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The phenology of dioecious *Ficus* spp. tree species and its importance for forest restoration projects

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ABSTRACT

Ficus spp. are keystone tree species in tropical forest ecosystems and therefore, it is vital to include them in tree planting for forest restoration programs. However, lack of knowledge about critical aspects of their reproductive ecology currently limits their use, particularly optimal seed collection times and potential interruption of their highly specialized pollination mechanisms. Therefore, the reproductive phenology of seven dioecious *Ficus* species (*Ficus auriculata*, *F. fulva*, *F. hispida*, *F. oligodon*, *F. semicordata*, *F. triloba* and *F. variegata*) was studied at Doi Suthep–Pui National Park, Northern Thailand, in order to provide useful data to support forest restoration projects. The fig crops on male and female trees of each species were quantified monthly over a full annual cycle (March 2008–February 2009), using the canopy density method. At the population-level, most species produced figs all year round, but fig abundance varied seasonally. Maximum production of ripe figs by female (i.e. seed-producing) trees of most species occurred in the rainy season (May–August, except for *F. triloba*), while the main fig crop of male (i.e. wasp-producing) trees peaked 1–3 months before female trees. Four species *F. auriculata*, *F. fulva*, *F. oligodon*, and *F. variegata* presented critical bottleneck periods for wasp survival, especially during the rainy season, when the wasp-producing figs of male trees were least abundant. The study generated scientifically-based recommendations that will be useful for development of efficient forest restoration programs that maintain keystone resources in tropical forest ecosystems such as (i) optimum time and place for seed collection, (ii) recommendations on the propagation of dioecious fig species, (iii) optimum planting sites for each species and (iv) forest restoration plans to sustain the obligate ecological relationships between fig-trees and their pollinators.

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1. Introduction

Forest restoration for biodiversity conservation, watershed protection and carbon sequestration requires detailed knowledge of plant phenology (FORRU, 2006). This is especially so for forest restoration programs based on the 'framework tree species method' which involves planting 20–30 carefully selected indigenous forest tree species (both pioneer and old growth simultaneously) to re-establish a basic forest structure that catalyzes the recovery of biodiversity (Goosem and Tucker, 1995). Indeed, propagation of a diverse crop of native forest tree species requires careful planning of seed collection and nursery work programs (FORRU, 2008). Furthermore, phenological data can be used to indicate the habitat preferences of tree species, provide information about pollination and seed dispersal mechanisms, and enable the identification of keystone tree species (Gilbert, 1980).

Due to their status as keystone species for frugivorous seed dispersers (Lambert and Marshall, 1991; Shanahan et al., 2001b), *Ficus* spp. have been promoted as framework species for tropical forest restoration (Goosem and Tucker, 1995; FORRU, 1998). *Ficus* produce figs that attract numerous seed-dispersing animals year-round, and they also grow very dense root systems that are excellent for preventing soil erosion and stabilizing river banks (FORRU, 2006). In addition, many species of *Ficus* are drought-resistant, pest-resistant and fire-resilient, which enable them to survive and grow well under the harsh, hot, dry, sunny conditions that prevail in most degraded sites (Condit, 1969; FORRU, 2006). Therefore, figs play an important role in supporting high biodiversity in the tropical forest ecosystems (Rønsted et al., 2008). Hence, dioecious *Ficus* species that thrive in secondary growth may have role in facilitating the regeneration of disturbed habitats (Shanahan et al., 2001a).

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However, currently the use of *Ficus* spp. trees in forest restoration programs is limited due to lack of knowledge about their basic ecology, phenology, propagation and planting techniques. Moreover, most studies of *Ficus* spp. phenology and their use in forest restoration program have been conducted on monoecious species rather than on dioecious ones (Yu et al., 2006). Therefore, knowledge of dioecious *Ficus* spp. phenology will increase understanding of their pollination and seed dispersal mechanisms, and will enable nursery work programs and planting techniques to be developed to improve forest restoration programs and provide constructive suggestions for the conservation of biodiversity in the tropics.

2. Materials and methods

2.1. Study site

This research was conducted in Doi Suthep–Pui National Park, (18°51′N latitude and 98°54′E longitude), Chiang Mai, Northern Thailand. The park supports three forest types: deciduous dipterocarp-oak forest from sea level to *c.* 800 m., mixed forest (evergreen + deciduous) from *c.* 800 to 1200 m. and primary, evergreen, seasonal forest above 1200 to the summit at 1685 m. (Maxwell and Elliott, 2001). The area has a monsoonal climate with pronounced dry and wet seasons. The wet season lasts from May to October and the dry season from November to April. The dry season is subdivided into the cool-dry season (November–January) and the hot-dry season (February–April; Fig. 1).

