CHAPTER 1

INTRODUCTION

Principle and rationale

Destruction of tropical forests continues to be a major threat to global biodiversity and also contributes significantly to global climate change. Forest restoration could be a significant part of the solution, if efficient techniques can be developed and socio-political conditions allow them to be practiced. Many tropical countries have recently started incentive programs to restore tropical forest lands, particularly for carbon sequestration and biodiversity conservation. However, the effectiveness of such restoration projects depends on the development of simple but effective methods to grow, plant, and take care of the many tree species that comprise tropical forest ecosystems. Restoration ecology is still a young and developing science, and tropical forest ecosystems are complex, with different sites requiring different restoration techniques. Several methods have been developed to restore degraded tropical forest lands such as maximum diversity plantings (Miyawaki, 1993), nurse crops or foster ecosystems (Parrotta, 1993), staggered planting of primary forest species (Knowles and Parrotta, 1995) and scattered tree planting (Lamb and Gilmour, 2003). Most approaches involve planting of tree seedlings. However, conventional reforestation methods involving planting of tree seedlings are costly, high labor and research input required (Engel and Parrota, 2001; Erskine, 2002; Lamb *et al.*, 2005; Shono *et al.*, 2007; Birch *et al.*, 2010).

Like many tropical countries, tree planting has become popular all over Thailand in particular as a response to mitigate global climate change. However, many tree planting projects fail, due to the planting of inappropriate species, and inadequate planting techniques and post-planting maintenance regimes (Elliott and Kuaraksa, 2008), particularly when using forest native tree species, about which little is known (Blakesley *et al.*, 2002). Since 1994, the Forest Restoration Research Unit of Chiang Mai University's Biology department (FORRU-CMU) has been developing methods to restore forest ecosystems to deforested sites within protected areas, for biodiversity conservation and environmental protection in northern, Thailand. FORRU-CMU scientists successfully developed accelerated natural regeneration (ANR) techniques by adapting the so-called "the framework species method" to restore evergreen forest (above 1000 m elevation) in northern Thailand. Biodiversity recovery was achieved and the tree species composition of restored plots approached that of the original primary forest more rapidly than would occur by natural regeneration. Planting 29 framework tree species resulted in more than 70 non-planted tree species re-colonizing the plots within 8 years (Sinhaseni, 2008) and bird species richness rose from 30, before planting, to more than 80, within 6 years (Toktang, 2005). This project not only carried out useful technical research on the science of restoration ecology, but on social factors that lead to successful project implementation. Education and outreach transferred the knowledge gained to various target groups such as school children, villagers, foresters and conservationists, both from Thailand and neighboring countries (FORRU, 2006; Elliott and Kuaraksa, 2008). However, two remaining challenges include i) how can these concepts and methods be scaled up and applied to larger areas or different degraded forest types and ii) lack of basic knowledge of each native tree species needed to support the framework tree species method.

In addition to well-known groups such as nitrogen-fixing species Legumes and oaks/chestnuts (Fagaceae), fig trees (*Ficus* spp., Moraceae) have been promoted as framework species for forest restoration (Goosem and Tucker, 1995; FORRU, 1998, 2006). Elliott *et al.* (1997) recommended that about 20% of planted seedlings should be *Ficus* spp.

1.1 The important characteristics that make fig trees as candidate framework species for forest restoration include:

1.1.1 Figs are considered as keystone species in tropical forests ecosystems because the can sustain frugivorous animal species and community through periods of resource scarcity (Howe, 1977; Jansen, 1979; Leighton and Leighton, 1983; Terborgh, 1986; Lambert and Marshall, 1991; Shanahan *et al.*, 2001b; Bleher *et al.*, 2003; Harrison *et al.*, 2008).

1.1.2 Figs have highly mutualistic relationships with diverse groups of animals (Compton and Disney, 1991; Herre, 1996; Novotny and Basset, 1998; Kerdelhue *et al.*, 2000; Harrison *et al.,* 2008).

1.1.3 Figs play an important role in supporting high biodiversity in the tropical forest ecosystems, particularly in regenerating forest ecosystems or in facilitating regeneration of disturbed habitats (Shanahan *et al.*, 2001a; Ronsted *et al.*, 2008b; Muhanguzi and Ipulet, 2011).

1.1.4 Figs have high value for Non-Timber Forest Product (Thomen, 1939; Condit, 1969; Berg and Corner, 2005).

1.1.5 Figs are fast-growing, high survival and growth performance when planted out in degraded areas (Jansen, 1979; FORRU, 2006) or under the harshest of conditions (i.e. forest fire, drought, salt and acid soil, and heavy polluted area (Condit, 1969; Morton, 1987; Riffle, 1998; Dazhi, *et al.*, 2003). Figs also are resistant to wind, herbivores and pathogen (Jansen, 1979; Harrison *et al.*, 2000; FORRU, 2006).

