 2010; Pavlovic *et al*., 2016), and providing habitats for wildlife and vegetation (Moungsrimuangdee & Nawajongpan, 2016; Waiboonya *et al*., 2016).

Phra Prong River, which flows through Watthana Nakhon and Muang District of Sa Kaeo Province, is an important water supply for local people and for irrigation systems of many crop fields, particularly rice, sugar cane and cassava. The diversity of flora and fauna within the Phra Prong riparian forest also supplies valuable resources for people living in the neighborhood, such as foliage, fruits, medicinal plants, mushrooms, and fuel-wood (Moungsrimuangdee *et al*., 2017). Recent research indicates that riparian forests along Phra Prong riverbanks are diminishing continuously due to an expansion of agricultural land and current irrigation management practices (Moungsrimuangdee *et al*., 2015). The research also reports that large size native riparian trees of *Hydnocarpus anthelminthicus*, *Xanthophyllum lanceatum*, *Dipterocarpus alatus*, and *Crateva magna* are scattered along the riverbanks. In addition, these species show low natural regeneration by having low numbers of saplings or seedlings. As the native riparian species gradually decrease, pioneer species, especially *Streblus asper*, and *Lepisanthes rubiginosa* are able to grow up and rapidly cover the degraded forest along Phra Prong riverbanks (Moungsrimuangdee *et al*., 2015). A study on seedling growth of existing species could give relevant information to understand the natural regeneration potential in this forest.

The riparian restoration is a key issue for conserving ecosystem services as mentioned above. Information on vegetation structure, composition, and phenology are crucial for restoring disturbed forest (Elliot *et al*., 2013). Phenology is a step for selecting species, providing information of optimum seed collection times, seedling propagation planning as well as relation with other taxa. This study aimed i) to document flowering and fruiting phenology of Phra Prong native species and ii) to monitor seedling growth. This will provide relevant information supporting the riparian restoration programs in these areas.

MATERIALS AND METHODS

Study area

The study was carried out along a 7km distance of the Phra Prong Riversides, Nong Mak Fai and Chong Kum Sub–district, Watthana Nakhon District (13º 54' 48" N 102º 22' 46" E, Figure 1). Phra Prong River, which originates from the mountainous range located in Dong Phayayen – Khao Yai Forest Complex, passes through Watthana Nakhon and Muang District of Sa Kaeo Province, flows southwestward to join Hanuman River, and becomes the Prachin Buri River in Krabin Buri District, Prachin Buri Province (Figure 1). *Streblus asper, Dipterocarpus alatus, Xanthophyllum lanceatum*, *Diospyros pendula*, *Nauclea orientalis,* and *Hydnocarpus anthelminthicus* are common species in this area. The soil properties appeared to be clay to sandy loam with a pH of 4.76 and 2.62 % of organic matter (Moungsrimuangdee *et al*., 2015). Climatic data (2006-2015) were obtained from Aranyaprathet Weather Station (Meteorological Department, 2016). Mean annual air temperature was 28.31 ºC with 73 % of mean annual relative air humidity and 1,404 mm of annual sum of rainfall. Monthly sum of rainfall, mean monthly air temperature, and mean monthly relative air humidity were presented in Figure 2.

Fig. 1: Location of Phra Prong River and the study site of the flowering and fruiting observation trails along Phra Prong River, Nong Mak Fai and Chong Kum Sub-district, Sa Kaeo Province, Thailand

