FINAL REPORT TO
THE BIODIVERSITY RESEARCH AND TRAINING PROGRAM
Y1-2 1/4/08 – 31/3/10

Project Title

การจัดตั้งพื้นที่ทดลองเพื่อคัดแปลงวิธีพรรณไม้โครงสร้างสำหรับการฟื้นฟูป่าเพื่อการกลับคืนมาของความหลากหลายทางชีวภาพในระบบนิเวศป่าผลัดใบ

"Propagation and performance trials of framework tree species for restoration of deciduous forest ecosystems"

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Project Duration

2 years

Re-commencement Date (Month/Year):	1st April 2008
Expected Completion Date (Month/Year):	31st March 2010

SUMMARY

Under the former project, BRT_R 368002, various candidate framework species to restore deciduous forest ecosystems (with high growth/survival rates, rapid site capture and attractive to wildlife) were identified. Establishment of demonstration plots was challenging because i) many of the tree species tested failed to achieve framework standards and ii) some plots were destroyed by fire, cattle damage and flooding. The purpose of the study presented here was to concentrate on i) improving propagation techniques of those selected species (to maximize planting stock quality) and ii) developing better silvicultural treatments (to maximize field performance) and therefore establish plots with a much higher likelihood of success.

Activities implemented were i) testing treatments to increase and accelerate seed germination and accelerate seedling growth rates in the nursery; ii) expansion of the field trial plot system at Huay Tung Tao, Chiang Mai, to test the impact of silvicultural treatments on field performance and collection of baseline data on soil conditions, ground flora and bird communities in the planted plots for future assessment of biodiversity recovery.

Optimal propagation methods and production schedules are presented for most of the target species. The field trial plot system was expanded by 8 rai under this project. Plot performance after two growing seasons was assessed for trees planted in 2007 and 2008 and for one growing season for trees planted in 2009.

By combining the results of this study with those from previous studies, we identified 43 species with high suitability for restoring deciduous forest ecosystems in N. Thailand. The list is dominated by fig tree species (11) and legumes (8). When carrying out restoration plantings, it is recommended that combinations of at least 20 species are planted. The mixture should include not more than 10 (Fig + Legumes) species, with the other species selected from the other families.

The recommended planting technique is to plant trees into holes approximately twice the size of the container, in which the trees were grown. Fill the hole with compost. After planting, apply 200 gm dried cow dung fertilizer in a ring on the soil surface and cover with a cardboard mulch mat. Weeding should be carried out with hand tools (herbicide is not recommended), followed by repeat applications of dried cow dung at least 3 times in each of the first two rainy seasons after planting at 6 week intervals (or more frequently if weed growth is rapid). Fire breaks and vigilant fire prevention measures are essential.

สรุป

จากโครงการวิจัย BRT_R 368002 ซึ่งได้ดำเนินงานมาก่อนหน้านี้ พรรณไม้หลายชนิดได้ถูกคัดเลือกว่ามีศักยภาพพอที่จะเป็นพรรณไม้โครงสำหรับการฟื้นฟูพื้นที่ป่าผลัดใบได้ (มีอัตราการเติบโตและอัตราการรอดตายสูง ยึดครองพื้นที่ได้ดี และ ดึงดูดสัตว์ป่า) การจัดตั้งแปลงปลูกป่าสาธิตในพื้นที่ลักษณะนี้ถือเป็นเรื่องท้าทาย เนื่องจาก 1) พันธุ์ไม้หลายชนิดที่ทำการทดสอบไม่ผ่านเกณฑ์มาตรฐานของการเป็นพรรณไม้โครงสร้าง 2) แปลงทดลองบางแปลงถูกทำลายจากไฟ ปศุสัตว์และน้ำท่วม งานวิจัยในครั้งนี้จึงจัดทำขึ้นโดยมีเป้าหมายเพื่อ 1) ปรับปรุงวิธีการขยายพันธุ์สำหรับพันธุ์ไม้ที่ได้รับการคัดเลือกเพื่อให้ได้ต้นกล้าคุณภาพดี 2) พัฒนาวิธีการทางวนวัฒนวิธีเพื่อทำให้การเติบโตของกล้าไม้ในแปลงปลูกดีขึ้น ซึ่งทั้งสองปัจจัยดังกล่าวจะทำให้แปลงปลูกป่าสาธิตมีโอกาสสำเร็จมากขึ้น

การทดลองครั้งนี้ประกอบด้วย 1) การทดสอบวิธีการที่จะเพิ่มอัตราการงอกและเร่งการเจริญเติบโตของกล้าไม้ในเรือนเพาะชำ 2) ขยายพื้นที่แปลงปลูกป่าทดลอง ณ ห้วยตึงเฒ่า จังหวัดเชียงใหม่ เพื่อทดสอบผลของวนวัฒนวิธีต่อการเจริญของต้นกล้าในแปลงทดลองและเก็บข้อมูลพื้นฐานเกี่ยวกับสภาพดิน พืชพื้นล่าง และสังคมของนกในพื้นที่เพื่อการประเมินการฟื้นตัวของความหลากหลายทางชีวภาพในอนาคต

จากการทดลองสามารถระบุวิธีการขยายพันธุ์ที่ได้ผลดีสำหรับพันธุ์ไม้ที่ทำการศึกษาส่วนใหญ่ และได้ขยายพื้นที่แปลงปลูกป่าไปอีก 8 ไร่ในโครงการนี้ ข้อมูลการเจริญเติบโตของกล้าไม้ในแปลงปลูกที่นำเสนอจะเป็นข้อมูลของกล้าไม้กลัง 2 ฤดูฝน สำหรับกล้าไม้ที่ปลูกในปี 2550 และ 2551 ส่วนข้อมูลสำหรับกล้าไม้ที่ปลูกในปี 2552 เป็นข้อมูลหลังฤดูฝนแรก

เมื่อนำข้อมูลจากการศึกษาครั้งนี้ผนวกเข้ากลับข้อมูลจากโครงการที่แล้ว เราสามารถคัดเลือกชนิดพืชที่น่าจะมีความเหมาะสมสำหรับการฟื้นฟูพื้นที่ป่าผลัดใบในเขตภาคเหนือของประเทศไทยได้ 43 ชนิด ซึ่งกลุ่มไม้ที่มีความโดดเด่นได้แก่ต้นไม้ในวงศ์มะเดื่อและไทร (11 ชนิดพันธุ์) และ ไม้วงศ์ถั่ว (8 ชนิดพันธุ์) ในการปลูกเพื่อฟื้นฟูพื้นที่ควรมีการปลูกพันธุ์ไม้ผสมกันอย่างน้อย 20 ชนิด โดยควรมี ไม้ในกลุ่มมะเดื่อไทรและ ถั่วรวมกันแล้วไม่เกิน 10 ชนิด ที่เหลือให้คัดเลือกจากพันธุ์ไม้ในวงศ์อื่น ๆ

สำหรับการปลูกควรปลูกกล้าไม้ในหลุมที่มีขนาดใหญ่กล่าภาชนะบรรจุกล้าไม้ประมาณสองเท่า รองก้นหลุมด้วยปุ๋ยหมัก หลังจากปลูกแล้วใส่ปุ๋ยมูลวัวแห้งประมาณ 200 กรัมรอบโคนต้น และคลุมโคนต้นด้วยกระดาษลัง การกำจัดวัชพืชควรทำด้วยมือ (ไม่ควรใช้สารกำจัดวัชพืช) ตามด้วยการให้ปุ๋ยมูลวัวอย่างน้อย 3 ครั้ง ในแต่ละฤดูฝนในสองฤดูฝนแรกหลังปลูก โดยแต่ละครั้งห่างกัน 6 สัปดาห์ (หรือถี่กว่านั้นถ้าหญ้าขึ้นเร็ว) การทำแนวกันไฟ และ ระบบป้องกันไฟป่าเป็นสิ่งที่จำเป็นมากสำหรับป่าลักษณะนี้

PROJECT RATIONAL

Loss of forest habitats is undoubtedly one of the greatest threats to terrestrial biodiversity in Thailand. Continued illegal logging, fire, clearance of land for agriculture and infrastructure development all continue to erode Thailand's forest cover at an annual rate of about 0.5%. This results in forest fragmentation, with remnant forest fragments incapable of supporting viable populations of large vertebrates and rare species.

This problem is now well-recognised and consequently, tree planting has become a popular activity. However, tree planting projects often fail, due to the planting of inappropriate tree species and inadequate or ineffective post-planting maintenance regimes. Monitoring the success or failure of such tree planting projects is often neglected and consideration of the role such activities could play in the recovery of biodiversity is usually also lacking.

Tree planting and associated activities require a great deal of labour, time and money, so it is important that they result in efficient biodiversity recovery as well as other benefits such as carbon storage for climate mitigation, watershed conservation and so on. Within protected areas, where conservation of biodiversity is the primary objective, tree planting should aim to restore the original forest ecosystem as closely as possible. Although, for species-rich, tropical, forest ecosystems, it is impossible to plant *all* tree species that may once have been present, it is possible to restore tree species richness and ecosystem structure and function to original levels, by planting forest tree species that were indigenous to the original forest type. This is a specific sub-type of reforestation termed "forest restoration" (Elliott, 2000).

Bauhinia purpurea – 2½ years after planting - already flowering and fruiting.

This project is further developing the framework species approach for the restoration of lowland deciduous forest ecosystems in N. Thailand. It involves planting 20 to 30 native forest tree species to shade out herbaceous weeds and attract wildlife into planted areas. Trees are selected with fast growth and dense spreading canopies, which enable them to rapidly close canopy and "recapture" sites. Framework tree species must also provide resources for wildlife, such as fruits, nectar, nesting sites or roosting sites for birds or mammals, preferably at an early age. Wildlife attracted into the plots should bring seeds with them from other forest tree species. When those seeds germinate, tree species diversity in planted plots gradually increases and the original tree species composition is restored (Goosem and Tucker, 1995).

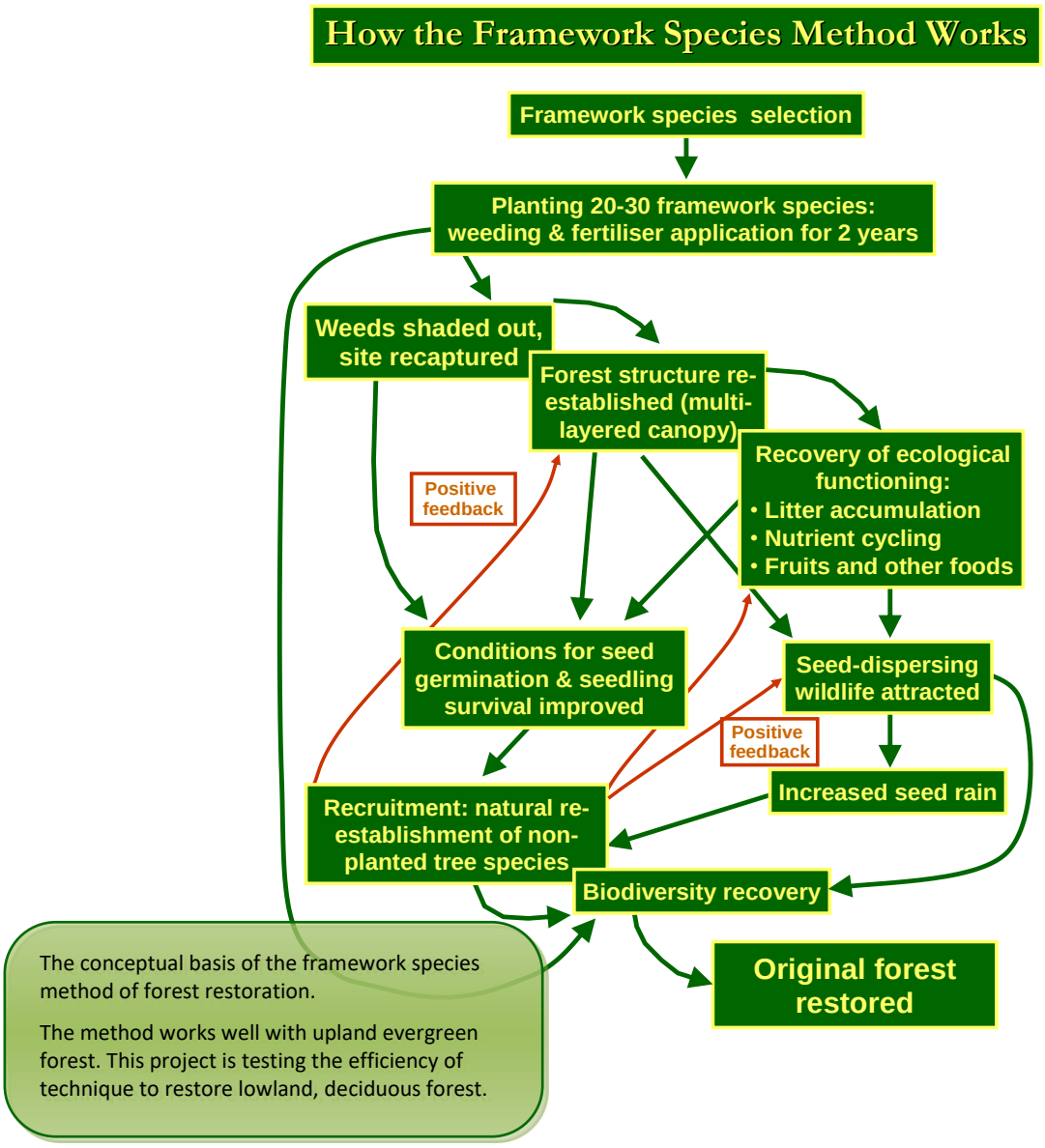
PROJECT OBJECTIVES

1. To propagate saplings of candidate framework tree species, likely to be suitable for enhancing biodiversity recovery in degraded deciduous forest ecosystems.

2. To establish field trial plots to assess for each planted tree species i) the degree to which they meet the criteria of framework species for restoration of deciduous forest ecosystems and ii) their responses to various silvicultural treatments.

3. To create an educational and research resource that can be used to encourage forest restoration projects for biodiversity recovery in northern Thailand and neighbouring regions.

4. To collect baseline data on biodiversity levels that will enable biodiversity recovery to be monitored in subsequent studies.



PROJECT ACHIEVEMENTS

Nursery Support and Training

This project provided support the FORRU-CMU's original research tree nursery, at the former HQ compound of Doi Suthep-Pui National Park. Nursery manager, Dr. Greuk Pakkad was responsible for nursery management and research. The project budget provided partial support of his salary and that of Nursery Technician, Kuhn Thonglaw Seethong. In June 2009 a new nursery area was constructed next to the Biology Department CMU to accommodate the overflow of saplings being produced at the FORRU-CMU nursery on Doi Suthep and also to provide a more natural climate for the lowland tree species.

The Doi Suthep nursery also continued to act as an educational facility for a wide range of visiting groups of students and teachers, as well as NGO's, interested in learning about forest restoration techniques. Training at the nursery ranged from simple learning events for school children (fruit and seed structure, potting trees etc.) and their teachers, to intensive workshops for NGO's on tree propagation methods, germination experiments, data analysis etc., not only for Thai NGO's etc. but also for foreign organizations including the Forest Administration of Cambodia. These events (listed in Appendix 1) reached well over 1,000 participants during the project period. Although not directly funded by the BRT grant, these events could not have taken place without BRT's support of the nursery facility and can therefore be regarded as considerable "leverage" created by this project.

Tree Propagation

Field trips were carried out every three weeks for 2 years to locate suitable seed trees in Doi Suthep-Pui National Park and Chiang Mai University. A minimum of 5 seed trees of each species, located at least 100 m apart, were located and tagged. Characteristics of the seed trees most likely to influence seed characteristics and quality were recorded: i) girth at breast height (gbh) as an indicator of age and ii) habitat factors (elevation etc.).

Nursery research focussed on seed germination and seedling growth of the target species to improve planting stock production. Germination experiments were conducted on all 25 species target species listed in the project proposal (although for some, the amount of seed found during the study period was insufficient for more than one treatment). A complete randomized block design was employed, with various pre-sowing treatments and three replications. Pre-sowing treatments are listed below, but not all species were subjected to all treatments. Treatments applied depended on seed structure, hardness, size and thickness of seed coat and seed availability (Table 1).

- control (T1). Seeds untreated.
- seeds soaked in water for 12 hours (T2)
- seeds soaked in water for 36 hours (T3)
- seeds soaked in 75% H2SO4 for 0.5 minutes (T4)
- seeds soaked in 75% H2SO4 for 2 minutes (T5)
- seeds scarified by scissors (T6).

Following treatment, seeds were sown in germination trays, in a medium of 25% coconut husk and 75% forest soil. Seed trays were placed on concrete benches, partially shaded under a transparent plastic roof, subject to approximately 40% sunlight (similar to the light intensity in partially regenerating forest gaps). Watering was carried out daily. Germination was monitored weekly and was defined as emergence of any part of the shoot. The dates on which individual seeds germinated were recorded. Non-germinating seeds were discarded from the experiment after 6 months.

Once the first pair of leaves on all seedlings had fully expanded, seedlings were pricked out and transplanted into black plastic bags, 2 ½ inches in diameter by 9 inches in depth (6.5 x 23 cm), filled with a potting medium of forest soil, peanut husk and coconut husk, mixed in the ratio of 2:1:1. Seedlings were shaded the nursery under a plastic roof (approximately 40% sunlight) for 2 weeks. Subsequently, they were placed outside, under black shade netting (slan, approximately 50% sunlight).

BRT-supported staff, Kuhn Thonglaw Srithong demonstrates how to germinate deciduous forest tree seeds to the Elephant Conservation Network, during a workshop at the BRT-supported nursery. This group is now successfully replicating FORRU-CMU's methods to restore elephant habitat at Salak Pra Wildlife Sanctuary.