1.1.6 Figs produce dense systems of tough roots which prevent soil erosion (FORRU, 2006).

1.1.7 Figs are important shade-donor species, especially in deciduous forest habitats (Rao, 1963 in Condit, 1969). They also are excellent weed suppressor when planting out in degraded habitats (FORRU, 2006).

In Thailand, deforestation has reduced large forest tracts to tiny isolated fragments, each of which is incapable of supporting viable populations of plant and animal species (FORRU, 2006). As keystone species such as *Ficus* species start to disappear, their extinction could have a devastating effect on biological diversity of tropical forest ecosystems (Terborgh, 1986; Nason *et al.*, 1998) because fig trees are important in maintaining diversity particularly in tropical and subtropical forests (Jansen, 1979; Cook and West 2006; Harrison, 2006; Dunn *et al.*, 2008).

Nevertheless, 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. reproductive ecology and their use in forest restoration program have been conducted on monoecious species rather than on dioecious ones (Yu *et al.*, 2006). Therefore, the investigation of scientific knowledge of dioecious *Ficus* tree species is necessary to enable inclusion of them in forest restoration programs and provide constructive suggestions for the conservation of keystone resources in tropical forest ecosystems. Not only scientific knowledge of fig tree species is necessary for successful restoration by using the framework tree species method, to maintain biodiversity in tropical forest ecosystems, but also basic knowledge of dioecious figs is important to plan and design adequate strategies for conservation and management, before *Ficus* spp. become extirpated from the local habitat.

1.2 Why study dioecious figs?

1.2.1 Most research on *Ficus* in the past was focused on monoecious rather than dioecious *Ficus* spp (Corlett, 1993; Patel, 1996; Harrison *et al*., 2000; Yu *et al*., 2006). Therefore, very little literature is available on dioecious figs (i.e. ecology, propagation and planting techniques) to enable inclusion of them in forest restoration programs.

1.2.2 Dioecious fig species are probably relatively more important in facilitating the regenerative process than monoecious species because most (dioecious fig species) are considered as pioneer species (Shanahan *et al*., 2001b).

1.2.3 For forest restoration plans, management of dioecious figs is more complex than for in monoecious figs because they have two sexes (Montagnini and Jordan, 2005).

1.2.4 Most dioecious *Ficus* trees species in Doi Suthep-Pui National Park are at high risk of extirpation (15 of 19 dioecious *Ficus* species are ranked as rare; Maxwell and Elliott, 2001).

1.3 Research objectives

1.3.1 To develop a better understanding of the reproductive ecology (including phenological patterns and interactions with their wasps) of the target dioecious *Ficus* species.

1.3.2 To facilitate the use of *Ficus* spp as keystone framework species in forest restoration programs by developing optimum propagation and planting techniques.

1.4 In order to achieve the aim, the observations were designed into four main parts including:

1.4.1 *Ficus* phenology

Specific questions were:

1.4.1.1 Are dioecious *Ficus* spp. keystone species which maintain biodiversity on Doi Suthep-Pui National Park?

1.4.1.2 Is fig/leaf development related to climate?

1.4.1.3 Is the phenological behavior of each species related in its abundance?

1.4.1.4 When is the optimum time for seed collection of each species?

1.4.1.5 Where is the optimum planting site for each species?

1.4.1.6 How can forest restoration projects be designed to conserve rare *Ficus* spp.?

1.4.1.7 Does phenological study help to separate two closely related species (*F. auriculata* and *F. oligodon*)?

1.4.2 *Ficus* and their associated wasps

Specific questions were:

1.4.2.1 How many species of fig-wasp (including pollinators and non-pollinators) associate with the selected *Ficus* species?

1.4.2.2 Does habitat fragmentation affect foundress and seed numbers (per fig)?

1.4.2.3 Does seasonality affect seeds number per fig?

1.4.3 *Ficus* propagation

Specific questions were:

1.4.3.1 What is the suitable propagation method for producing planting stock of *Ficus* in nursery to support forest restoration projects?

1.4.3.2 What are the optimal treatments (medium composition and fungicide application) to maximize germination and prevent damping off diseases on young *Ficus* seedlings?

1.4.3.3 What are the optimal methods of cutting propagation (cutting position and application of rooting hormone) to maximize rooting ability of *Ficus*?

1.4.3.4 Do light intensity conditions and fertilizer application accelerate *Ficus* seedling growth and make them ready for planting (about 30-60 cm tall) within a year in nursery?

1.4.4 *Ficus* planting

Specific question was:

1.4.4.1 What is the optimum method (both in terms of field performance and cost effectiveness) for establishing *Ficus* spp. tree under field conditions, which can be applied to broad-scale restoration activities?