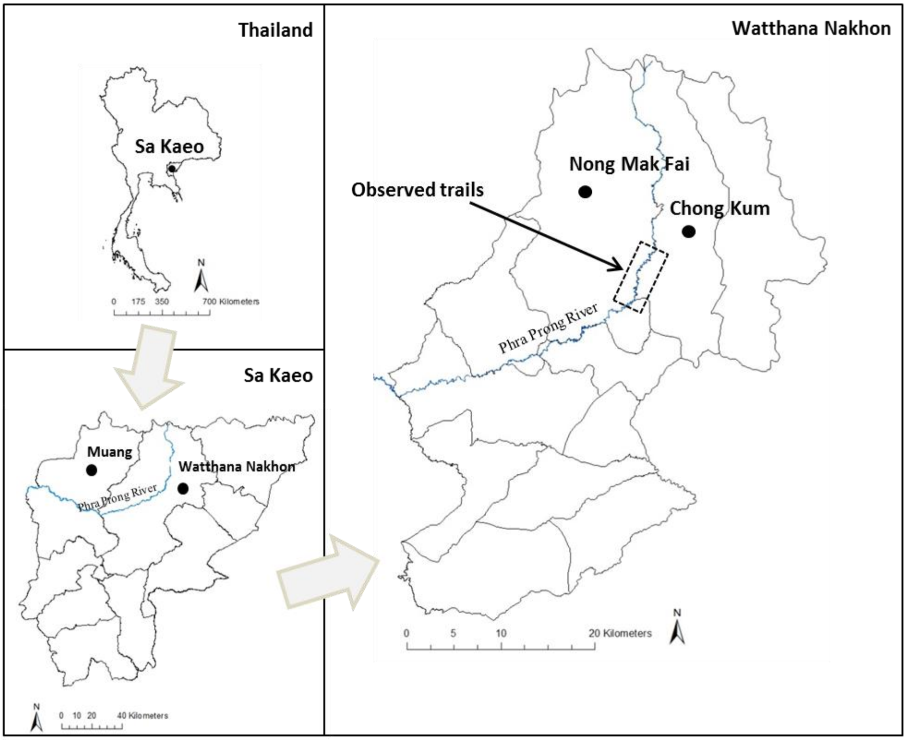
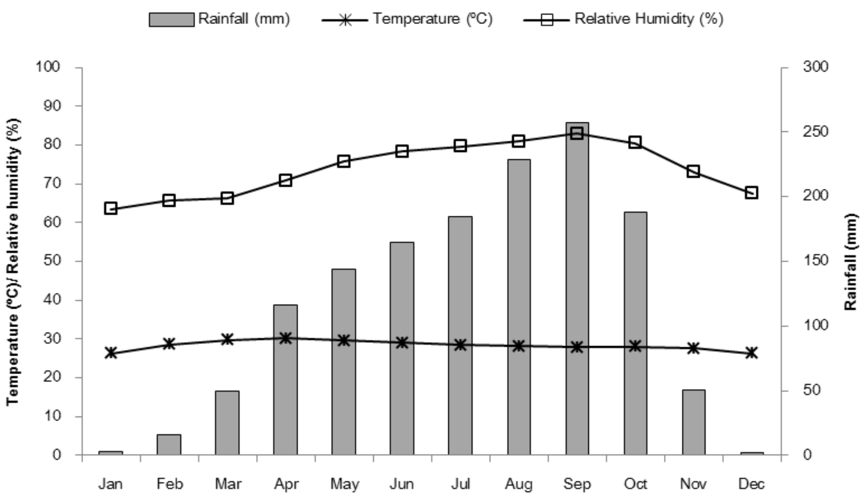


Fig. 2: Monthly sum of rainfall, mean monthly air temperature, and mean monthly relative air humidity at Watthana Nakhon District (Aranyaprathet Weather Station) over 2006-2015



Flowering and fruiting of riparian species

All individuals of riparian species found along the surveyed trails were observed in this study. Fruiting and flowering periods were recorded when at least three individuals produced the reproductive parts. The trails were visited monthly from February 2015 to January 2016. The studied species were identified. Taxonomic nomenclature and life forms followed Pooma & Suddee (2014). Voucher specimens were deposited at the laboratory of Bodhivijjalaya College, Srinakharinwirot University.

Germination test of riparian species

The germination ability of three riparian woody species was investigated under nursery conditions at Bodhivijjalaya College, Srinakharinwirot University, Sa Kaeo Province. Mature fruits of *Xanthophyllum lanceatum*, *Crateva magna* and *Hydnocarpus anthelminthicus* were collected randomly in late July 2015. Three replications of 50 seeds, without any damages or decayed parts, were sown into two different soil types, dry sandy soil and wet peat soil. The seed germination, defined as radical emergence, was recorded daily, until 30 days after the last germination recorded. Accumulative germination percentage and Median Length of Dormancy (MLD) were calculated and a comparison between the two different sowing conditions was done.