Table 1 - Species studied and treatments applied

S. no	**Species**	Control	Soaking in water		Soaking in H_2SO_4		Scarification
			12 hours	36 hours	75%		
					0.5 min	2 min	
		T1	**T2**	**T3**	**T4**	**T5**	**T6**
133	*Afzelia xylocarpa* (Kurz) Craib	x		x		x	x
392	*Albizia lebbeck* (L.) Bth.	x	x		x		x
212	*Alstonia scholaris (L.) R. Br. var. scholaris*	x	x				
121	*Careya arborea* Roxb.	x		x			
320	*Bauhinia purpurea* L.	x	x				
323	*Erythrina stricta* Roxb.	x	x				x
326	*Eugenia fruticosa* (DC.) Roxb.	x	x				
385	*Eugenia grata* Wight	x	x				
29	*Ficus benjamina* L. var. *benjamina*	x					
59	*Ficus fistulosa* Reinw. *ex* Bl. var. *fistulosa*	x					
361	*Ficus glaberrima* Bl. var. *glaberrima*	x					
380	*Ficus hispida* L. f. var. *hispida*	x					
87	*Ficus microcarpa* L. f. var. *microcarpa*	x					
365	*Ficus racemosa* L. var. *racemosa*	x					
226	*Ficus rumphii* Bl.	x					
315	Ficus *semicordata* B.-H. *ex* J.E. Sm. var. *semicordata*	x					
78	*Gmelina arborea* Roxb.	x	x		x		x
294	*Phyllanthus emblica* L.	x	x		x		x
266	*Quercus kerrii* Craib var. *kerrii*	x		x			
330	*Sindora siamensis* Teysm. *ex* Miq. var. *siamensis*	x		x		x	x
192	*Spondias pinnata* (L. f.) Kurz	x		x		x	x
79	*Strychnos nux-vomica* L.	x	x				
94	*Tectona grandis* L. f.	x		x		x	x
195	*Terminalia bellirica* (Gaertn.) Roxb.	x		x		x	x
183	*Terminalia chebula* Retz. var. *chebula*	x		x	x		x

Table 2 - Final germination percentages

S. no	**Species**	Control	Soaking in water		Soaking in H_2SO_4		Scarification
			12 hours	36 hours	75%		
					0.5 min	2 min	
		T1	**T2**	**T3**	**T4**	**T5**	**T6**
133	*Afzelia xylocarpa* (Kurz) Craib	0^{a}		39^{b}		32^{b}	92^{c}
392	*Albizia lebbeck* (L.) Bth.	4^{a}	2^{a}		76^{b}		89^{b}
212	*Alstonia scholaris (L.) R. Br. var. scholaris*	75^{a}	78^{a}				
121	*Careya arborea* Roxb.	94^{a}		99^{a}			
320	*Bauhinia purpurea* L.	74^{a}	36^{b}				
323	*Erythrina stricta* Roxb.	6^{b}	$7a^{b}$				51^{a}
326	*Eugenia fruticosa* (DC.) Roxb.	67^{a}	75^{a}				
385	*Eugenia grata* Wight	68^{a}	87^{a}				
29	*Ficus benjamina* L. var. *benjamina*	72					
59	*Ficus fistulosa* Reinw. *ex* Bl. var. *fistulosa*	58					
361	*Ficus glaberrima* Bl. var. *glaberrima*	60					
380	*Ficus hispida* L. f. var. *hispida*	61					
87	*Ficus microcarpa* L. f. var. *microcarpa*	-					
365	*Ficus racemosa* L. var. *racemosa*	68					
226	*Ficus rumphii* Bl.	78					
315	*Ficus semicordata* B.-H. *ex* J.E. Sm. var. *semicordata*	65					
78	*Gmelina arborea* Roxb.	11^{a}	33^{bc}		0^{a}		24^{ac}
294	*Phyllanthus emblica* L.	96^{a}	93^{a}		42^{b}		100^{a}
266	*Quercus kerrii* Craib var. *kerrii*	26^{a}		17^{a}			
330	*Sindora siamensis* Teysm. *ex* Miq. var. *siamensis*	12^{a}		7^{ac}		12.50^{ac}	68^{ab}
192	*Spondias pinnata* (L. f.) Kurz	27^{b}		20^{b}		0^{a}	23^{b}
79	*Strychnos nux-vomica* L.	91^{a}	95.96^{a}				
94	*Tectona grandis* L. f.	0		0		0	0
195	*Terminalia bellirica* (Gaertn.) Roxb.	56^{a}		71^{a}		77.78^{a}	82^{a}
183	*Terminalia chebula* Retz. var. *chebula*	11^{a}		12^{a}	0^{a}		12^{a}

Table 3 - Median length of dormancy (MLD) (days)

S. no	**Species**	Control	Soaking in water		Soaking in H_2SO_4		Scarification
			12 hours	36 hours	75%		
					0.5 min	2 min	
		T1	**T2**	**T3**	**T4**	**T5**	**T6**
133	*Afzelia xylocarpa* (Kurz) Craib	-		20		23	23
392	*Albizia lebbeck* (L.) Bth.	7	16		7		5
212	*Alstonia scholaris (L.) R. Br. var. scholaris*	20	17				
121	*Careya arborea* Roxb.	37		37			
320	*Bauhinia purpurea* L.	28	28				
323	*Erythrina stricta* Roxb.	30	37				9
326	*Eugenia fruticosa* (DC.) Roxb.	37	37				
385	*Eugenia grata* Wight	42	56				
29	*Ficus benjamina* L. var. *benjamina*	43					
59	*Ficus fistulosa* Reinw. *ex* Bl. var. *fistulosa*	13					
361	*Ficus glaberrima* Bl. var. *glaberrima*	24					
380	*Ficus hispida* L. f. var. *hispida*	23					
87	*Ficus microcarpa* L. f. var. *microcarpa*	-					
365	*Ficus racemosa* L. var. *racemosa*	18					
226	*Ficus rumphii* Bl.	18					
315	*Ficus semicordata* B.-H. *ex* J.E. Sm. var. *semicordata*	21					
78	*Gmelina arborea* Roxb.	18	18		9		19
294	*Phyllanthus emblica* L.	16	16		13		13
266	*Quercus kerrii* Craib var. *kerrii*	147		147			
330	*Sindora siamensis* Teysm. *ex* Miq. var. *siamensis*	23		30		8	16
192	*Spondias pinnata* (L. f.) Kurz	29		21		0	26
79	*Strychnos nux-vomica* L.	55	55				
94	*Tectona grandis* L. f.	0		0		0	0
195	*Terminalia bellirica* (Gaertn.) Roxb.	37		30		37	27
183	*Terminalia chebula* Retz. var. *chebula*	125		118	0		140

Results of germination trials for each species

Germination curves and associated data are presented in Appendix 2.

Afzelia xylocarpa

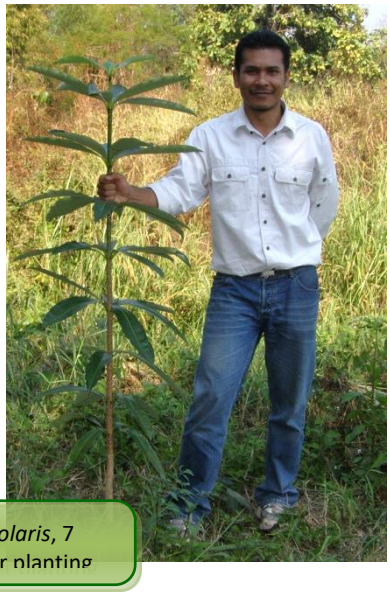
Seeds were collected from the ground within Chiang Mai University on 10 May 2009 and seeds were sown on 19 May 2009. Seeds of *A. xylocarpa* began to germinate 2 weeks after seed sowing. Seeds germinated rapidly for all seed treatments, with the exception of the control, in which no seeds germinated. The MLD was 20 days for seeds soaked in water for 36 hours, and 23 days for seeds soaked in 75% H_2SO_4 and when scarified. The germination percentage was highest for the seed scarification treatment (92%), significantly higher than for seeds soaked in water for 36 hours (39% germination) (T3), seeds soaked in 75% H_2SO_4 for 2 minutes (28% germination) (T5) and the control (0% germination) (T1) (Tables 2 and 3). Seeds of this species had a very hard seed coat. Scarification stimulated germination by permitting penetration of water (at cutting site) to the embryo and allowed gaseous exchange. These results agree with those from previous experiments conducted by FORRU (unpublished data).

Albizia lebbeck

Seeds were collected from the ground in Doi Suthep-Pui National Park on 23 March 2009 and seeds were sown on 12 May 2009. Seeds of *A. lebbeck* began to germinate 1 week after seed sowing. Seeds germinated rapidly for all seed treatments. The MLD was 7 days for the control and seeds soaked in 75% H_2SO_4 for 0.5 minute, 16 days for seeds soaked in water for 12 hours, and 5 days when treated to scarification. The germination percentage was high for the seed scarification treatment (89%) and seeds soaked in 75% H_2SO_4 for 0.5 minute, significantly higher than the control and for seed soaked in water for 12 hours (4% and 2% germination, respectively). Seeds of this species had a very hard seed coat. Scarification stimulated germination by permitting penetration of water (at cutting site) to the embryo and allowed gaseous exchange. (Table 2 and 3).

Alstonia scholaris

The fruits ripened between February and April, and were collected from trees in Doi Suthep-Pui National Park on 7 March 2009. Seeds were sown on 25 May 2009, beginning to germinate approximately 2 weeks after sowing. Seeds germinated rapidly when soaked in water for 12 hours. The median length of dormancy (MLD) was 17 days and 20 days for seeds soaked in water for 12 hours and for the control, respectively. However, MLD did not differ significantly amongst seed treatments. The germination percentages were fairly high, ranging from 75% for control seeds, to 78% for seeds soaked in water for 12 hours. Germination percentages did not differ significantly amongst seed treatments (Table 2 and 3).



Alstonia scholaris, 7 months after planting

Careya arborea

The fruits ripen between November to July. Bright green fruits were collected from the ground within Chiang Mai University on 25th May 2009. Seeds were extracted from the fruits and sown on 2nd June 2009. Seeds of *C. arborea* began to germinate approximately 3 weeks after sowing. The mean time to germination was 37 days for the control and for seeds soaked in water for 36 hours. The germination percentage was high for both seed treatments, ranging from 94 to 99% (Table 2 and 3).

Bauhinia purpurea

The fruits ripen between January and March. Dark brown seeds were collected from the ground in Doi Suthep-Pui National Park on 15 January 2010 and sown on 1 February 2010. Seeds of *B. purpurea* began to germinate 1 week after sowing. The mean time to germination was 28 days for control seeds and for seeds soaked in water for 12 hours. The germination percentage for control seeds was 74%, significantly higher than for seeds soaked in water for 12 hours (36%) (Tables 2 and 3).

Erythrina stricta

Seeds of *E. stricta* were collected from the ground in Doi Suthep-Pui National Park on 31 May 2009 and sown on 2 June 2009. Seeds germinated approximately 1 week after sowing. Scarified seeds germinated rapidly (9 days MLD), while seeds soaked in water for 12 hours had the longest time to germination (37 days). MLD differed significantly amongst seed treatments. The germination percentages were fairly high for scarified seeds (51%). The germination percentage was very low for control seeds and seeds soaked in water for 12 hours. Scarification stimulates germination by permitting penetration of water to the embryo and enabling gaseous exchange (Table 2 and 3).

Eugenia fruticosa

The fruit of this species ripens between May and August. Red fruits were collected from the ground in Doi Suthep-Pui National Park on 30 May 2009. Red fruits ferment rapidly, and may contain insect larvae. The pericarp was removed from the seeds by rubbing against a wire mesh and then soaking the seeds and pericarp in water, until the seeds sinks to the bottom. The seeds were sown on 2 June 2009. Seeds of *E. fruticosa* began to germinate 3 weeks after sowing. The MLD was 37 days for both treatments. The germination percentages were 67% for control, and 75% for seeds soaked in water for 12 hours, and did not differ significantly amongst seed treatments (Tables 2 and 3).

Eugenia grata

The fruit of this species ripens between May and July. White - brownish fruits were collected from the ground in Doi Suthep-Pui National Park on 26 May 2009. The pericarp was removed from the seeds by rubbing against a wire mesh and then soaking the seeds and pericarp in water, until the seeds sinks to the bottom. The seeds were sown on 2 June 2009. Seeds of *E. grata began* to germinate 4 weeks after sowing. The MLD was 42 days for seeds of control

treatment and 56 days for seeds soaked in water for 12 hours. The germination percentages were 68% for seeds of control treatment, and 75% for seeds soaked in water for 12 hours, and did not differ significantly amongst seed treatments.

Ficus spp.

Ficus spp. have proved to be excellent framework species for restoring forest ecosystems. Firstly, their very dense root systems enable them to survive and grow well under the harshest of conditions and to grow back rapidly after severe damage such as burning or slashing. Most species retain their leaves throughout the dry season, by tapping into supplies of soil moisture deep underground. This makes *Ficus* spp. trees excellent for preventing soil erosion and stabilizing river banks. Secondly, figs are an essential food for a wide range of seed-dispersing animals, including many species of birds and bats, as well as primates, civets, squirrels, bears, deer and wild pig. Consequently, *Ficus* spp are known as "keystone species" i.e. their figs sustain populations of fruit-eating animals during lean periods, when fruits are in short supply. Thus, they help to maintain viable populations of seed-dispersers, which are vital for recovery of tree species richness. Fig trees also appear to be highly resistant to attack by insects.

However, germination and early seedling development of fig tree is slow and difficult, with damping off disease being a particular problem. Therefore, former FORRU staff member Mr. Cherdsak Kuaraksa paid particular attention to the germination of fig seeds, testing various germination media, as part of his PhD program. Usually sand is recommended for germination of tiny seeds but in Cherdsak's experiments, forest soil was the best germination medium. Forest soil probably provides essential mycorrhizal fungi, needed immediately after seed germination. Since fig seeds are so small, they do not contain sufficient food reserves (endosperm) to support early seedling growth. Therefore, a symbiotic relationship with mycorrhizal fungi is essential to provide the young seedling with nutrients. The symbionts may also help the young seedlings to resist the pathogenic fungi that cause damping off diseases.

Table 4 - Results of some propagation experiments on Ficus spp (fig trees)

Species	%Germi-nation	MLD (days)	Best Treatment
F.benjamina	72	43	Soil
F.fistulosa	58	13	Soil:Sand (1:1)
F.glaberrima	60	24	Soil
F.hispida	44	22	Soil:Sand (1:1)
F.racemosa	66	22	Soil
F.rumphii	69	58	Soil
F.semicordata	65	21	Soil

Gmelina arborea

The fruit of this species ripens between March and June. Yellow fruits were collected from the ground in Doi Suthep-Pui National Park on 23rd March 2009. Yellow fruits ferment rapidly, and may contain insect larvae. Each fruit contains a single pyrene, in which there are usually 1-3 seeds. The pericarp was removed from the pyrene by rubbing the fruit against a wire mesh and then soaking the pyrene and pericarp in water, until the pyrene sank. The pyrenes were

sown whole, without extracting individual seeds, on 12 May 2009. Although each pyrene may produce up to three seedlings, only the first seedling to emerge was counted as germination. Seeds germinated rapidly for all seed treatments, with the exception of seeds soaked in 75% H_2SO_4 (0% germination). The germination percentage was highest (33.3%) for seeds soaked in water for 12 hours, and significantly higher than those for control, and seed scarification treatments. Almost all seeds were killed when seeds soaked in 75% H_2SO_4 for 30 seconds (Tables 2 and 3).

Phyllanthus emblica

The fruits of this species ripen between February and March. Yellowish fruits were collected from the ground in Doi Suthep-Pui National Park on 18 February 2009. Each fruit contains a single pyrene, in which there are usually 3-6 seeds. The pericarp was removed from the pyrene by rubbing it against a wire mesh. The pyrene and pericarp were soaked in water, until the pyrene sank. The pyrenes were exposed to the sun to release the seeds. Seeds were sown on 12 May 2009. Seeds germinated rapidly for all seed treatments, approximately 2 weeks after sowing. The germination percentage was highest (100, 96, and 93%) for seed scarification, seeds of control treatment and seeds soaked in water for 12 hours, respectively. These values were significantly higher than those for seeds soaked in 75% H_2SO_4 for 30 seconds. Some of seeds were killed when seeds were soaked in 75% H_2SO_4 for 30 seconds (Tables 2 and 3).

Quercus kerrii

Brown nuts were collected from trees in Doi Suthep-Pui National Park on 10 October 2009 and sown on 12 October 2009. Seeds germinated slowly for this species, seeds began to germinate only 16 week after sowing. MLD was 147 days for seeds of control treatment and seeds soaked in water for 36 hours. Germination percentage was very low for this species, only 26% and 17% for seeds of control treatment and seeds soaked in water for 36 hours, respectively (Table 2 and 3).

Sindora siamensis

Seeds were collected from the ground within Chiang Mai University on 17 May 2009 and seeds were sown on 19 May 2009. Seeds of *S. siamensis* began to germinate 2 weeks after seed sowing. Seeds germinated rapidly after soaking in 75% H_2SO_4 and when scarified. The MLD was shortest for seeds soaked in 75% H_2SO_4 for 0.5 minute and longest for seeds soaked in water for 36 hours. The germination percentage was highest for scarified seeds (68%); significantly higher than for control seeds (13%), seeds soaked in water for 36 hours (7%) and seeds soaked in 75% H_2SO_4 for 0.5 minute (13%). Seeds of this species had a very hard seed coat. Scarification stimulated germination by permitting penetration of water (at cutting site) to the embryo and allowed gaseous exchange (Table 2 and 3).

Spondias pinnata

Seeds of *S. pinnata* were collected from the ground in Doi Suthep-Pui National Park on 30 April 2008 and sown on 12 May 2009. Seeds germinated approximately 2 weeks after sowing. Soaked seeds germinated rapidly (21 days MLD), while seeds in the control treatment had the longest time to germination (29 days). The germination percentages for all seed treatments were fairly low, 27 % seed germination for seeds control treatment, 23% for seeds subjected to scarification, 20% for seeds soaked in water for 36 hours. All seeds were killed (0% germination) when soaked in 75% H_2SO_4 for 2 minutes (Table 2 and 3).

Strychnos nux-vomica

The fruits of this species ripen between May and July. Bright orange fruits were collected from the ground in Doi Suthep-Pui National Park on 3 May 2009. Each fruit contains 4-15 ellipsoid seeds. The seeds were extracted from fruits. The seeds were sown on 4 May 2009. Seeds germinated slowly for all treatments, approximately 7 weeks after sowing. The germination percentage was high: 96% for seeds soaked in water for 12 hours, and 90% for control seed (Tables 2 and 3).

Tectona grandis

The fruit of this species ripens between February and April. Brown fruits were collected from the ground in Doi Suthep-Pui National Park on 14 May 2009. Each fruit contains a single pyrene, in which there are usually 1-3 seeds. The fruits were sown whole, without extracting individual seeds, on 19 May 2009. Zero seed germination was achieved, probably due to non-viable seeds.