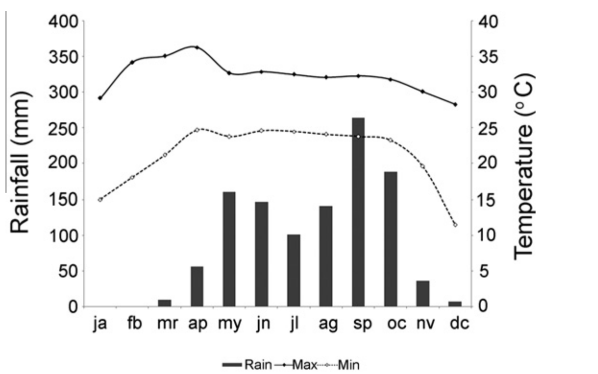

Fig. 1. Average monthly rainfall (mm), maximum and minimum temperature (°C) at the Northern Meteorological Center, about 3 km. from the National Park (from March 2008 to February 2009).

Two transect lines were established to study the phenology of these species, traversing every forest type found in the National Park (from 320 to 1685 m. elevation). Trail A ran across the park from east to west, whilst trail B ran from north to south (Fig. 2). All mature individuals of the selected *Ficus* species (dbh > 10 cm), within 20 m to the left and right of the transect lines, were selected for monitoring, tagged and their position recorded by GPS. Selected fig trees were observed monthly from March 2008 to February 2009. They were scanned with binoculars and scored for different pheno-phases of figs and leaves, using the crown density method (Koelmeyer, 1959). This method uses a linear scale of 0–4; with 4 representing the maximum intensity of figs or leaves. Values of 3, 2, and 1 represent three quarters, half and one quarter of the maximum intensity, respectively. A value of 0.5 was used to indicate the presence of small amounts of figs and leaves below one-quarter of the maximum intensity.

Since the habits of the seven selected *Ficus* tree species were different (figs in leaf-axils, stem-figs and earth-figs), the abundance of figs was assessed in relation to the density of fig-bearing spurs or stolons on each tree. The scoring system for the developmental phases of the figs was modified from Galil and Eisikowich (1968) and Koelmeyer (1959) by splitting the developmental cycle into four pheno-phases and by using a linear scale of 0–5 (with five representing the maximum intensity of figs). However, for leaf phenology, the original crown density method (using scores ranging from 0 to 4) was followed (Table 1). During each census, samples of 10–20 figs from each tree were collected for dissection and determining the stage of development. Figs at the receptive

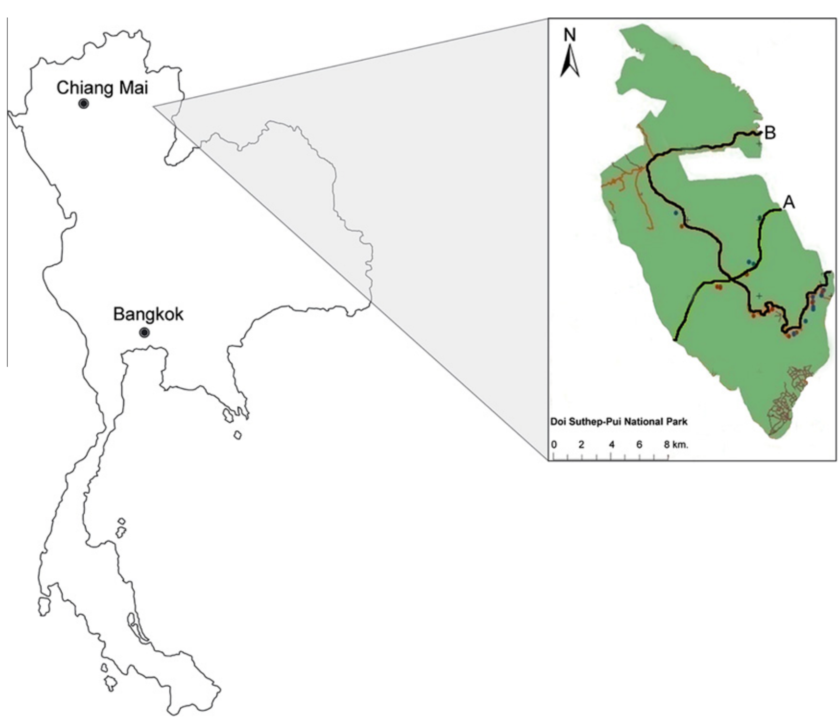

Fig. 2. Location of Doi Suthep–Pui National Park and two phenology trails (A and B) along the park.

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