Growth of riparian species

The growth of native woody species seedlings was observed. *Cinnamomum iners*, *Dipterocarpus alatus*, *Hydnocarpus anthelminthicus*, and *Hopea odorata* are native riparian species. They regenerate and grow naturally in the Phra Prong riparian forest. *C. iners* (n=33), *D. alatus* (n=50), *H. anthelminthicus* (n=27), and *H. odorata* (n=31) seedlings, aged 1-2 years old were selected randomly. The selected seedlings were healthy and had similar diameter at ground level (D_0) and total height (H_t) at the initial stage. Seedlings were labelled with plastic tags, and the location recorded for subsequent measurements. Diameter at ground level and total height were measured every three months (July 2015 – June 2016). Relative growth rates (RGR) were assessed using the formula as follow

$$RGR = \frac{\ln G_2 - \ln G_1}{t_2 - t_1}$$

Where G_1 and G_2 are diameter at ground level (D_0) or total height (H_t) of seedlings at the beginning (t_1) and end (t_2) of monitoring periods, respectively.

RESULTS

Flowering and fruiting periods of the riparian species

Flowering and fruiting periods of 66 species, from 36 families were observed (Table 1). Flowers were seen every month during the one-year observations, but fruits were not present in November. The number of riparian species producing flowers and fruits was highest in March, with 36 species and 33 species, respectively, whereas, the period from September to January presented the lowest species number (Figure 3). A few species had prolonged flowering and fruiting periods, up to six months, such as *Hydnocarpus anthelminthicus*, *Uvaria rufa*, and *Combretum latifolium*. Nine species produced flowers, and seven species produced fruits more than once a year (Table 1).

Table 1: Flowering and fruiting periods of Phra Prong riparian species, Watthana Nakhon District, Sa Kaeo Province during February 2015 – January 2016