Terminalia bellirica

Seeds were collected from the ground in Doi Suthep-Pui National Park on 24 January 2009 and sown on 12 May 2009. Seeds of *T. bellirica* began to germinate 3 weeks after sowing. Seeds germinated rapidly for seeds subjected to scarification (MLD 27 days). The germination percentage was fairly high for all seed treatments, 82% for seed scarification treatment, 78% for seeds soaked in 75% H_2SO_4 for 2 minutes, 71% for seed soaked in water for 36 hours, and 56% for seeds of control treatment (Tables 2 and 3).

Terminalia chebula

Seeds were collected from the ground in Doi Suthep-Pui National Park on 28 October 2009 and sown on 1 December 2009. Seeds of *T. chebula* germinated slowly, seeds began to germinate 7 weeks after sowing. The germination percentage was fairly low for all seed treatments, 13% for seed scarification treatment and seeds soaked in water for 36 hours, 11% for seeds of control treatment. All seeds were killed (0% germination) when soaked in 75% H_2SO_4 for 0.5 minute (Table 2 and 3).

Overall, scarification was the most successful treatment, resulting in the highest germination percentage for *Afzelia xylocarpa, Albizia lebbeck, Erythrina stricta, Phyllanthus emblica, Sindora siamensis,* and *Terminalia bellirica.* Seeds of those species are orthodox and can survive drying and chilling. For recalcitrant seed species, the only treatments tested was soaking in water, compared with a control. Soaking in water resulted in higher germination percentages than controls for *Alstonia scholaris, Careya arborea, Eugenia fruticosa, Eugenia grata, Gmelina arborea* and *Strychnos nux-vomica.* But results for soaking were usually not statistically insignificant.

Seedling growth rates in the nursery

Once the first pair of leaves has fully expanded, seedlings were pricked out of the germination trays and transplanted into black plastic bags, 2.5 inches in diameter by 9 inches tall (6.5 x 23 cm). Subsequent experiments are carried out on containerized seedlings to accelerate seedling growth in order to produce planting stock of a suitable size by the optimum planting date (i.e. mid-June). The main experimental design was an RCBD with a minimum of 3 replicates and four treatments:

- Control
- Osmocote slow-release fertilizers (15:15:15): 10 granules/seedlings, applied every 3 months
- Effective Microorganisms (EM), applied every week
- Normal fertilizer (Rabbit brand, 15:15:15) 10 granules/seedling, applied every month.

The height and root collar diameter of every seedling was measured every 45 days using vernier callipers. Relative growth rates (RGR) were calculated using the formula:

Relative growth rate of Root collar diameter (RRGR) (% year^{-1})

$$= \frac{[\ln (RCD_2) - \ln (RCD_1)]}{(T_2-T_1)} \times 100 \times 365$$

Where RCD_2 = RCD at time T_2 (at the end of measurement)
RCD_1 = RCD at time T_1 (at the beginning of measurement)
T_2-T_1 = Number of days between the beginning (T_1) and the end (T_2) time of measurement

Relative growth rate of height (RHGR) (% year^{-1})

$$= \frac{[\ln (H_2) - \ln (H_1)]}{(T_2-T_1)} \times 100 \times 365$$

Where H2 = height at time T2 (at the end of measurement)
H1 = height at time T1 (at the beginning of measurement)
T2-T1 = Number of days between the beginning (T1) and the end (T2) time of measurement

Table 5 - Seedling treatments applied to target species

		T1	T2	T3	T4
S. no	Species	Control	Osmocote	EM	Rabbit fertilizer
133	*Afzelia xylocarpa*	Yes	Yes	Yes	No
392	*Albizia lebbeck*	Yes	Yes	No	No
121	*Careya arborea*	Yes	Yes	Yes	No
323	*Erythrina stricta*	Yes	No	No	No
326	*Eugenia fruticosa*	Yes	Yes	Yes	Yes
385	*Eugenia grata*	Yes	Yes	Yes	Yes
78	*Gmelina arborea*	Yes	Yes	Yes	No
294	*Phyllanthus emblica*	Yes	Yes	Yes	Yes
330	*Sindora siamensis*	Yes	Yes	No	No
192	*Spondias pinnata*	Yes	No	No	No
79	*Strychnos nux-vomica*	Yes	Yes	Yes	Yes
195	*Terminalia bellirica*	Yes	Yes	Yes	No
	Species tested	**12**	**10**	**8**	**8**

Afzelia xylocarpa

Most seedlings were ready for planting at the start of the wet season, as the majority of seedlings had reached a mean height of more than 30 cm by then; which is considered suitable for planting (FORRU 1998). Osmocote produced the best results for seedling height and RCD. However, there were no significant differences in seedling size and relative growth rate for all treatments. Seedlings will be ready for planting out by the 1st planting season after seed collection.

Albizia lebbeck

The seedling growth rate of this species was fairly low. After 200 days, seedling height ranged from 8.0 cm (EM) to 8.8 cm (control), with RCD's between 1.5 (EM) to 1.78 (control) mm. RHGR and RRGR was less than 100 % $year^{-1}$ for all treatments (Table 6, 7, 8 and 9). Seedlings will be ready for planting out by the 2nd planting season after seed collection.

Albizia lebbeck fruits

Table 6 - Seedling heights (at end of experiments)

Species	Height							
	Control		Osmocote		EM*		Rabbit	
	T1		T2		T3		T4	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Afzelia xylocarpa (Kurz) Craib	33.06[a]	2.43	29.26[a]	1.37	30.07[a]	0.00		
Albizia lebbeck (L.) Bth.	8.75[a]	0.33	8.19[a]	0.00	8.00[a]	0.00		
Careya arborea Roxb.	4.86[a]	0.16	5.11[a]	0.00	4.63[a]	0.56		
Erythrina stricta Roxb.	27.13	9.43						
Eugenia fruticosa (DC.) Roxb.	10.50[a]	1.15	10.59[a]	5.62	11.06[a]	3.19	12.06[a]	5.62
Eugenia grata Wight	7.61[a]	0.27	8.88[a]	1.25	9.87[a]	4.72	8.59[a]	1.25
Gmelina arborea Roxb.	24.87[a]	1.84	30.17[a]	1.37	24.05[a]	1.00	28.37[a]	1.37
Phyllanthus emblica L.	12.80[a]	0.87	14.92[a]	2.70	12.85[a]	0.69	14.62[a]	2.70
Sindora siamensis Teysm. *ex* Miq. var. *siamensis*	10.76[a]	0.27	10.46[a]	0.86				
Spondias pinnata (L. f.) Kurz	10.75	2.09						
Strychnos nux-vomica L.	5.78[a]	0.62	6.67[a]	0.40	5.56[a]	0.40	5.28[a]	0.40
Terminalia bellirica (Gaertn.) Roxb.	17.43[a]	2.92	17.29[ab]	1.37	16.05[b]	0.85		

Table 7 - Root collar diameter (RCD) of seedlings at end of experiments

Species	RCD							
	Control		Osmocote		EM		Rabbit	
	T1		T2		T3		T4	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Afzelia xylocarpa (Kurz) Craib	6.86[a]	0.13	6.76[ab]	0.23	6.32[b]	0.00		
Albizia lebbeck (L.) Bth.	1.78[a]	0.07	1.74[a]	0.00	1.50[a]	0.00		
Careya arborea Roxb.	1.89[a]	0.03	1.95[a]	0.00	1.90[a]	0.03		
Erythrina stricta Roxb.	9.43	1.76						
Eugenia fruticosa (DC.) Roxb.	1.84[a]	0.22	2.13[a]	0.34	1.93[a]	0.24	1.90[a]	0.34
Eugenia grata Wight	0.87[a]	0.07	0.94[a]	0.11	0.83[a]	0.24	0.98[a]	0.11
Gmelina arborea Roxb.	3.72[a]	0.50	5.42[ab]	0.23	3.55[a]	0.21	5.46[b]	0.23
Phyllanthus emblica L.	2.22[a]	0.20	2.68[a]	0.03	2.30[a]	0.04	2.60[a]	0.03
Sindora siamensis Teysm. *ex* Miq. var. *siamensis*	3.23[a]	0.01	3.40[b]	0.013				
Spondias pinnata (L. f.) Kurz	3.16	0.52						
Strychnos nux-vomica L.	2.17[a]	0.30	2.26[a]	0.05	2.14[a]	0.18	2.05[a]	0.05
Terminalia bellirica (Gaertn.) Roxb.	3.44[a]	0.31	4.12[a]	0.23	3.87[a]	0.56		

Table 8 - Relative growth rate for height (RHGR, %/yr)

Species	Height							
	Control		Osmocote		EM		Rabbit	
	T1		T2		T3		T4	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Afzelia xylocarpa (Kurz) Craib	27.47[a]	31.13	17.96[a]	41.22	14.65[a]	21.33		
Albizia lebbeck (L.) Bth.	31.19[a]	61.97	19.61[a]	80.22				
Careya arborea Roxb.	67.78[a]	53.95	76.10[a]	58.44	77.05[ab]	56.86		
Erythrina stricta Roxb.	4.98	11.10						
Eugenia fruticosa (DC.) Roxb.	130.68[a]	61.01	125.29[a]	89.16	138.25[a]	130.30	186.81[a]	111.91
Eugenia grata Wight	174.47[a]	64.67	190.35[a]	96.16	201.33[a]	138.37	228.32[a]	104.06
Gmelina arborea Roxb.	100.54[a]	93.02	111.66[a]	108.02	97.25[ab]	53.53	125.54[ac]	61.70
Phyllanthus emblica L.	57.20[a]	52.18	90.87[a]	58.36	61.94[a]	61.49	85.57[a]	69.26
Sindora siamensis Teysm. *ex* Miq. var. *siamensis*	54.05[a]	65.80	32.63[a]	126.52				
Spondias pinnata (L. f.) Kurz	11.76	13.54						
Strychnos nux-vomica L.	24.09[a]	73.01	59.88[b]	46.43	64.64[ab]	73.25	48.20[ab]	58.52
Terminalia bellirica (Gaertn.) Roxb.	34.64[a]	44.14	32.36[a]	26.63	38.04[a]	44.81		

Table 9 - Relative growth rate for root collar diameter (RRGR %/yr) of 12 species studied

Species	RCD							
	Control		Osmocote		EM		Rabbit	
	T1		T2		T3		T4	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Afzelia xylocarpa (Kurz) Craib	35.43[a]	25.82	30.57[a]	26.35	18.13[a]	22.74		
Albizia lebbeck (L.) Bth.	85.66[a]	65.85	82.09[a]	50.40				
Careya arborea Roxb.	96.40[a]	55.72	102.99[b]	62.91	76.52[a]	45.42		
Erythrina stricta Roxb.	19.71	41.97						
Eugenia fruticosa (DC.) Roxb.	163.96[a]	76.18	193.34[a]	79.72	200.59[a]	101.70	176.41[a]	100.61
Eugenia grata Wight	122.37[a]	80.90	134.95[a]	92.32	99.71[a]	92.34	148.65[a]	81.43
Gmelina arborea Roxb.	176.39[a]	54.27	246.14[b]	79.95	188.98[a]	66.73	267.80[b]	50.75
Phyllanthus emblica L.	133.43[a]	57.20	183.33[b]	65.85	156.61[ab]	75.58	169.76[ab]	57.67
Sindora siamensis Teysm. *ex* Miq. var. *siamensis*	77.36[a]	86.64	70.76[a]	84.66				
Spondias pinnata (L. f.) Kurz	9.87	24.18						
Strychnos nux-vomica L.	-59.31[a]	66.49	-67.70[a]	65.68	-65.09[a]	72.18	-68.76[a]	84.32
Terminalia bellirica (Gaertn.) Roxb.	64.47[a]	34.64	106.01[a]	43.80	97.84[a]	38.04		

Careya arborea

The seedling growth rate of this species was very slow. After 150 days, seedling height, RCD, RHGR and RRGR were highest for seedlings treated with Osmocote, and lowest in the control treatment and seedlings treated with EM treatment (Table 6, 7, 8 and 9). Relative growth rate for seedlings treated with Osmocote was significantly higher than for other seedling treatments. Seedlings will be ready for planting out by the 2nd planting season after seed collection if Osmocote is applied.

Erythrina stricta

The seedling growth rate of this species was fairly low. After 150 days, seedling height was 27.1 cm and root collar diameter (RCD) was 9.4 mm. Seedling relative growth rate for height (RHGR) and seedling relative growth rate for root collar diameter (RRGR) was very slow, only 4.98 and 19.71 % $year^{-1}$, respectively (Table 6, 7, 8 and 9).

Eugenia fruticosa

The seedling growth rate of this species was fairly high. After 150 days, seedling height was highest in seedlings treated with rabbit fertilizer (12.1 cm) and lowest for seedlings in control treatment (10.5 cm). Seedling root collar diameter was highest for seedlings treated with Osmocote and lowest in control. RHGR was highest for seedlings treated with Rabbit fertilizer and lowest for the control. RRGR was highest for seedlings treated with EM, and lowest in control. However, seedling size and relative growth rate was not significantly different among all seedling treatments (Table 6, 7, 8 and 9). Seedlings will be ready for planting out by the 2nd planting season after seed collection.

Eugenia grata

After 150 days, seedling height was highest for seedlings treated with EM (9.9 cm) and lowest in control. The root collar diameter (RCD) was less than 1.0 mm for all seedling treatments, ranging from 0.83 mm (EM) to 0.98 mm (rabbit). Seedling relative growth rates for height (RHGR) and root collar diameter were very high for all treatments, but did not differ significantly among any of the treatments (Table 6, 7, 8 and 9). Seedlings will be ready for planting out by the 2nd planting season.

Eugenia grata, 7 months after planting.

Gmelina arborea

The seedling growth rate of this species was fairly high. After 200 days, seedling height, RCD, RHGR and RRGR of seedlings treated with Osmocote and treated with rabbit fertilizer were higher significantly than those in control and EM treated seedlings (Table 6, 7, 8 and 9). Seedlings will be ready for planting out by 2nd planting season after seed collection.

Phyllanthus emblica

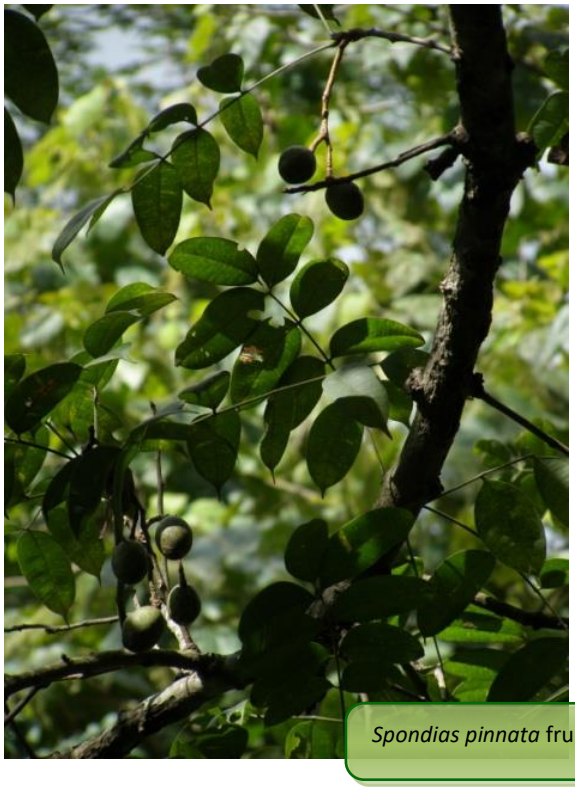
The seedling growth rate of this species was fairly high. After 200 days, seedling height, RCD, RHGR and RRGR were highest in seedling treated with Osmocote and lowest in control (Table 4, 5,6 and 7), However, seedling size and relative growth rates did not differ significantly among any treatments. Seedlings will be ready for planting out by the 2nd planting season after seed collection if Osmocote applied.

Sindora siamensis

After 200 days, seedling height was 10.8 cm and 10.5 cm for control and seedlings treated with Osmocote, respectively. However, RCD of seedlings treated with Osmocote was slightly larger than those from control (3.4 mm and 3.2 mm, respectively). Seedling growth rate for this species was below the acceptable rate of 100% $year^{-1}$ for all seedling treatments. Seedlings will be ready for planting out by the 2nd planting season after seed collection.

Spondias pinnata

The seedling growth rate of this species was fairly low. After 150 days, seedling height was 10.8 cm and root collar diameter (RCD) was 3.2 mm. Seedling relative growth rate for height (RHGR) and root collar diameter (RRGR) was very slow, only 11.76 and 9.87 % $year^{-1}$, respectively (Table 6, 7, 8 and 9). Seedlings will be ready for planting out by the 2nd planting season after seed collection.



Spondias pinnata fruits

Strychnos nux-vomica

The seedling growth rate of this species was very low. After 150 days, seedling height, RCD, RHGR and RRGR of the seedlings exhibited considerable variation amongst seedling treatments. Mean seedling height was highest in seedlings treated with Osmocote, and lowest in seedlings treated with rabbit fertilizer. Mean seedling RCD was highest in control. Mean RHGR was highest in seedlings treated with EM, and mean RRGR was highest in Osmocote fertilized seedlings. Seedlings will be ready for planting out by the 3rd planting season after seed collection.

Terminalia bellirica

The seedling growth rate of this species was fairly low. After 200 days, seedling height was highest in seedlings treated with Osmocote (17.4 cm) in control and lowest for seedlings treated with EM (16.1 cm). Seedling root collar diameter was highest for seedlings treated with Osmocote and lowest in control. For the seedling relative growth rate, RHGR was highest for seedling treated with EM and lowest in seedlings treated with Osmocote. RRGR was highest for seedlings treated with Osmocote lowest in control. However, the seedling size and relative growth rate was not significantly different between all seedling treatments (Table 6, 7, 8 and 9). Seedlings will be ready for planting out by the 2nd planting season after seed collection.

Terminalia bellirica saplings left in the nursery ready for planting and right after 7 months growth in the field.