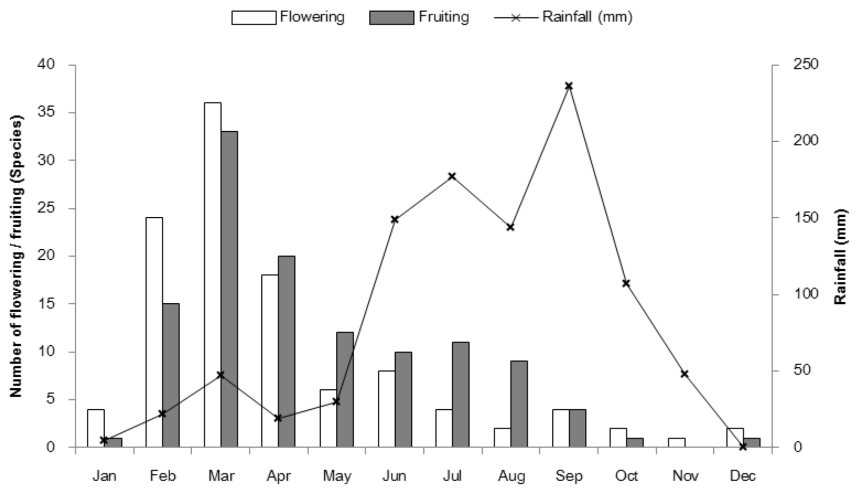
No	Family name	Scientific name	Life form*	Period	
				Flowering	Fruiting
1	Achariaceae	*Hydnocarpus anthelminthicus* Pierre ex Laness.	T	Jan-Jun	Feb-Jul
2	Anacardiaceae	*Semecarpus cochinchinensis* Engl.	T	Jan-Feb	Feb-Apr
3	Annonaceae	*Dasymaschalon lomentaceum* Finet & Gagnep.	S	Mar	
4		*Desmos chinensis* Lour.	C	Jun-Jul	
5		*Goniothalamus* sp.	T	Mar	
6		*Polyalthia suberosa* (Roxb.) Thwaites	S/ST	Feb-Apr	Feb-May
7		*Uvaria rufa* Blume	C	Mar-Jul	May-Aug
8	Apocynaceae	*Amphineurion marginatum (Roxb.) D. J. Middleton*	C	Apr	
9		*Artabotrys siamensis* Miq.			Jul
10		*Ichnocarpus frutescens* (L.) W. T. Aiton	C	Apr, Oct	Mar, Sep, Dec
11		*Oxystelma esculentum* (L. f.) Sm.	C	Feb-Mar, Sep-Oct	Feb-Mar, Sep-Oct
12		*Parameria laevigata* (Juss.) Moldenke	C	Feb-Mar	Feb-Mar
13		*Tabernaemontana bufalina* Lour.	ST	Mar	Jun
14		*Toxocarpus villosus* (Blume) Decne.	C	Nov	Mar
15		*Wrightia religiosa* (Teijsm. & Binn.) Benth. ex Kurz	S	Mar	
16	Asteraceae	*Tarlmounia elliptica* (DC) H. Rob., S. C. Keeley, Skvaria & R. Chan	C	Feb-Mar	
17	Burseraceae	*Garuga pinnata* Roxb.	T	Mar	Mar-May
18	Capparaceae	*Capparis micracantha* DC.	S/ST	Jan-Apr, Dec	
19		*Crateva magna* (Lour.) DC.	T	Feb-Mar	Apr-Aug
20	Combretaceae	*Combretum latifolium* Blume	C	Jan-May	Jan-May
21	Connaraceae	*Connarus cochinchinensis* (Baill.) Pierre	S/ST	Feb-Mar, Aug-Sep	Feb-Mar, Jul-Sep
22	Convolvulaceae	*Merremia hederacea* (Burm. f.) Hallier f.	HC	Feb-Mar, Sep	Mar
23	Dilleniaceae	*Tetracera loureireii* (Finet & Gagnep.) Pierre ex Craib	C	Mar, Jun	Jun
24	Dipterocarpaceae	*Dipterocarpus alatus* Roxb. ex G. Don	T	Feb-Mar	Feb-May
25	Euphorbiaceae	*Homonoia riparia* Lour.	S/ST	Feb-Mar	
26	Fabaceae	*Acacia pennata* (L.) Willd.	C	Feb-Mar	Feb-Apr
27		*Acacia* sp.	C	Apr	Feb-Mar

No	Family name	Scientific name	Life form*	Period	
				Flowering	Fruiting
28		*Derris scandens* (Roxb.) Benth.	C	Apr, Aug	Feb-Mar, Sep
29		*Peltophorum dasyrrhachis* (Miq.) Kurz	T	Feb	
30	Gnetaceae	*Gnetum montanum* Markgr.	C	Feb-Mar, Sep	Mar
31	Lamiaceae	*Gmelina asiatica* L.	S	Feb-Mar	Feb-Mar, Aug
32		*Sphenodesme pentandra* Jack	C	Mar	Apr
33	Lauraceae	*Cinnamomum iners* Reinw. ex Blume	T	Feb	Feb
34	Loranthaceae	*Loranthus sp.*	PaS	Mar	
35	Malvaceae	*Colona auriculata* (Desf.) Craib	S	Feb, Jun-Jul	Mar, Aug
36		*Microcos tomentosa* Sm.	T	Apr-Jun	May-Aug
37	Marantaceae	*Donax canniformis* (G. Forster) K. Schum.	H	Mar-Apr	
38	Moraceae	*Ficus heterophylla* L. f.	CrS		Mar-Apr
39		*Ficus hispida* L.f.	ST		Mar
40		*Ficus racemosa* L.	T		Feb-Mar, Jul
41		*Streblus asper* Lour.	T	Feb	Mar
42	Myristicaceae	*Knema globularia* (Lam.) Warb.	T		Mar-May
43	Passifloraceae	*Passiflora foetida* L.	ExC	Mar	Mar-Apr
44	Phyllanthaceae	*Antidesma acidum* Retz.	S/ST	Mar-May	May-Aug
45		*Antidesma ghaesembilla* Gaertn.	S/T	Apr	Apr
46		*Breynia retusa* (Dennst.) Alston	S/ST		Mar
47		*Bridelia stipularis* (L.) Blume	ScanS/ST		Mar
48		*Hymenocardia punctata* Wall. ex Lindl.	S/T	Mar-Apr	Mar-Jul
49	Oleaceae	*Jasminum scandens* (Retz.) Vahl	ScanS/C	Feb-Mar	
50	Orchidaceae	*Aerides falcata* Lindl. & Paxton	EO	Jun	
51	Polygalaceae	*Xanthophyllum lanceatum* J. J. Sm.	ST	Feb-Mar	Apr-Jul
52	Primulaceae	*Ardisia sanguinolenta* Blume	S/ST	Mar	Mar
53	Rhamnaceae	*Ventilago harmandiana* Pierre	C		Feb-Apr
54		*Ziziphus cambodiana* Pierre	ST		Jun
55	Rhizophoraceae	*Carallia brachiata* (Lour.) Merr.	T		Mar-Apr
56	Rubiaceae	*Nauclea orientalis* (L.) L.	T	Jul	Aug
57		*Oxyceros horridus* Lour.	ScanS	Mar	

No	Family name	Scientific name	Life form*	Period	
				Flowering	**Fruiting**
58		*Xantonnea parvifolia* (Kuntze) Craib	S	Mar	Mar
59	Rutaceae	*Glycosmis pentaphylla* (Retz.) DC.	S/ST		Mar
60	Salicaceae	*Casearia grewiifolia* Vent.	T	Feb	
61	Sapindaceae	*Allophylus cobbe* (L.) Raeusch.	S	Apr	
62		*Lepisanthes rubiginosa* (Roxb.) Leenh.	S/ST	Feb-Mar	Mar-Apr
63		*Nephelium hypoleucum* Kruz	T		Apr
64	Urticaceae	*Poikilospermum suaveolens* (Blume) Merr.	C	Mar-Apr	
65	Vitaceae	*Ampelocissus* sp.	C	Apr-Jun	Jul-Aug
66		*Tetrastigma* sp.	C	Mar	

*C= Climber, CrS = Creeping Shrub, ExC = Exotic Climber, EO = Epiphytic Orchid, H = Herb, HC = Herbaceous Climber, PaS = Parasitic Shrub, S = Shrub, ScanS = Scandent Shrub, ST = Shrubby Tree, T = Tree (Pooma & Suddee, 2014)

Fig. 3: Flowering and fruiting periods of riparian species along Phra Prong River, Watthana Nakhon District, Sa Kaeo Province and monthly sum of rainfall during February 2015 – January 2016 (Aranyaprathet Weather Station).



Germination test

Seeds from *Xanthophyllum lanceatum* started to germinate four weeks after sowing. The germination rate (%) did not significantly differ between the two treatments, wet peat soil and dry sandy soil (Figure 4, *t*-test, p=0.55). A similar result was found in the length of dormancy, where mean length of dormancy in the two treatments were not statistically different (Table 2, *t*-test, p=0.14). *Crateva magna* seeds left in dry sandy soil started to germinate after three weeks, and after four weeks in wet peat soil. Seeds sown in dry sandy soil had a germination rate of 76%, significantly higher (Figure 5, *t*-test, p<0.01) than in wet peat soil with a rate of 37.3 %. The mean dormancy was also significantly different among the two treatments (Table 2, *t*-test, p=0.04). Seed germination percentages in both species were considered as high (>70 %). *Hydnocarpus anthelminthicus* did not germinate during the 14 weeks experiment.