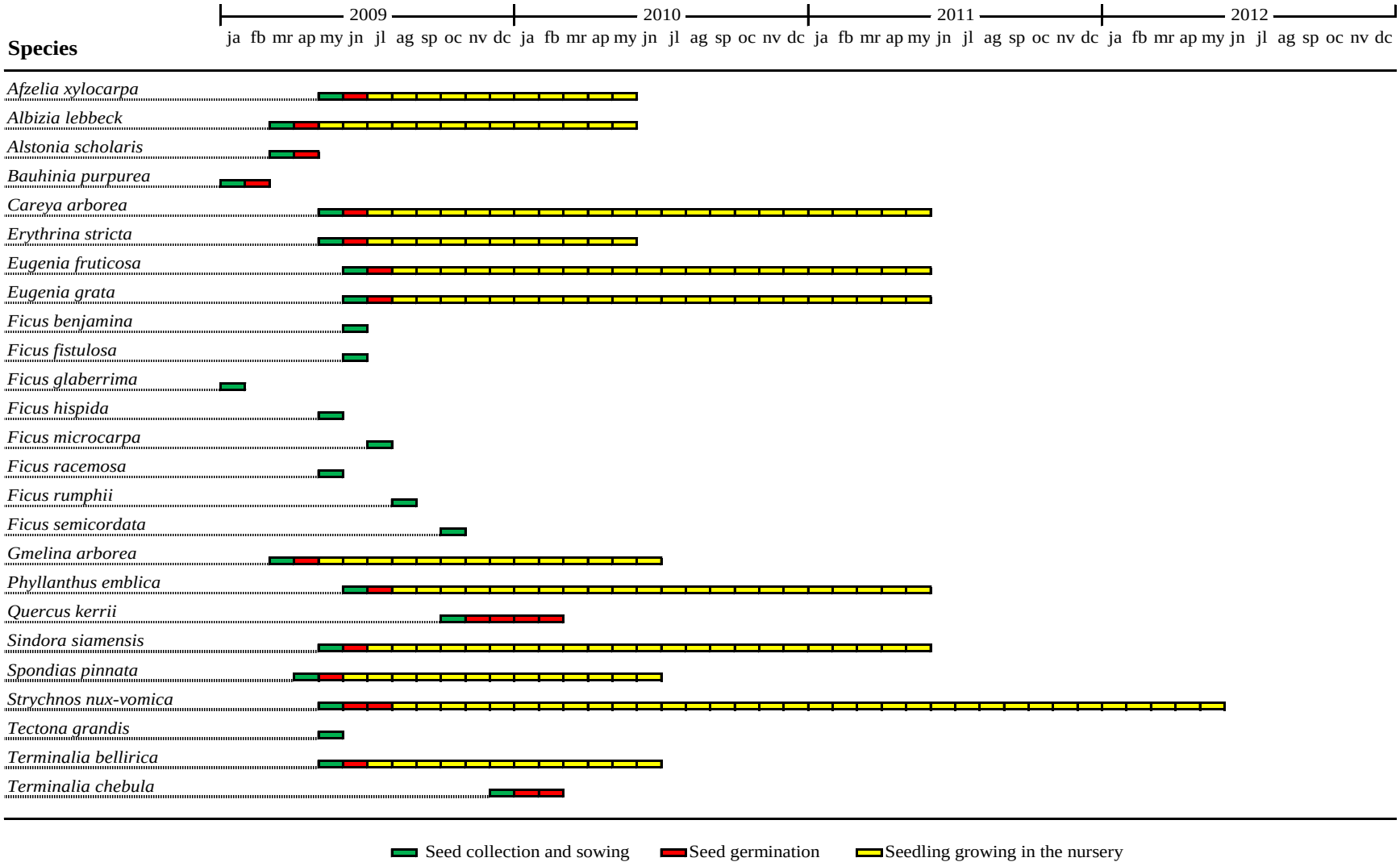
By combining germination and seedling growth data we were able to make recommendations for optimal seedling production procedures (Table 10) and devise production schedules (Table 11).

Table 10 - Summary of the best seed treatment and seedlings treatments

Species	**Best seed treatment**	**Best seedling treatment**
Afzelia xylocarpa (Kurz) Craib	Scarification	Control
Albizia lebbeck (L.) Bth.	Scarification	All treatments
Alstonia scholaris (L.) R. Br. var. scholaris	Control and soaked in water for 12 hours	
Careya arborea Roxb.	Control and soaked in water for 36 hours	All treatments
Bauhinia purpurea L.	Control	-
Erythrina stricta Roxb.	Scarification	Control
Eugenia fruticosa (DC.) Roxb.	Control and soaked in water for 12 hours	All treatments
Eugenia grata Wight	Control and soaked in water for 12 hours	All treatments
Ficus benjamina L. var. *benjamina*	-	-
Ficus fistulosa Reinw. *ex* Bl. var. *fistulosa*	-	-
Ficus glaberrima Bl. var. *glaberrima*	-	-
Ficus hispida L. f. var. *hispida*	Control	-
Ficus microcarpa L. f. var. *microcarpa*	-	-
Ficus racemosa L. var. *racemosa*	Control	-
Ficus rumphii Bl.	Control	-
Ficus semicordata B.-H. *ex* J.E. Sm. var. *Semicordata*	-	-
Gmelina arborea Roxb.	Soaked in water for 12 hours	Osmocote
Phyllanthus emblica L.	Control and soaked in water for 12 hours	Osmocote
Quercus kerrii Craib var. *kerrii*	Control	-
Sindora siamensis Teysm. *ex* Miq. var. *siamensis*	Scarification	Control and osmocote
Spondias pinnata (L. f.) Kurz	Control	Control
Strychnos nux-vomica L.	Control and soaked in water for 12 hours	Osmocote
Tectona grandis L. f.	-	-
Terminalia bellirica (Gaertn.) Roxb.	Scarification	Control and osmocote
Terminalia chebula Retz. var. *chebula*	All seed treatments	-

** Only control treatment applied*

Table 11 - Production schedule for species studied



Expanding the Plot System

Under this project, a lowland, deciduous forest, field trial, plot system (FTPS), begun with a previous BRT project in 20071, at Huay Thung Taew (HTT) recreational area, in collaboration with the Royal Thai Army was expanded by 8 rai. Four rai were planted in 2008 and an additional 4 rai in June 2009.

HTT is a recreational area, owned by the Royal Thai Army, 10 km north of Chiang Mai city. It adjoins the eastern slopes of Doi Suthep-Pui National Park at an elevation of 360 m.

At the beginning of the project, this highly degraded, ex-deciduous dipterocarp-oak forest site had almost no tree cover, except for some previously planted, exotic eucalyptus trees in one corner. The area, planted with potential framework tree species under this project, forms a riparian strip along both banks of a small stream, running from the forested lower slopes of Doi Suthep-Pui National Park between two reservoirs, where bird populations become concentrated. The area is known for its high species diversity of birds and there were plans to develop the area into a bird sanctuary (although at present the army does not support the plan). Ground covered consisted mostly of scattered clumps of grasses interspersed with bare soil. The soil was degraded, with top soil and leaf litter largely absent. Five-kilogram combined soil samples were collected from each site and analyzed at the laboratory of Faculty of Agriculture, Chiang Mai.

Table 13 - Soil Conditions at the Field Trail Plot System (FTPS)

Soil Property	Rai 1	Rai 2	Rai 3	Rai 4
pH	5.20	5.74	5.99	5.93
OM (g/100g)	1.38	2.38	1.24	2.90
Total N (g/100g)	0.05	0.11	0.09	0.15
P (mg/kg)	16.60	19.30	31.70	51.70
K (mg/kg)	125.40	144.40	172.90	449.60
Sand (%)	82.30	77.10	74.80	61.60
Silt (%)	13.70	13.90	11.20	21.10
Clay (%)	4.00	9.00	14.00	17.30
Texture	Loamy sand	Sandy loam	Sandy loam	Sandy loam

These data serve to illustrate to challenging conditions prevalent at former deciduous forest sites: acidic soils with low organic matter and clay content (which consequently result in low moisture-holding capacity) and low levels of macro-nutrients. Such conditions predicate the need for mulching and fertilizer treatments to ensure acceptable performance of planted trees, as well as identification and selection of species, capable of thriving in such conditions.

[1] BRT_R 348006: "Establishing test plots for adaptation of the framework species method of forest restoration for biodiversity recovery in deciduous forest ecosystems"

The 2007 Plots

Under the previous project (BRT_R 348006), 15 lowland tree species (1,200 seedlings) were planted into 4 x 1-rai plots. For plot establishment details, effects of treatments and early monitoring results please see the report for BRT_R348006T.

The data presented here are for the standard species comparison monitoring at 18 months after planting (which was undertaken during the current project). This is the earliest time at which framework species field performance can be reliably indicated and compared among species. The data below was collected on 25 October 2008. Recorders included international volunteers from the NGO, Pro-Thailand as well as FORRU staff.

Unfortunately, in the dry season 2008, fire invaded part of the planted areas, which limited sapling performance. Nevertheless, seven species grew to mean heights of more than 1.5 m within 18 months. The 7 top-performing species, recommended for future deciduous forest plantings are *Albizia lebbeck, Bauhinia purpurea, Dalbergia oliveri, Ficus fistulosa, F. racemosa, Gmelina arborea, Oroxylum indicum* and *Phyllanthus emblica*.

Table 13 – Mean survival and height growth for species tested in the 2007 plots

Species lists	Family	Thai name	Percent survival	Average height
Afzelia xylocarpa	Leguminosae(C)	มะค่าโมง	40	72.92
Alangium salvifolium	Alangiaceae	ปรู	42.5	136.87
Albizia lebbeck	**Leguminosae(M)**	พฤกษ์	**61.25**	**175.96**
Alstonia scholaris	Apocynaceae	สัตตบรรณ	36.25	120.80
Bauhinia purpurea	**Leguminosae(C)**	**เสี้ยวดอกแดง**	**67.5**	**251.70**
Careya arborea	Lecythidaceae	กระโดน	51.25	85.68
Cassia fistula	Leguminosae(C)	ราชพฤกษ์	31.25	88.75
Dalbergia oliveri	**Leguminosae(P)**	**ชิงชัน**	**66.25**	**156.49**
Eugenia cinerea	Myrtaceae	เสม็ดแดง	17.5	124.38
Ficus fistulosa	**Moraceae**	มะเดื่อปล้อง	**51.25**	**149.30**
Ficus racemosa	**Moraceae**	**มะเดื่ออุทุมพร**	**78.75**	**236.74**
Gmelina arborea	**Verbenaceae**	**ซ้อ**	**78.75**	**241.07**
Oroxylum indicum	**Bignoniaceae**	เพกา	**65**	**143.75**
Phyllanthus emblica	**Euphorbiaceae**	**มะขามป้อม**	**63.75**	**174.33**
Terminalia bellirica	Combretaceae	สมอพิเภก	53.75	113.85

The 2008 Plots

A total of 2,000 saplings, representing 32 tree species, all produced from the project's nursery, were planted on an additional 4 rai (adjacent to the 2007 plots) on June 14th 2008, 500 saplings per rai. The experiment was designed to test the effects of different fertilizer types. Due to the steep increase in the cost of inorganic fertilizer (because of oil cost), cattle dung was tested as an alternative fertilizer. Cardboard mulch was used on all sites, since previous results had shown this treatment has significant positive effects on survival and growth of trees, particularly in harsh soil conditions:

Rai 1 200 g commercial organic fertilizer + cardboard mulch.
Rai 2 400 g cow dung fertilizer + cardboard mulch.
Rai 3 200 g cow dung fertilizer + cardboard mulch.
Rai 4 400 g cow dung fertilizer + cardboard mulch.

Several community groups joined in the planting event including students from Prem International Centre, CMU Environmental Science students and lecturers, CMU Conservation Club, staff from Parker's Restaurant and Estate Agent (lead by Mr. Nigel Parker). After training in tree planting methods, the whole group finished the work within one day.

Volunteers from many organizations came to help plant the trees on 4 rai on June 14th 2008. Weeds were cut and sprayed with glyphosate (dead brown vegetation in the photo) 2 weeks before. The area was staked out with bamboos, 1.8 m apart, to indicate planting spots. Project staff instructed all participants in the correct tree-planting techniques and application of fertilizer treatments before planting.

Project staff carried out the first monitoring on July 4th 2008, to assess immediate post-planting mortality. High survival (88-96%) was achieved by all species, indicating proper care of the saplings during planting, as well as production of sturdy planting stock by the nursery. The next monitoring took place at the end of the first rainy season, with a second monitoring at the end of 2009.

Erythrina stricta, showing excellent growth and vigour, 4 months after planting.

Four months after planting:
Right: *Albizia lebbeck*
Far Right: *Ficus racemosa*

The data presented below are for the standard monitoring, at the end of the second rainy season after planting, when framework species performance can be indicated. These data were collected in December 2009 by FORRU-CMU staff.

About half of the species tested achieved acceptable survival rates (>50% after 18 months): *Adenanthera microsperma, Albizia lebbeck, Artocarpus lakoocha, Bauhinia purpurea, Dalbergia oliveri, Eugenia fruiticosa, Ficus capillipes, Ficus racemosa, Gmelina arborea, Hiptage benghalensis, Holarrhena pubescens, Oroxylum indicum, Protium serratum, Trewia nudiflora* and *Xylia xylocarpa* and one achieved excellent survival (>75%): *Ficus callosa* (Table 14).

Table 14 - Percent of survival after 2 growing seasons of trees planted in 2008

Species	Rai 1	Rai 2	Rai 3	Rai 4	**Average**
Adenanthera microsperma	**35.0**	**35.0**	**70.6**	**81.0**	**55.4**
Afzelia xylocarpa	10.0	50.0	50.0	50.0	40.0
Albizia lebbeck	**79.2**	**63.6**	**47.8**	**57.7**	**62.1**
Aphanamixis polystachya	13.3	53.3	46.7	26.7	35.0
Artocarpus lakoocha	**73.3**	**66.7**	**26.7**	**53.3**	**55.0**
Bauhinia purpurea	**70.0**	**60.0**	**80.0**	**70.0**	**70.0**
Cassia bakeriana	33.3	50.0	61.5	21.1	41.5
Chukrasia tabularis	0.0	50.0	80.0	44.4	43.6
Croton roxberghii	60.0	44.4	50.0	18.2	43.2
Dalbergia cultrata	26.7	60.0	33.3	46.7	41.7
Dalbergia oliveri	**70.0**	**80.0**	**60.0**	**54.5**	**66.1**
Debregeasia longifolia	50.0	0.0	0.0	25.0	18.8
Erythrina stricta	76.9	57.1	53.8	7.1	48.8
Eugenia Formosa	40.0	11.1	10.0	0.0	15.3
Eugenia fruiticosa	**33.3**	**80.0**	**30.0**	**60.0**	**50.8**
Ficus callosa	**86.7**	**83.3**	**130.0**	**34.5**	**83.6**
Ficus capillipes	**80.0**	**50.0**	**44.4**	**30.0**	**51.1**
Ficus racemosa	**79.2**	**48.0**	**88.0**	**62.0**	**69.3**
Ficus semicordata	57.1	50.0	20.0	33.3	40.1
Gmelina arborea	**50.0**	**100.0**	**114.3**	**30.8**	**73.8**
Hiptage benghalensis	**86.7**	**53.3**	**13.3**	**46.7**	**50.0**
Holarrhena pubescens	**60.0**	**46.7**	**46.2**	**52.9**	**51.4**
Holoptelea intergrifolia	40.0	6.7	50.0	0.0	24.2
Irvingia malayana	20.0	30.0	50.0	60.0	40.0
Oroxylum indicum	**78.9**	**25.0**	**95.0**	**50.0**	**62.2**
Phyllanthus emblica	60.0	50.0	14.3	68.0	48.1
Protium serratum	**50.0**	**70.0**	**50.0**	**80.0**	**62.5**
Quercus brandisiana	20.0	38.9	-	10.0	23.0
Terminalia bellirica	40.0	52.4	36.0	53.8	45.6
Toona ciliate	73.3	42.9	66.7	15.4	49.6
Trewia nudiflora	**0.0**	**100.0**	**90.0**	**80.0**	**67.5**
Xylia xylocarpa	**90.0**	**70.0**	**30.0**	**60.0**	**62.5**
Average	**51.3**	**52.5**	**52.9**	**43.2**	**50.0**

Eight species achieved acceptable or excellent height growth by the end of the second rainy season: *Bauhinia purpurea, Erythrina stricta, Ficus callosa, Ficus racemosa, Ficus semicordata, Gmelina arborea, Phyllanthus emblica* and *Trewia nudiflora*. All plots treated with cow dung out-performed the plot treated with standard fertilizer. Therefore, cow dung is recommended to improve performance of deciduous forest plots (Table 15).

Table 15 - Average height of saplings (cm) planted in 2008 at the end of the second growing season

Species	Rai 1	Rai 2	Rai 3	Rai 4	Average
Adenanthera microsperma	110.0	101.1	154.3	194.5	140.0
Afzelia xylocarpa	62.5	72.0	100.0	100.5	83.8
Albizia lebbeck	73.2	111.3	160.1	167.8	128.1
Aphanamixis polystachya	45.0	40.9	121.0	81.0	72.0
Artocarpus lakoocha	68.2	69.6	109.5	136.1	95.9
Bauhinia purpurea	**98.1**	**207.2**	**229.6**	**301.4**	**209.1**
Cassia bakeriana	73.0	113.3	227.6	101.0	128.7
Chukrasia tabularis	0.0	74.3	167.1	170.8	103.0
Croton roxberghii	77.8	150.5	109.4	143.5	120.3
Dalbergia cultrata	46.3	68.4	96.0	155.6	91.6
Dalbergia oliveri	70.0	127.5	106.3	108.8	103.2
Debregeasia longifolia	203.0	0.0	0.0	164.0	91.8
Erythrina stricta	**157.5**	**216.4**	**325.7**	**450.0**	**287.4**
Eugenia formosa	63.8	20.0	110.0	0.0	48.4
Eugenia fruiticosa	68.3	47.0	137.0	109.5	90.5
Ficus callosa	**129.1**	**148.3**	**246.3**	**251.8**	**193.9**
Ficus capillipes	97.1	108.4	160.0	203.3	142.2
Ficus racemosa	**138.3**	**140.3**	**211.1**	**245.0**	**183.7**
Ficus semicordata	**139.8**	**119.9**	**377.3**	**206.7**	**210.9**
Gmelina arborea	**95.0**	**289.5**	**257.5**	**262.0**	**226.0**
Hiptage benghalensis	84.9	42.5	102.5	65.1	73.8
Holarrhena pubescens	61.1	42.4	88.3	103.0	73.7
Holoptelea intergrifolia	142.5	100.0	158.6	0.0	100.3
Irvingia malayana	85.0	102.0	148.0	97.8	108.2
Oroxylum indicum	84.7	121.4	150.9	143.3	125.1
Phyllanthus emblica	**107.1**	**115.4**	**188.1**	**282.7**	**173.3**
Protium serratum	62.0	89.6	150.8	185.5	122.0
Quercus brandisiana	27.5	24.3		37.0	29.6
Terminalia bellirica	50.4	44.9	118.1	104.2	79.4
Toona ciliate	68.4	128.8	182.9	188.5	142.1
Trewia nudiflora	**0.0**	**214.5**	**215.2**	**241.0**	**167.7**
Xylia xylocarpa	49.4	56.1	150.7	96.5	88.2
Average height	**82.5**	**103.4**	**163.2**	**159.3**	**127.1**

Planting 2009

New plots, established on 5th July 2009, were designed to test the performance of additional tree species and also the effects of different weeding regimes. A total 1,600 trees of 23 species, all produced from the project's nurseries, were planted over four rai, adjacent to the 2008 plots. Half of each planting hole was filled with 100 g commercial organic fertilizer (Humost) before planting each sapling into the planting hole. After planting, a commercial organic fertilizer was applied, in a ring, 10-20 cm away from the stems of the saplings. Circular mulch mats (50 cm in diameter), made of corrugated cardboard, were laid around each sapling and pegged in place with a bamboo pole. Many groups, including Mae Jo university students and teachers, Chiang Mai university students, Chiang Mai Technician college students, V4N (the volunteer group from Bangkok), Doi Suthep Pui National Park officers, Pakee Rak Chiang Mai and FORRU staff, joined in the planting event, which was finished within half day.