Fig. 4: Accumulative germination of *Xanthophyllum lanceatum* in different sowing medias, dry sandy soil and wet peat soil under nursery conditions

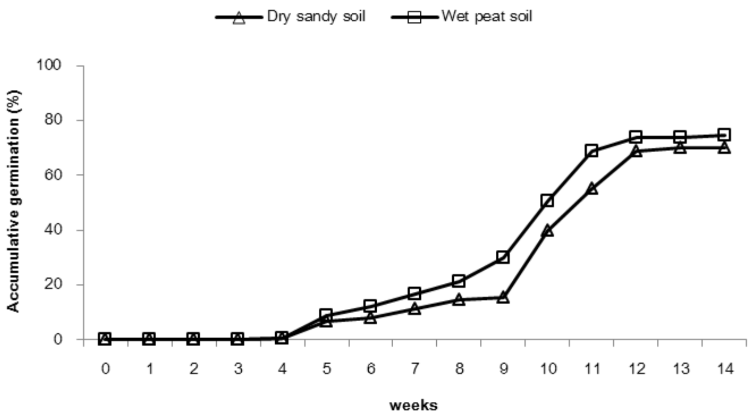


Fig. 5: Accumulative germination of *Crateva magna* in different sowing medias, dry sandy soil and wet peat soil under nursery conditions

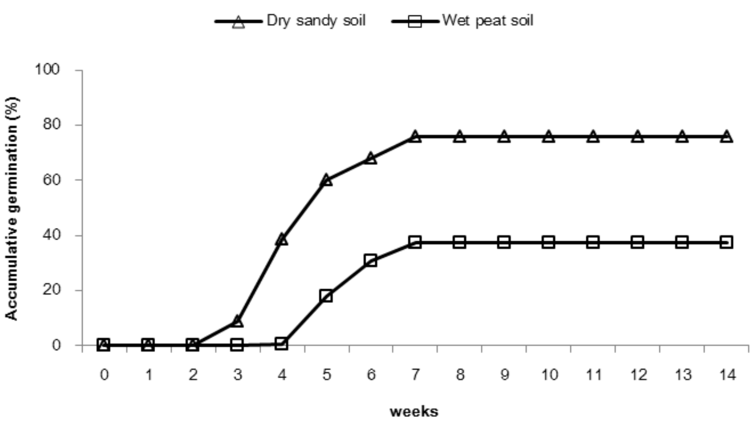


Table 2: Median length of dormancy (MLD) of *Xanthophyllum lanceatum* and *Crateva magna* in different sowing media, dry sandy soil and wet peat soil

Species	MLD (Days)		P-value
	Dry sandy soil	Wet peat soil	
Xanthophyllum lanceatum	69.4 ± 1.5	65.9 ± 1.2	0.14^{NS}
Crateva magna	28.5 ± 1.6	35.0 ± 1.6	0.04^{*}

NS = not statistically significant
* = difference significant at $p<0.05$

Growth of riparian seedlings

Seedlings of *Dipterocarpus alatus* presented significantly higher diameter growth rate during July- September than other monitoring periods. (ANOVA, $p<0.01$, Figure 6). The diameter growth of *Cinnamomum iners, Hydnocarpus anthelminthicus* and *Hopea odorata* seedlings were not significantly different among monitoring periods (Figure 6). Height growth rate of *D. alatus*, *H. anthelminthicus*, and *H. odorata* seedlings did not differ significantly among monitoring periods (Figure 7). Conversely, height growth rate of *C. iners* seedlings was significantly highest during January-March, compared to other periods (ANOVA, $p<0.01$, Figure 7).

Fig. 6: Relative growth rate in diameter at ground level (D_0) of natural riparian seedlings, Phra Prong River, Watthana Nakhon District, Sa Kaeo Province. Data are given as mean and standard errors are shown above the bars. Different letters in each column indicate significant differences within species (P<0.01) using Tukey's HSD test. NS means not statistically significant differences within species using ANOVA

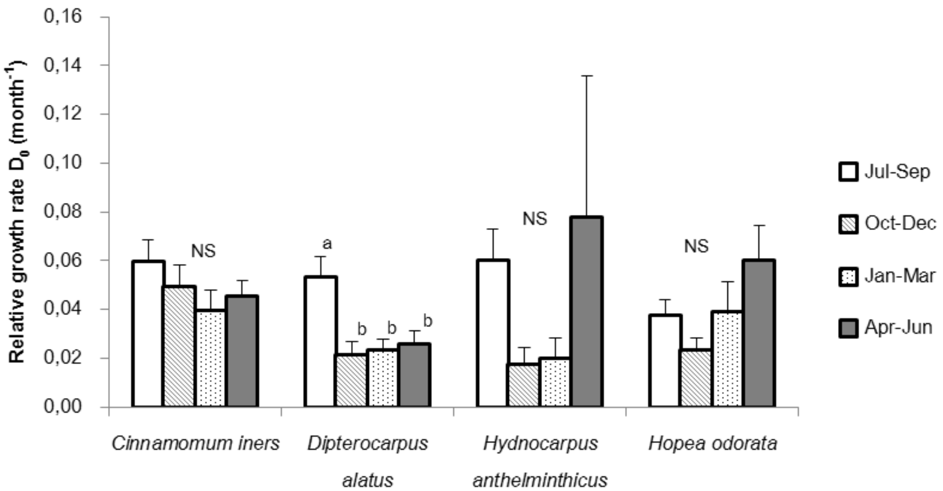
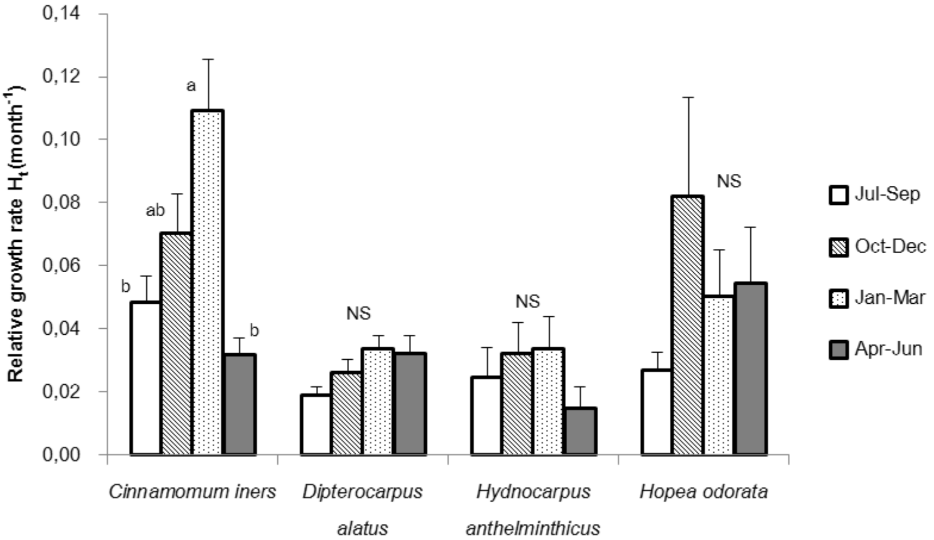


Fig. 7: Relative growth rate in total height (H_t) of natural riparian seedlings, Phra Prong River, Watthana Nakhon District, Sa Kaeo Province. Data are given as mean and standard errors are shown above the bars. Different letters in each column indicate significant differences within species (P<0.01) using Tukey's HSD test. NS means not statistically significant differences within species using ANOVA



DISCUSSION AND SUGGESTIONS

The flowering and fruiting periods of 66 species from 36 families were observed monthly along the Phra Prong riparian forest, Watthana Nakhon District, Sa Kaeo Province, during February 2015 to January 2016. The number of species producing flowers fluctuated throughout the year, ranging from 1-36 species. The number of flowering and fruiting species sharply increased in February, March and April and achieved the highest number in March. Phra Prong riparian species had a favorable production of flowers and fruits during late dry to early wet season. A similar phenological pattern was found in forests in Northern Thailand, where a majority of dry tropical forest tree species had a flowering peak in March and a fruiting peak in April (Elliot *et al.*, 1994). In the tropical region, with high relative air humidity and no pronounced dry season, riparian forest species have been reported to flower mostly when air temperature changes from cool to warm (Cascaes *et al*., 2013). On the other hand, in the tropical region where two seasons (wet and dry) are clearly defined, flowers are found to bloom mainly in the dry season and produce fruits in the wet season (de Azevedo *et al*., 2014). In addition, Savannas riparian species were found to have flowering and fruiting periods in the wet season (Silva *et al*., 2011). These findings suggested that variation of flowering and fruiting periods were highly site specific (Elliot *et al*., 1994; Kikim & Yodava, 2001; Sulistyawati *et al*. 2012).