Treatments tested in 2009 were:

Treatment 1 (Rai 1, red poles)	Manual weeding 3 times in the rainy season
Treatment 2 (Rai 2, yellow poles)	Herbicide weeding (Glyphosate) 3 times in rainy season
Treatment 3 (Rai 3, white poles)	Manual weeding 3 times in the rainy season + extra weeding in the dry season
Treatment4 (Rai 4, black poles)	Herbicide weeding (Glyphosate) 3 times in the rainy season + extra weeding in the dry season

Two weeks after planting, the planted saplings were monitored on 21st July 2009 by FORRU-CMU staff. The height and root collar diameter (using Vernier callipers) were measured and the health of saplings recorded. The purpose of the monitoring was to establish baseline data (Table 5) for the subsequent calculation of growth rates and also to determine immediate post planting mortality, due to transplantation shock or rough handling during the planting procedure. Mortality due to transplantation shock was less than 10%. The trees were also monitored at the end of the first rainy season 2009 with CMU students, studying Biomonitoring.

CMU students, studying the core course, "Biomonitoring", helped to monitor the planted trees in Dec. 2009

Table 16 – Per cent survival, at the end of the first rainy season, of trees planted in 2009

Species	Rai 1	Rai 2	Rai 3	Rai 4	Average
Adenanthera microsperma	85.0	95.0	100.0	85.0	91.3
Afzelia xylocarpa	91.4	97.1	100.0	85.7	93.6
Albizia lebbeck	66.7	100.0	100.0	100.0	91.7
Alstonia scholaris	100.0	80.0	80.0	80.0	85.0
Bauhinia purpurea	96.7	36.7	80.0	10.0	55.8
Cassia bakeriana	9.5	73.7	100.0	50.0	58.3
Eugenia fruiticosa	93.3	93.3	96.7	93.3	94.2
Ficus capillipes	90.0	90.0	100.0	70.0	87.5
Ficus hispida	80.0	40.0	60.0	20.0	50.0
Ficus racemosa	90.0	80.0	100.0	20.0	72.5
Ficus semicordata	90.0	30.0	95.0	15.0	57.5
Gmelina arborea	100.0	72.0	92.0	60.0	81.0
Holoptelea intergrifolia	100.0	100.0	100.0	100.0	100.0
Lithocarpus polystachyus	80.0	90.0	70.0	90.0	82.5
Phyllanthus emblica	87.5	12.5	87.5	50.0	59.4
Protium serratum	90.0	66.7	96.7	66.7	80.0
Quercus kerrii	22.2	100.0	88.9	66.7	69.4
Shorea roxburghii	50.0	55.0	60.0	55.0	55.0
Sindora siamensis	60.0	70.0	80.0	90.0	75.0
Spondias pinnata	71.4	71.4	85.7	0.0	57.1
Tectona grandis	85.0	50.0	95.0	35.0	66.3
Terminalia bellirica	97.1	85.7	85.7	77.1	86.4
Xylia xylocarpa	10.0	100.0	95.0	80.0	71.3
Average	78.0	72.3	89.6	60.0	75.0

At the end of the first growing season, all species maintained acceptable or excellent survival rates. Manual weeding appeared to be a slightly superior method than herbicide treatments, probably because application of the herbicide after planting may have accidentally killed some planted trees due to drift of the spray. Species that had achieved a doubling of size by the end of the first rainy season were: *Phyllanthus emblica*, *Alstonia scholaris* and *Ficus racemosa.*

CMU students, measuring the canopy width of *Albizia lebbeck,* 5 months after

Table 17 - Average height, at the end of the first rainy season, of saplings planted in 2009

Species	Rai 1	Rai 2	Rai 3	Rai 4	Average
Adenanthera microsperma	38.6	35.5	53.6	45.4	43.2
Afzelia xylocarpa	62.8	62.6	61.1	52.0	59.6
Albizia lebbeck	42.3	41.3	37.3	24.5	36.4
Alstonia scholaris	**58.9**	**60.5**	**61.0**	**70.0**	**62.6**
Bauhinia purpurea	72.4	52.7	67.8	29.3	55.6
Cassia bakeriana	52.1	46.3	49.2	39.9	46.9
Eugenia fruiticosa	54.4	38.3	49.5	43.8	46.5
Ficus capillipes	52.6	46.7	57.9	43.8	50.3
Ficus hispida	59.1	31.8	45.8	54.5	47.8
Ficus racemosa	**64.4**	**63.2**	**74.0**	**41.5**	**60.8**
Ficus semicordata	74.4	56.2	66.2	36.5	58.3
Gmelina arborea	58.7	48.5	51.7	48.3	51.8
Holoptelea intergrifolia	44.7	50.3	55.5	46.7	49.3
Lithocarpus polystachyus	54.5	55.4	42.7	46.2	49.7
Phyllanthus emblica	**81.9**	**40.0**	**72.9**	**69.5**	**66.1**
Protium serratum	43.5	37.6	46.1	34.7	40.5
Quercus kerrii	47.6	35.4	26.6	36.3	36.5
Shorea roxburghii	32.1	20.8	22.0	21.5	24.1
Sindora siamensis	21.8	16.6	17.4	16.2	18.0
Spondias pinnata	44.8	36.8	44.3	0.0	31.5
Tectona grandis	31.1	36.2	31.8	31.6	32.7
Terminalia bellirica	40.8	36.6	47.5	54.1	44.7
Xylia xylocarpa	34.1	35.6	36.6	26.6	33.2
Average	**50.8**	**42.8**	**48.6**	**39.7**	**45.5**

Fire

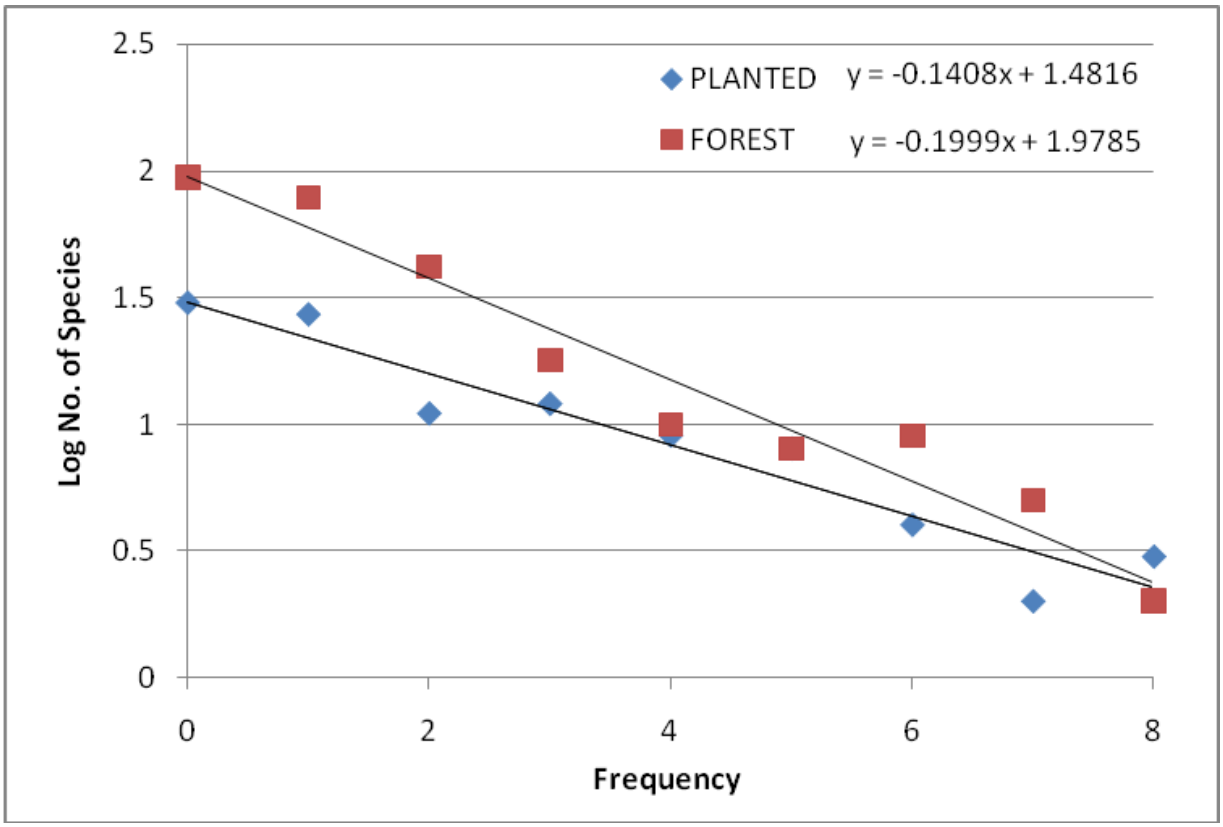
Despite cutting fire breaks, about 70% of the plot system burnt in February 2009, due to the extreme fire hazard conditions this year (due to last year's El Nino) and failure of the local fire prevention crew. One week after the fire, the entire plot system was re-surveyed, recording the condition and RCD of all labeled trees. This survey will be repeated at the end of the rainy season to determine relative fire resilience of the planted species, their coppicing ability and the sizes of the trees that survived. These data will help to design plantings that can recover after fire in the future.

The plot system, left, in December 2009 and, right, after fire in February 2010.

Baseline Vegetation survey

A baseline survey of ground vegetation across the site, including nearby forest in the Doi Suthep-Pui National Park was carried out on 5-13th November 2008. Eight circular sample plots, 10 m in diameter, were laid out in planted areas (4 in the 2008 plots and 4 in the 2007 plots), and 8 in nearby deciduous forest (randomly). The ground flora was surveyed, using the Braun Blanquette scale as an estimate of cover of each species. All plants in the circles were identified to species level by J. F. Maxwell, CMU's herbarium curator.

The ground flora in the planted area was dominated by herbaceous plant species, while that in nearby forest was characterized by a high density of tree seedling and saplings. Total species richness was estimated by plotting a graph of log frequency (0-8) against the number of species occur at each frequency and extrapolating back to zero to obtain an estimate of unseen species (i.e those that occurred in zero sample units). Species richness was much higher in the forest (with 173 observed and 95 predicted; total 268 species) compared with areas affected by forest restoration activities, including weeding (77 observed species and 30 predicted: total 107). Weed control (necessary to maintain the planted trees) and lack of tree cover (as a source of natural tree seedlings), were probably the main factors causing lower species richness in the planted areas. Future vegetation surveys will be carried out to determine to what extent the ground flora diversity and species composition tend towards those of natural forest, as the planted plots mature.



Baseline data on bird species richness

A similar approach was used to collect baseline data on the bird communities of the area. Mr Somboon Kamtaeja (MSc student in ornithology at CMU) was engaged by the project to record birds present both in nearby natural forest and in the planted plots. He carried out a total of 96 hours observations spread between 6 observation points in forest 6 more scattered evenly across the planted plots. Bird species richness was surprisingly similar in both planted plots an adjacent forest, although the species composition differed, in contrast to results obtained in upland evergreen sites, where tree planting resulted in a temporary decline in bird species richness immediately following tree planting and weeding. Mr. Somboon's detailed report was submitted to BRT as an appendix to an earlier report.

CONCLUSIONS

By combining the above results with those from BRT_R348006, as well as from some earlier field trials conducted by FORRU, we updated our on-going assessment of species suitability for planting to restore deciduous forest ecosystems in N. Thailand. The suitability score (0-100) indicates the extent to which each species conforms to framework species criteria for deciduous forest ecosystems. The list, presented in Appendix 3, is of those species most likely to succeed in restoration plantings for deciduous forest ecosystems in N. Thailand, based on current best data.

The list includes 43 species. Figs (11 spp.) and Legumes (8 spp.) dominate the list, together accounting for almost half the species. When carrying out restoration plantings, it is recommended that combinations of at least 20 species are planted. The mixture should include not more than 10 (Fig+Legumes) species, with the other species selected from the other families. This list does not include any dipterocarps, which are often dominant in such ecosystems, because they grow very slowly in nursery and in the field. In addition they are wind dispersed and should re-colonize sites undergoing restoration naturally, as the planted framework species gradually ameliorate site conditions.

Based on the results of the field trials, comparing various post-planting treatments, the recommended planting technique is to plant trees into holes approximately twice the size of the container, in which the trees were grown. Fill the hole with compost. After planting, apply 200 gm dried cow dung fertilizer in a ring on the soil surface and cover with a cardboard mulch mat. Weeding should be carried out with hand tools (herbicide is not recommended), followed by repeat applications of dried cow dung at least 3 times in each of the first two rainy seasons after planting at 6 week intervals (or more frequently if weed growth is rapid). Fire breaks and more vigilant fire prevention measures than those implemented for this project are obviously needed essential for the re-establishment of any deciduous tropical forest ecosystem.

REFERENCES

Elliott, S., 2000. Defining forest restoration for wildlife conservation. In Elliott, S., J., Kerby, D. Blakesley, K. Hardwick, K. Woods and V. Anusarnsunthorn (Eds). Forest Restoration for Wildlife Conservation. Chiang Mai University.

Elliott, S., P. Navakitbumrung, C. Kuarak, S. Zangkum, V. Anusarnsunthorn and D. Blakesley, 2003. Selecting framework tree species for restoring seasonally dry tropical forests in northern Thailand based on field performance. Forest Ecology and Management 184: 177-191

Goosem, S. and N. Tucker, 1995. Repairing the Rainforest. Cassowary Publications, Cairns, Australia.

Ficus callosa – 1 year 5 months after planting in the 2008 plots.

CONDITION OF THE PLOTS DECEMBER 2009

Fastest growing trees in the 2009 plots, 5 months after planting: G*melina arborea* (left) and *Ficus racemosa* (right).

Action Plan

"Propagation and performance trials of framework tree species for restoration of deciduous forest ecosystems"

Year	Year 1		Year 2		
Months	Apr-Sep	Oct-Mar	Apr-Sep	Oct-Mar	
Activities					Expected outputs
Seed Collection	X	X	X	X	Up to 20,000 trees of at least 20 tree species.
Germination Experiments	X	X	X	X	More rapid and higher germination
Seedling Growth Experiments in Nursery		X	X	X	Improved planting stock quality
Site Preparation	X		X		Plots cleared ready for planting
Planting field experiments	X		X		Experimental plots
Weeding fertiliser application, fire prevention etc		X	X	X	Maximal survival and growth of healthy trees.
Monitoring of planted trees	X	X	X	X	Identification of best silvicultural treatments to apply.
Ground flora surveys	X	(X)			Data on site capture effectiveness.
Observational study on use of trees by wildlife	X			X	Bird survey (repeat survey deferred until recovery after fire).
Data analysis and reporting	X	X	X	X	Biannual reports to BRT

APPENDIX 1 - LIST OF EDUCATIONAL EVENTS AT THE BRT-SUPPORT TREE NURSERY SINCE APRIL 1ST 2008

Date	Organization	Participants
8-10 April-08	WWF Khonkaen	12
12 April 2008	Qatar (Prem)	45
29-30 Jun-08	Rachapruk Institute	15
22-24 August 2008	EW Siam Travel	15
29 August 2008	Kardinia IC	27
09 September 2008	Prem Tinsulanonda International School	36
09 September 2008	Prem Tinsulanonda International School	47
9-11 September 2008	Doi Mae Salong (IUCN)	20
22-26 September 2008	Vietnamese Foresters	18
07 October 2008	Kardinia IC	10
13-17 October 2008	Elephant Conservation Network	12
30 October 2008	Prem Barge	27
10-12 Nov 2008	Utahloy School	64
06 November 2008	Prem Barge	33
07 November 2008	Kardinia IC	24
13 November 2008	Beacon school	20
27 November 2008	Prem Barge	29
14 May 2009	Kardinia (Prem)	25
21 May 2009	Kyoto (Prem)	16
15 June 2009	British School of Manila (Prem)	16
17 June 2009	British School of Manila (Prem)	17
18 June 2009	British School of Manila (Prem)	18
21 June 2009	Mae Pha Luang Uinversity	15
08 July 2009	Kardinia (Prem)	25
21 August 2009	Khiri Travel	17
24 August 2009	Kardinia (Prem)	25
29 October 2009	Beacon school (Prem)	25
09 November 2009	Kardinia (Prem)	24
10 November 2009	Uthaloy (Prem)	27
11 November 2009	Uthaloy (Prem)	27
12 November 2009	Tri Taksa (Thai)	30
18 November 2009	SatitSchool CMU (Thai)	29
27 January 2010	St.Andrews (prem)	34
02 February 2010	Chiang Msai Iem	20
10 February 2010	Kardinia (Prem)	24
13 February 2010	Metta suksa (Thai)	60
25 March 2010	Kardinia (Prem)	27
26 March 2010	Silvicultural Department, Kasetsart University	30
21 April 2010	Siam Cement Group	12
10,19-Mar-2010	Chiang Mai Iam (Schools)	39
	TOTAL	**1036**

APPENDIX 2

RESULTS OF SOME GERMINATION EXPERIMENTS

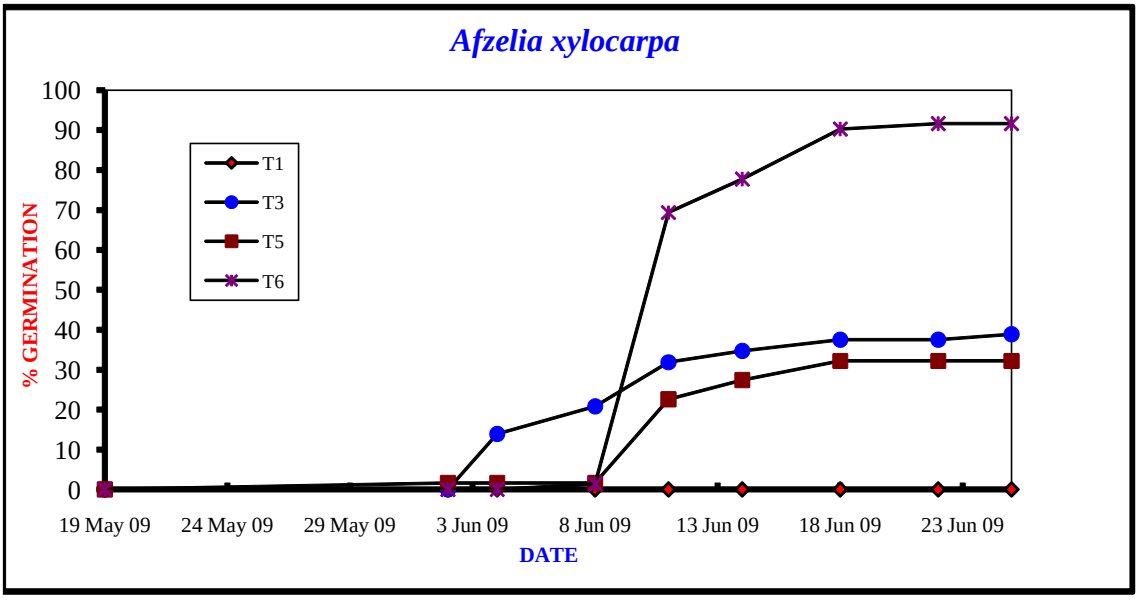
S.NO.	SPECIES	PLANTING DATE
S133	*Afzelia xylocarpa*	19 May 09

N		NO.GERM.				% GERM.				GERM.RATE			
		72	72	62	72								
DATE	DAYS	T1	T3	T5	T6	T1	T3	T5	T6	T1	T3	T5	T6
19 May 09	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00
2 Jun 09	14	0	0	1	0	0	0	2	0	0.00	0.00	0.07	0.00
4 Jun 09	16	0	10	1	0	0	14	2	0	0.00	5.00	0.00	0.00
8 Jun 09	20	0	15	1	1	0	21	2	1	0.00	1.25	0.00	0.25
11 Jun 09	23	0	23	14	50	0	32	23	69	0.00	2.67	4.33	16.33
14 Jun 09	26	0	25	17	56	0	35	27	78	0.00	0.67	1.00	2.00
18 Jun 09	30	0	27	20	65	0	38	32	90	0.00	0.50	0.75	2.25
22 Jun 09	34	0	27	20	66	0	38	32	92	0.00	0.00	0.00	0.25
25 Jun 09	37	0	28	20	66	0	39	32	92	0.00	0.33	0.00	0.00

	T1	T3	T5	T6
R1	0	7	7	21
R2	0	11	7	24
R3	0	10	6	21
Total	**0**	**28**	**20**	**66**
Mean	**0**	**9.333**	**6.667**	**22**
SD	**0**	**2.08**	**0.58**	**1.73**
MLD	**0**	**20**	**23**	**23**
LSD	**a**	**b**	**c**	**b**

Germination

***The mean is significant at the 0.05 level



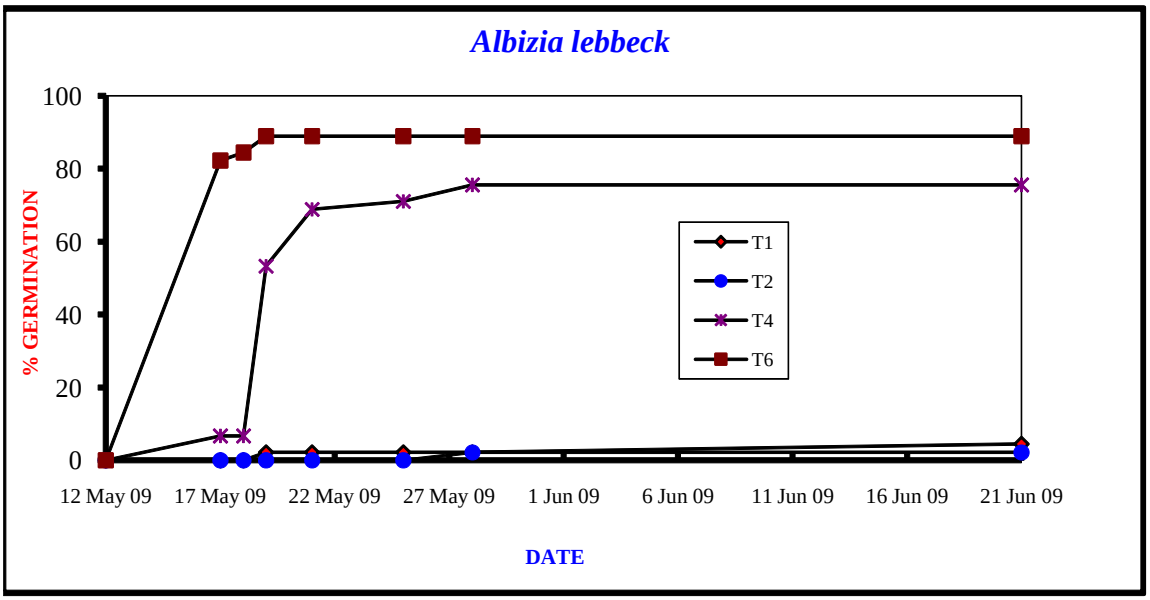
S.NO.	SPECIES	PLANTING DATE
S392	*Albizia lebbeck*	12 May 09

N		NO.GERM.				% GERM.				GERM.RATE			
		45	45	45	45								
DATE	DAYS	T1	T2	T4	T6	T1	T2	T4	T6	T1	T2	T4	T6
12 May 09	0	0	0	0	0	0	0	0	0	0.00	1.00	2.00	3.00
17 May 09	5	0	0	3	37	0	0	7	82	0.00	0.00	0.60	7.40
18 May 09	6	0	0	3	38	0	0	7	84	0.00	0.00	0.00	1.00
19 May 09	7	1	0	24	40	2	0	53	89	1.00	0.00	21.00	2.00
21 May 09	9	1	0	31	40	2	0	69	89	0.00	0.00	3.50	0.00
25 May 09	13	1	0	32	40	2	0	71	89	0.00	0.00	0.25	0.00
28 May 09	16	1	1	34	40	2	2	76	89	0.00	0.33	0.67	0.00
21 Jun 09	40	2	1	34	40	4	2	76	89	0.04	0.00	0.00	0.00

	T1	T2	T4	T6
R1	1	0	11	14
R2	0	0	13	14
R3	1	1	10	12
Total	**2**	**1**	**34**	**40**
Mean	**0.667**	**0.333**	**11.33**	**13.33**
SD	**0.58**	**0.58**	**1.53**	**1.15**
MLD	**7**	**16**	**7**	**5**
LSD	**a**	**a**	**b**	**b**

Germination

***The mean is significant at the 0.05 level



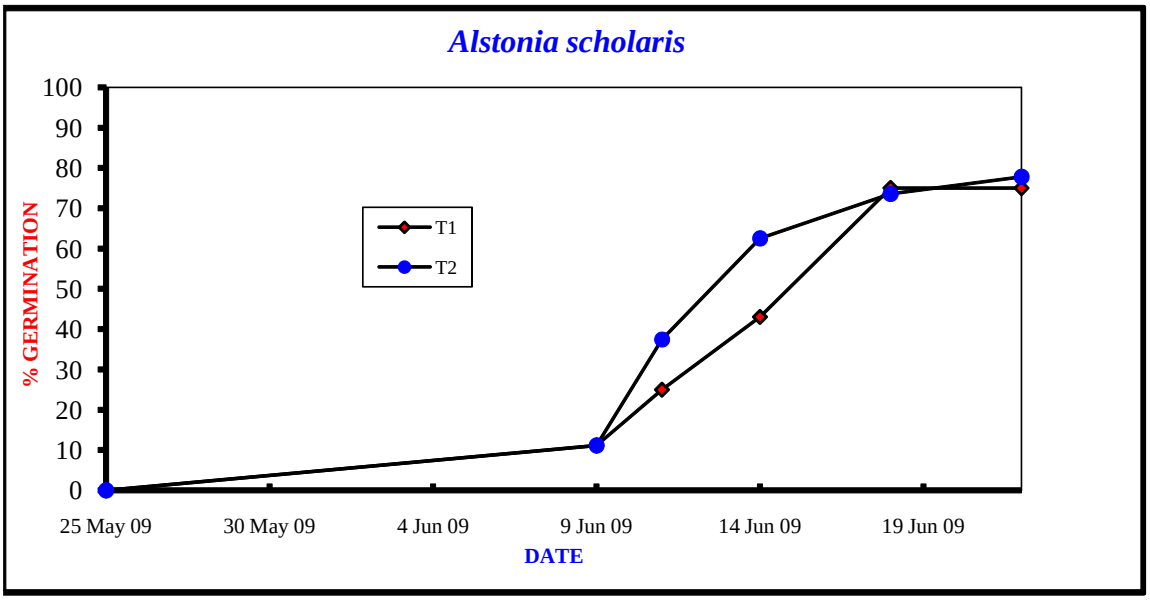
S.NO.	SPECIES	PLANTING DATE
S212	*Alstonia scholaris*	25 May 09

N		NO.GERM.				% GERM.				GERM.RATE			
		72	72										
DATE	DAYS	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
25 May 09	0	0	0			0	0			0.00	0.00		
9 Jun 09	15	8	8			11	11			0.53	0.53		
11 Jun 09	17	18	27			25	38			5.00	9.50		
14 Jun 09	20	31	45			43	63			4.33	6.00		
18 Jun 09	24	54	53			75	74			5.75	2.00		
22 Jun 09	28	54	56			75	78			0.00	0.75		

	T1	T2	T3	T4
R1	17	22		
R2	15	18		
R3	22	16		
Total	54	56		
Mean	18	18.67		
SD	3.61	3.06		
MLD	20	17		
LSD	a	a		

Germination

***The mean is significant at the 0.05 level



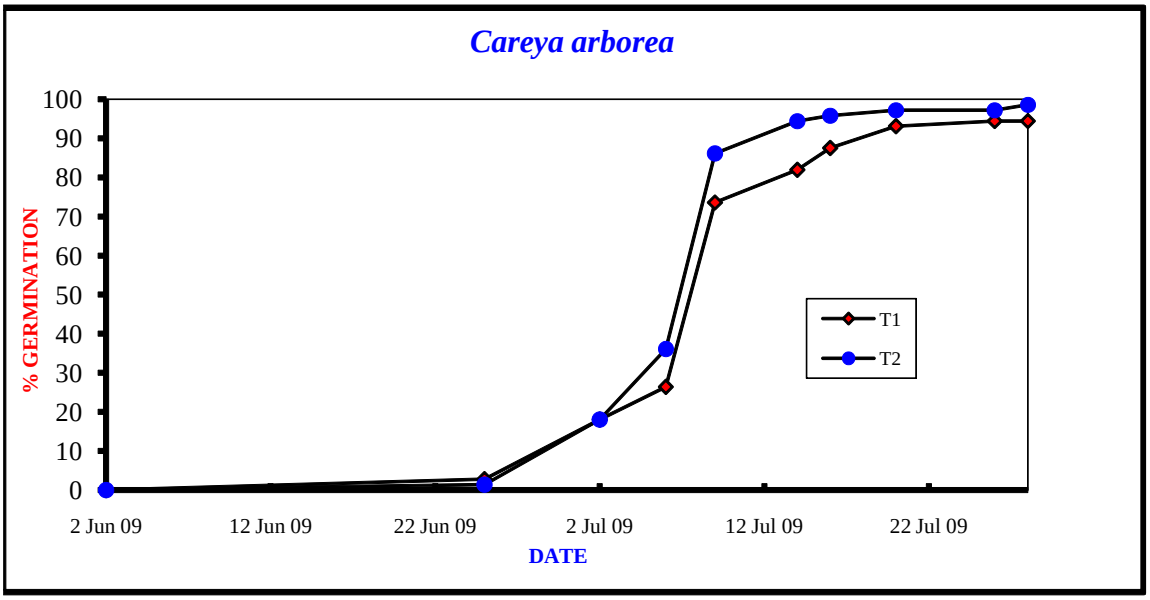
S.NO.	SPECIES	PLANTING DATE
S121	*Careya arborea*	2 Jun 09

N		NO.GERM.				% GERM.				GERM.RATE			
		72	72										
DATE	DAYS	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
2 Jun 09	0	0	0			0	0			0.00	0.00		
25 Jun 09	23	2	1			3	1			0.09	0.04		
2 Jul 09	30	13	13			18	18			1.57	1.71		
6 Jul 09	34	19	26			26	36			1.50	3.25		
9 Jul 09	37	53	62			74	86			####	####		
14 Jul 09	42	59	68			82	94			1.20	1.20		
16 Jul 09	44	63	69			88	96			2.00	0.50		
20 Jul 09	48	67	70			93	97			1.00	0.25		
26 Jul 09	54	68	70			94	97			0.17	0.00		
28 Jul 09	56	68	71			94	99			0.00	0.50		

	T1	T2	T3	T4
R1	24	24		
R2	21	23		
R3	23	24		
Total	68	71		
Mean	22.67	23.67		
SD	1.53	0.58		
MLD	37	37		
LSD	a	a		

Germination

***The mean is significant at the 0.05 level



S.NO.	SPECIES	PLANTING DATE
S320	*Bauhinia purpurea*	1 Feb 10

N		NO.GERM.				% GERM.				GERM.RATE			
		72	72										
DATE	DAYS	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
8 Feb 10	7	1	0			1	0			0.00	0.00		
21 Feb 10	20	17	9			24	13			1.23	0.69		
28 Feb 10	27	20	9			28	13			0.43	0.00		
1 Mar 10	28	33	18			46	25			####	9.00		
8 Mar 10	35	38	25			53	35			0.71	1.00		
15 Mar 10	42	50	26			69	36			1.71	0.14		
28 Mar 10	55	53	26			74	36			0.23	0.00		

TERMINATION CODE = TR

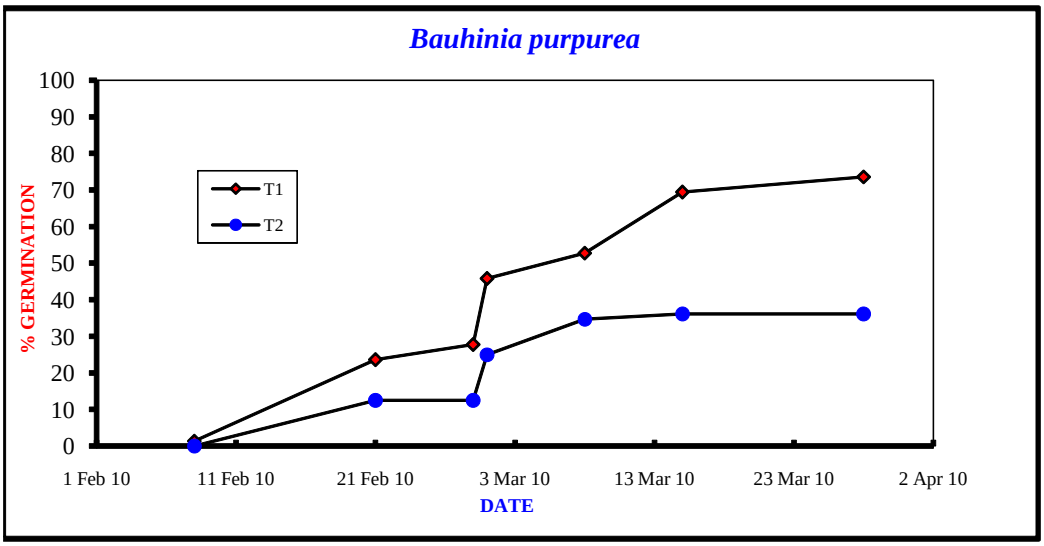
FINAL NO.OF SEED GERMINATED =	T1	T2	T3	T4
	43	42		

	T1	T2	T3	T4
R1	17	11		
R2	15	6		
R3	21	9		
Total	53	26		
Mean	17.67	8.667		
SD	3.06	2.52		
MLD	28	28		
LSD	a	b		

Germination

***The mean is significant at the 0.05 level

Treatments Detail		
T1	Control	yes
T2	Soaking in water	1 night
		minute



S.NO.	SPECIES	PLANTING DATE
S323	*Erythrina stricta*	2 Jun 09

N		NO.GERM.				% GERM.				GERM.RATE			
		72	72	72	72								
DATE	DAYS	T1	T2	T6		T1	T2	T6		T1	T2	T6	
2 Jun 09	0	0	0	0		0	0	0		0.00	0.00	0.00	
8 Jun 09	6	0	0	7		0	0	10		0.00	0.00	1.17	
9 Jun 09	7	0	0	9		0	0	13		0.00	0.00	2.00	
11 Jun 09	9	0	0	32		0	0	44		0.00	0.00	11.50	
14 Jun 09	12	0	0	37		0	0	51		0.00	0.00	1.67	
25 Jun 09	23	1	0	37		1	0	51		0.09	0.00	0.00	
2 Jul 09	30	2	1	37		3	1	51		0.14	0.14	0.00	
9 Jul 09	37	2	4	37		3	6	51		0.00	0.43	0.00	
14 Jul 09	42	3	4	37		4	6	51		0.20	0.00	0.00	
20 Jul 09	48	3	5	37		4	7	51		0.00	0.17	0.00	
24 Jul 09	52	4	5	37		6	7	51		0.25	0.00	0.00	