Plant reproductive events correlate with climatic factors, such as rainfall, temperature, photoperiod, and soil moisture (Elliot *et al*., 1994; Kikim & Yodava, 2001; Silva *et al*., 2011; Sulistyawati *et al*. 2012; Cascaes *et al*., 2013; de Azevedo *et al*., 2014). In addition, biological factors, pollinators, dispersers, predators, and competitors, potentially influence plant cycles phenomena (Elliot *et al*., 1994, Cascaes *et al*., 2013). Phylogenetic constraints are considered as an important factor, regulating the phenological events, and similar species are expected sharing similar flowering and fruiting patterns (Silva *et al*., 2011).

The riparian species flowering during the dry season, were beneficial for attracting pollinators since many tree species shed their leaves. Furthermore, it is also desirable with fruits ripening and seed disperse at the beginning of the rainy season, when conditions for seed germination and seedling survival are optimal (Elliot *et al*., 1994). This study suggests a need for further studies on the influences of environmental factors on riparian species phenology. Based on the results found in this study, the appropriate seed collecting time in Phra Prong riparian forest starts from February and continue until August. However, long-term monitoring could be implemented to generate a flowering and fruiting database for this area.

A number of species produced flowers and fruits more than once a year, for example, *Oxystelma esculentum, Capparis micracantha*, *Connarus cochinchinensis*, *Derris scandens*, and *Ficus racemosa*. Furthermore, some riparian species had long lasting flowering and fruiting periods, such as *Hydnocarpus anthelminthicus*, *Uvaria rufa*, and *Combretum latifolium*. Those species may play important roles in making food resources available for wildlife, during the time most other riparian species have low levels of flower and fruit production. Cascaes *et al*. (2013) found that flowering and fruiting species with long periods in Brazilian tropical forests could support local community with the natural resources such as ornithophilous species (*Fuchsia regia* and *Nematanthus tessmannii*) and zoochorous species (*Myrcia spectabilis*, *Rudgea jasminoides*, *Posoqueria latifolia* and *Cabralea canjerana*). These findings were not discussed for tropical forests in general, and they suggested that the pattern in duration of reproductive phases should be determined to understand the relationships of interspecies associations with the reproductive systems of the species (Cascaes *et al*., 2013).

Understanding of seed ecology of native species is necessary to improve forest restoration techniques. Many factors have been documented that affect seed germination, such as light, temperature, pH, water availability, and salinity (Young & Clements, 2003; Garcia *et al*., 2006; Ghaderi-Far *et al*., 2010). We did a preliminarily test of the effect of different sowing media on seed germination. Germination of *Crateva magna* seeds sown in wet peat soil showed a remarkably decreased percent germination when compared with dry sandy soil. Different zones within the riparian forest buffer provide different soil characters. It is possible that seed germination of some riparian species is correlated with soil conditions exhibited in each riparian zone. Study on regeneration, composition and succession of riparian vegetation in the natural forest should be undergone to provide more insight into ecology of selected species for the management of riparian restoration.

Percent seed germination of *C. magna* and *Xanthophyllum lanceatum* were high in both species (> 70 %). These two species can potentially be selected for nursery propagation for riparian restoration. Further tests could have emphasis on nursery propagation techniques and seedling growth in degraded sites. *Hydnocarpus anthelminthicus* seeds did not germinate after 14 weeks experiment. This species might need a longer dormancy than the study period. Seed germination experiments may need to be continued as well as study of pretreatment techniques.

In general, diameter growth of all studied riparian species did not statistically differ among seasons, except *Dipterocarpus alatus*, which seemed to respond positively to water availability by exhibiting higher growth rate during the wet season (July-September) than the other seasons. Height growth rate of *Cinnamomum iners* was greater during the dry season (January-March), whereas seasonal growth rate of the rest showed no significant differences. The growth pattern of riparian tree species tended to correlate with local climatic conditions, which are affected by hydrology of riparian forest (Boakye *et al*., 2016). Regular and irregular flooding phenomena at the study site influencing growth responses of the plant community should be considered.

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