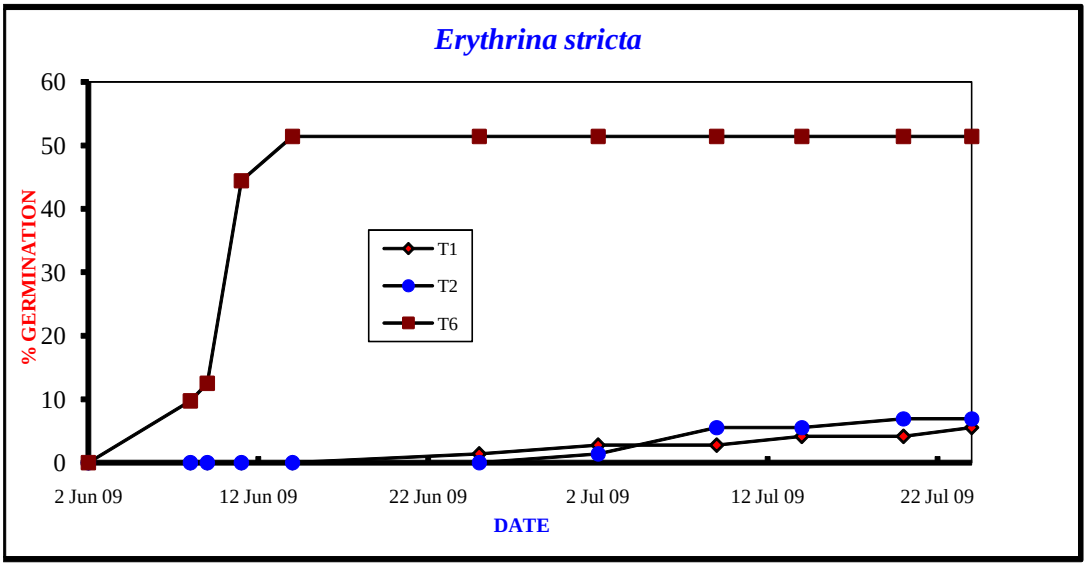
TERMINATION CODE = TR

FINAL NO.OF SEED GERMINATED =	T1	T2	T6
	4	5	37

	T1	T2	T6
R1	1	1	8
R2	2	4	13
R3	1	0	16
Total	**4**	**5**	**37**
Mean	**1.333**	**1.667**	**12.33**
SD	**0.58**	**2.08**	**4.04**
MLD	**30**	**37**	**9**
LSD	**b**	**ab**	**a**

Germination

***The mean is significant at the 0.05 level



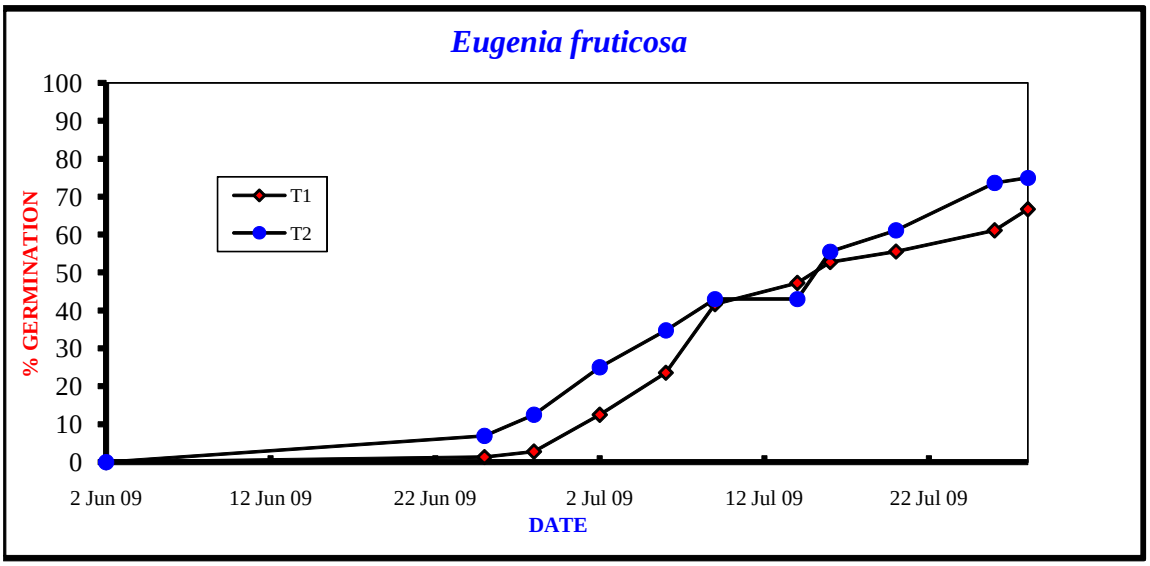
S.NO.	SPECIES	PLANTING DATE
S326	*Eugenia fruticosa*	2 Jun 09

N		NO.GERM.				% GERM.				GERM.RATE			
		72	72										
DATE	DAYS	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
2 Jun 09	0	0	0			0	0			0.00	0.00		
25 Jun 09	23	1	5			1	7			0.04	0.22		
28 Jun 09	26	2	9			3	13			0.33	1.33		
2 Jul 09	30	9	18			13	25			1.75	2.25		
6 Jul 09	34	17	25			24	35			2.00	1.75		
9 Jul 09	37	30	31			42	43			4.33	2.00		
14 Jul 09	42	34	31			47	43			0.80	0.00		
16 Jul 09	44	38	40			53	56			2.00	4.50		
20 Jul 09	48	40	44			56	61			0.50	1.00		
26 Jul 09	54	44	53			61	74			0.67	1.50		
28 Jul 09	56	48	54			67	75			2.00	0.50		

	T1	T2	T3	T4
R1	14	16		
R2	17	19		
R3	17	19		
Total	**48**	**54**		
Mean	**16**	**18**		
SD	**1.73**	**1.73**		
MLD	**37**	**37**		
LSD	**a**	**a**		

Germination

***The mean is significant at the 0.05 level



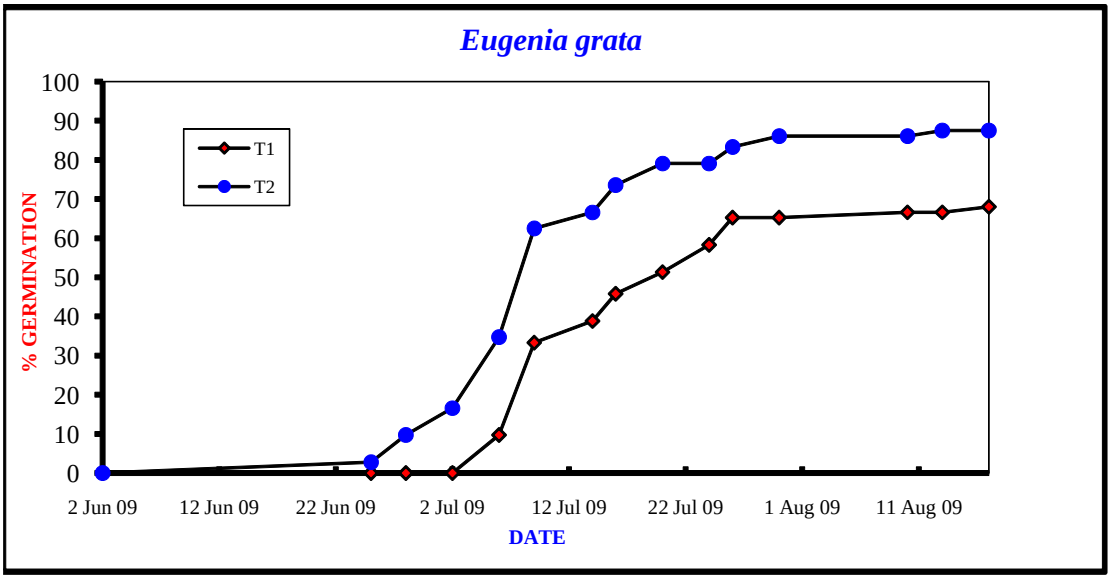
S.NO.	SPECIES	PLANTING DATE
S385	*Eugenia grata*	2 Jun 09

N		NO.GERM.				% GERM.				GERM.RATE			
		72	72	72	72								
DATE	DAYS	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
2 Jun 09	0	0	0			0	0			0.00	0.00		
25 Jun 09	23	0	2			0	3			0.00	0.09		
28 Jun 09	26	0	7			0	10			0.00	1.67		
2 Jul 09	30	0	12			0	17			0.00	1.25		
6 Jul 09	34	7	25			10	35			1.75	3.25		
9 Jul 09	37	24	45			33	63			5.67	6.67		
14 Jul 09	42	28	48			39	67			0.80	0.60		
16 Jul 09	44	33	53			46	74			2.50	2.50		
20 Jul 09	48	37	57			51	79			1.00	1.00		
24 Jul 09	52	42	57			58	79			1.25	0.00		
26 Jul 09	54	47	60			65	83			2.50	1.50		
30 Jul 09	58	47	62			65	86			0.00	0.50		
10 Aug 09	69	48	62			67	86			0.09	0.00		
13 Aug 09	72	48	63			67	88			0.00	0.33		
17 Aug 09	76	49	63			68	88			0.25	0.00		

	T1	T2	T3	T4
R1	17	23		
R2	13	20		
R3	19	20		
Total	49	63		
Mean	16.33	21		
SD	3.06	1.73		
MLD	42	56		
LSD	a	a		

Germination

***The mean is significant at the 0.05 level



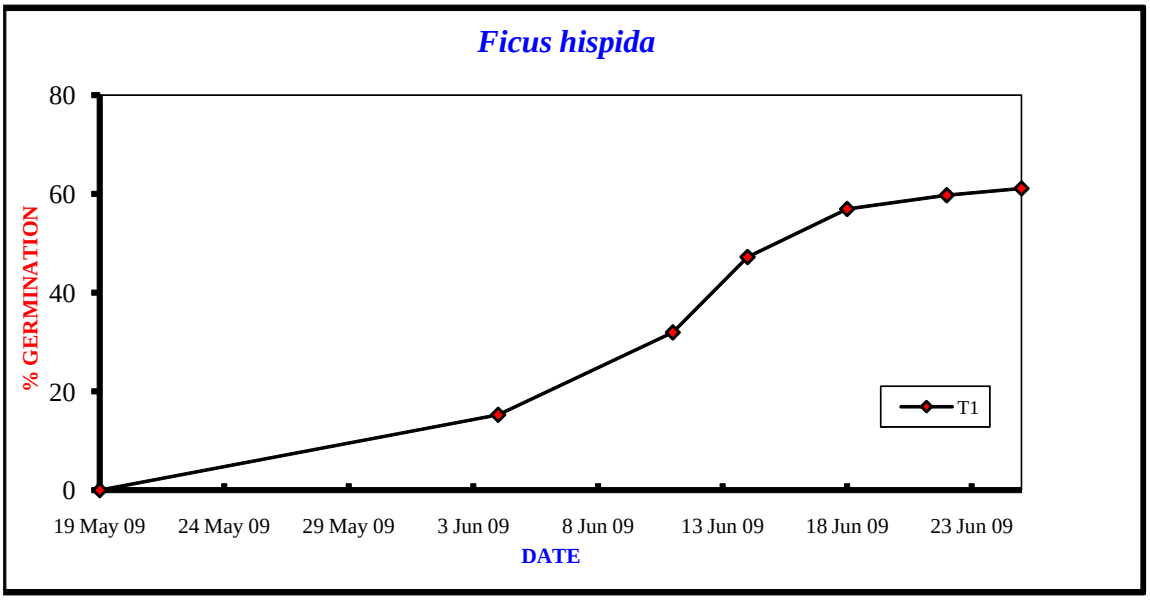
S.NO.	SPECIES	PLANTING DATE
S380	*Ficus hispida*	19 May 09

N		NO.GERM.				% GERM.				GERM.RATE			
		72											
DATE	DAYS	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
19 May 09	0	0				0				0.00			
4 Jun 09	16	11				15				0.69			
11 Jun 09	23	23				32				1.71			
14 Jun 09	26	34				47				3.67			
18 Jun 09	30	41				57				1.75			
22 Jun 09	34	43				60				0.50			
25 Jun 09	37	44				61				0.33			

	T1	T2	T3	T4
R1	12			
R2	16			
R3	16			
Total	**44**			
Mean	**14.67**			
SD	**2.31**			
MLD	**23**			
LSD				

Germination

***The mean is significant at the 0.05 level



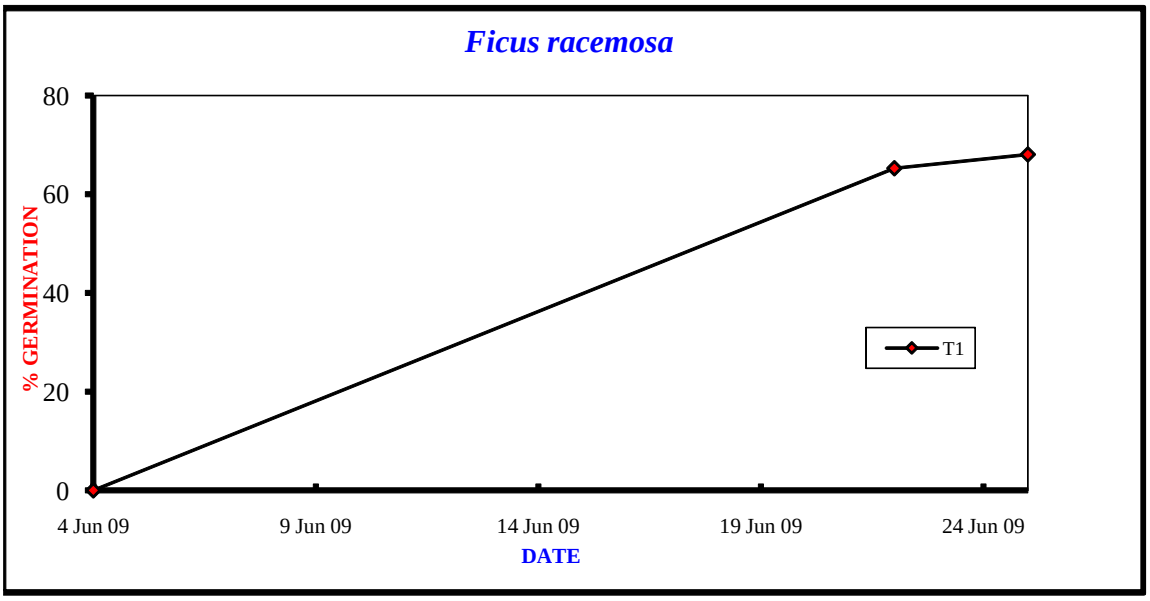
S.NO.	SPECIES	PLANTING DATE
S365	*Ficus racemosa*	4 Jun 09

N		NO.GERM.				% GERM.				GERM.RATE			
		72											
DATE	DAYS	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
4 Jun 09	0	0				0				0.00			
22 Jun 09	18	47				65				2.61			
25 Jun 09	21	49				68				0.67			

	T1	T2	T3	T4
R1	18			
R2	14			
R3	17			
Total	**49**			
Mean	**16.33**			
SD	**2.08**			
MLD	**18**			
LSD				

Germination

***The mean is significant at the 0.05 level



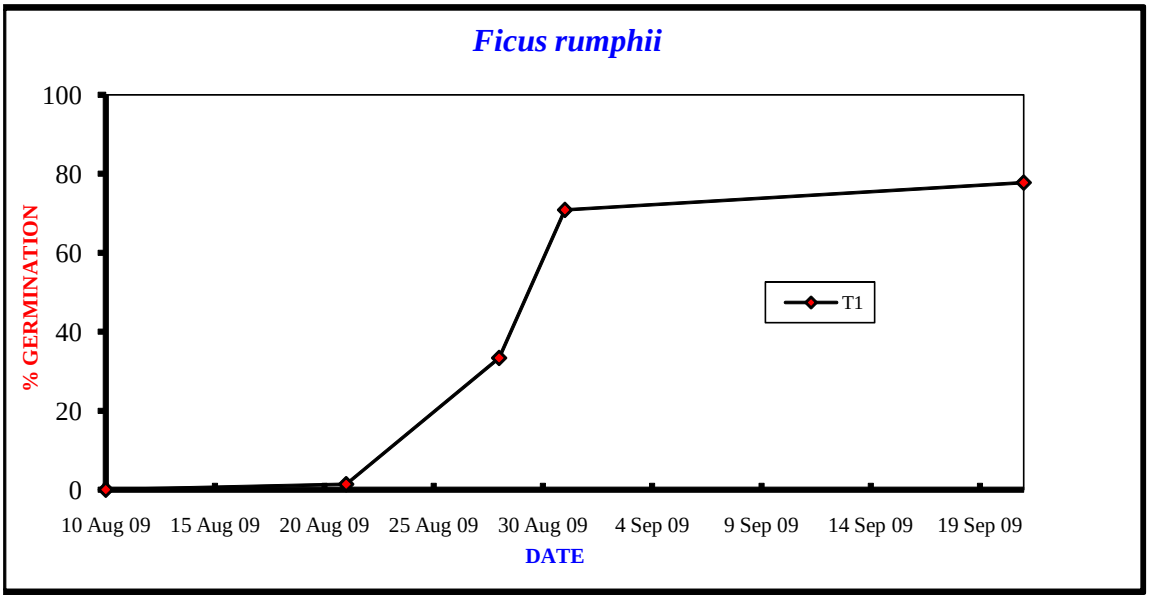
S.NO.	SPECIES	PLANTING DATE
S226	*Ficus rumphii*	10 Aug 09

N		NO.GERM.				% GERM.				GERM.RATE			
		72											
DATE	DAYS	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
10 Aug 09	0	0				0				0.00			
21 Aug 09	11	1				1				0.09			
28 Aug 09	18	24				33				3.29			
31 Aug 09	21	51				71				9.00			
21 Sep 09	42	56				78				0.24			

	T1	T2	T3	T4
R1	21			
R2	21			
R3	14			
Total	56			0
Mean	18.67			
SD	4.04			
MLD	18			
LSD				

Germination

***The mean is significant at the 0.05 level



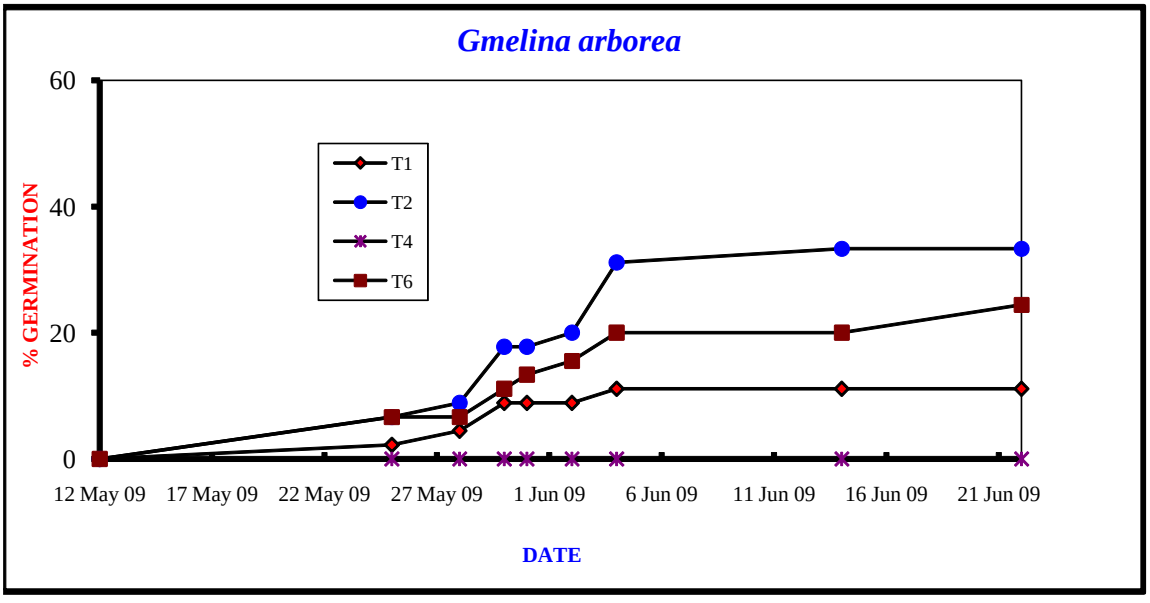
S.NO.	SPECIES	PLANTING DATE
S078	*Gmelina arborea*	12 May 09

N		NO.GERM.				% GERM.				GERM.RATE			
		45	45	45	45								
DATE	DAYS	T1	T2	T4	T6	T1	T2	T4	T6	T1	T2	T4	T6
12 May 09	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00
25 May 09	13	1	3	0	3	2	7	0	7	0.08	0.23	0.00	0.23
28 May 09	16	2	4	0	3	4	9	0	7	0.33	0.33	0.00	0.00
30 May 09	18	4	8	0	5	9	18	0	11	1.00	2.00	0.00	1.00
31 May 09	19	4	8	0	6	9	18	0	13	0.00	0.00	0.00	1.00
2 Jun 09	21	4	9	0	7	9	20	0	16	0.00	0.50	0.00	0.50
4 Jun 09	23	5	14	0	9	11	31	0	20	0.50	2.50	0.00	1.00
14 Jun 09	33	5	15	0	9	11	33	0	20	0.00	0.10	0.00	0.00
22 Jun 09	41	5	15	0	11	11	33	0	24	0.00	0.00	0.00	0.25

	T1	T2	T4	T6
R1	3	6	0	6
R2	1	5	0	3
R3	1	4	0	2
Total	5	15	0	11
Mean	1.667	5	0	3.667
SD	1.15	1	0	2.08
MLD	18	18	0	19
LSD	a	bc	a	ac

Germination

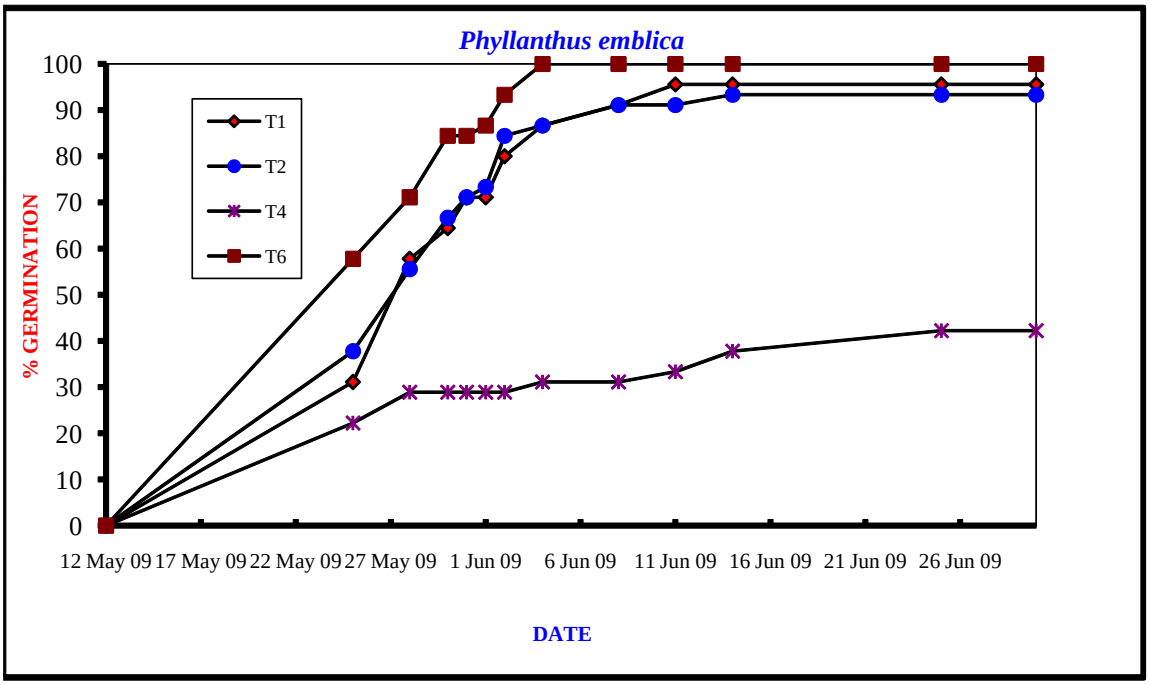
***The mean is significant at the 0.05 level



S.NO.	SPECIES	PLANTING DATE
S294	*Phyllanthus emblica*	12 May 09

N		NO.GERM.				% GERM.				GERM.RATE			
		45	45	45	45								
DATE	DAYS	T1	T2	T4	T6	T1	T2	T4	T6	T1	T2	T4	T6
12 May 09	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00
25 May 09	13	14	17	10	26	31	38	22	58	1.08	1.31	0.77	2.00
28 May 09	16	26	25	13	32	58	56	29	71	4.00	2.67	1.00	2.00
30 May 09	18	29	30	13	38	64	67	29	84	1.50	2.50	0.00	3.00
31 May 09	19	32	32	13	38	71	71	29	84	3.00	2.00	0.00	0.00
1 Jun 09	20	32	33	13	39	71	73	29	87	0.00	1.00	0.00	1.00
2 Jun 09	21	36	38	13	42	80	84	29	93	4.00	5.00	0.00	3.00
4 Jun 09	23	39	39	14	45	87	87	31	100	1.50	0.50	0.50	1.50
8 Jun 09	27	41	41	14	45	91	91	31	100	0.50	0.50	0.00	0.00
11 Jun 09	30	43	41	15	45	96	91	33	100	0.67	0.00	0.33	0.00
14 Jun 09	33	43	42	17	45	96	93	38	100	0.00	0.33	0.67	0.00
25 Jun 09	44	43	42	19	45	96	93	42	100	0.00	0.00	0.18	0.00
30 Jun 09	49	43	42	19	45	96	93	42	100	0.00	0.00	0.00	0.00

	T1	T2	T4	T6
R1	15	12	8	15
R2	15	15	5	15
R3	13	15	6	15
Total	**43**	**42**	**19**	**45**
Mean	**14.33**	**14**	**6.333**	**15**



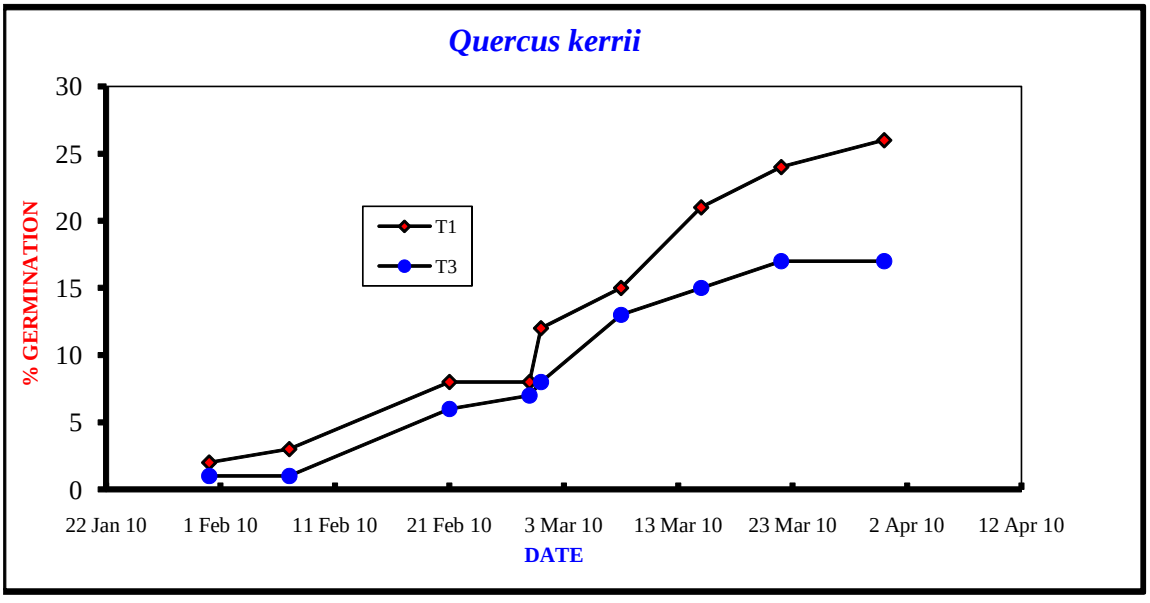
S.NO.	SPECIES	PLANTING DATE
S266	*Quercus kerrii*	12 Oct 09

N		NO.GERM.				% GERM.				GERM.RATE			
		100	100										
DATE	DAYS	T1	T3			T1	T3			T1	T3		
31 Jan 10	111	2	1			2	1			0.00	0.00		
7 Feb 10	118	3	1			3	1			0.14	0.00		
21 Feb 10	132	8	6			8	6			0.36	0.36		
28 Feb 10	139	8	7			8	7			0.00	0.14		
1 Mar 10	140	12	8			12	8			4.00	1.00		
8 Mar 10	147	15	13			15	13			0.43	0.71		
15 Mar 10	154	21	15			21	15			0.86	0.29		
22 Mar 10	161	24	17			24	17			0.43	0.29		
31 Mar 10	170	26	17			26	17			0.22	0.00		

	T1	T3		
R1	7	2		
R2	11	7		
R3	8	8		
Total	**26**	**17**		
Mean	**8.667**	**5.667**		
SD	**2.08**	**3.21**		
MLD	**147**	**147**		
LSD	**a**	**a**		

Germination

***The mean is significant at the 0.05 level



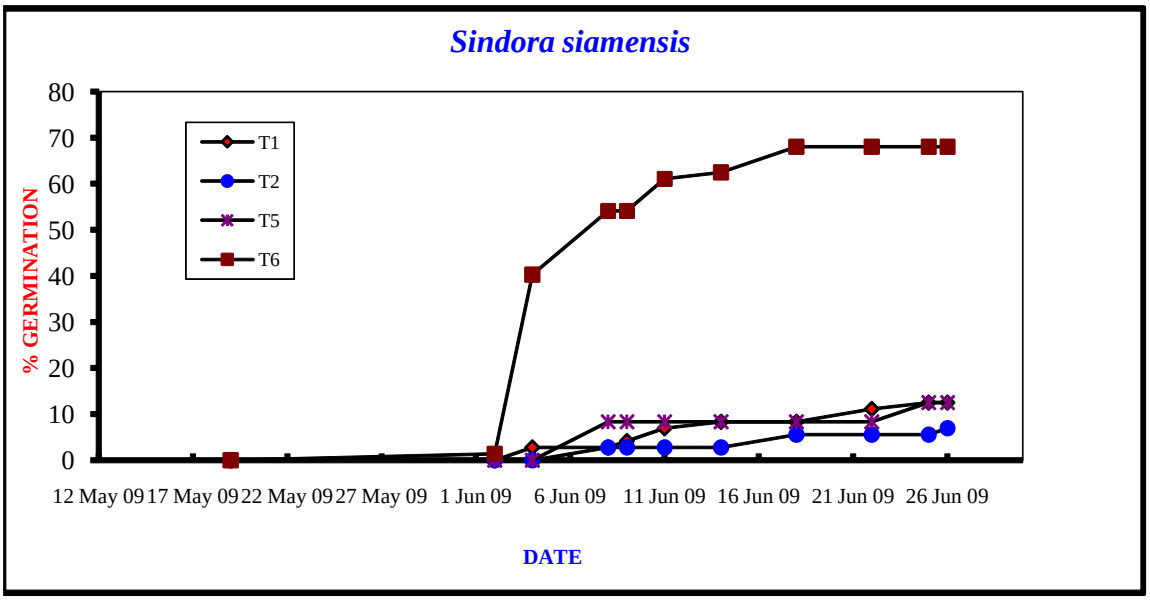
S.NO.	SPECIES	PLANTING DATE
S330	*Sindora siamensis*	19 May 09

N		NO.GERM.				% GERM.				GERM.RATE			
		72	72	72	72								
DATE	DAYS	T1	T2	T5	T6	T1	T2	T5	T6	T1	T2	T5	T6
19 May 09	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00
2 Jun 09	14	0	0	0	1	0	0	0	1	0.00	0.00	0.00	0.07
4 Jun 09	16	2	0	0	29	3	0	0	40	1.00	0.00	0.00	14.00
8 Jun 09	20	2	2	6	39	3	3	8	54	0.00	0.50	1.50	2.50
9 Jun 09	21	3	2	6	39	4	3	8	54	1.00	0.00	0.00	0.00
11 Jun 09	23	5	2	6	44	7	3	8	61	1.00	0.00	0.00	2.50
14 Jun 09	26	6	2	6	45	8	3	8	63	0.33	0.00	0.00	0.33
18 Jun 09	30	6	4	6	49	8	6	8	68	0.00	0.50	0.00	1.00
22 Jun 09	34	8	4	6	49	11	6	8	68	0.50	0.00	0.00	0.00
25 Jun 09	37	9	4	9	49	13	6	13	68	0.33	0.00	1.00	0.00
26 Jun 09	38	9	5	9	49	13	7	13	68	0.00	1.00	0.00	0.00

	T1	T2	T5	T6
R1	5	2	2	13
R2	4	2	5	15
R3	0	1	2	21
Total	**9**	**5**	**9**	**49**
Mean	**3**	**1.667**	**3**	**16.33**
SD	**2.65**	**0.58**	**1.73**	**4.16**
MLD	**23**	**30**	**8**	**16**
LSD	**a**	**ac**	**ac**	**ab**

Germination

***The mean is significant at the 0.05 level



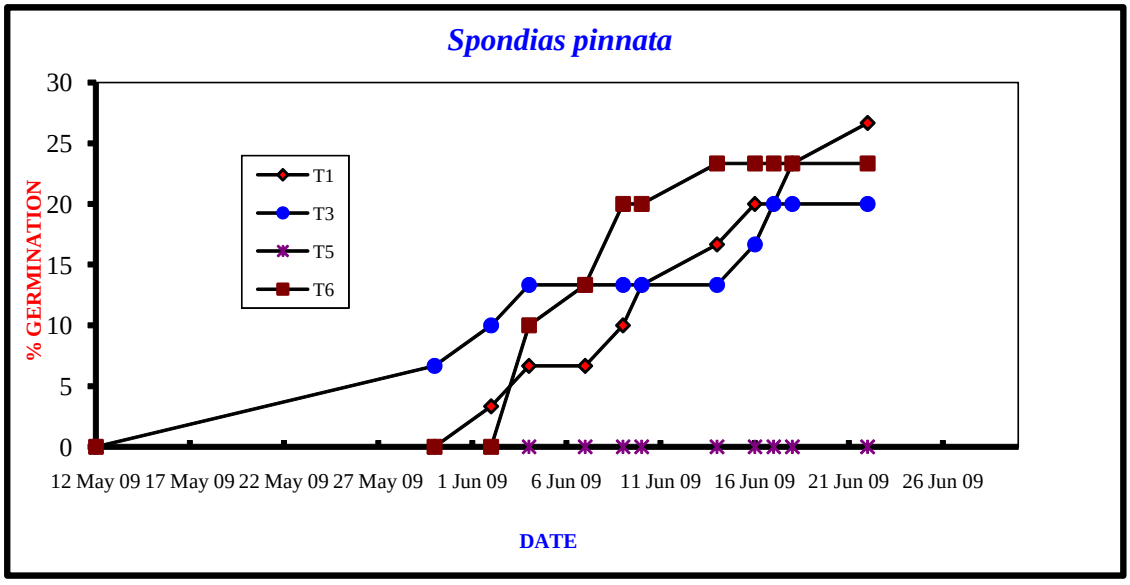
S.NO.	SPECIES	PLANTING DATE
S192	*Spondias pinnata*	12 May 09

N		NO.GERM.				% GERM.				GERM.RATE			
		30	30	30	30								
DATE	DAYS	T1	T3	T5	T6	T1	T3	T5	T6	T1	T3	T5	T6
12 May 09	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0.00
30 May 09	18	0	2	0	0	0	7	0	0	0.00	0.11	0.00	0.00
2 Jun 09	21	1	3	0	0	3	10	0	0	0.33	0.33	0.00	0.00
4 Jun 09	23	2	4	0	3	7	13	0	10	0.50	0.50	0.00	1.50
7 Jun 09	26	2	4	0	4	7	13	0	13	0.00	0.00	0.00	0.33
9 Jun 09	28	3	4	0	6	10	13	0	20	0.50	0.00	0.00	1.00
10 Jun 09	29	4	4	0	6	13	13	0	20	1.00	0.00	0.00	0.00
14 Jun 09	33	5	4	0	7	17	13	0	23	0.25	0.00	0.00	0.25
16 Jun 09	35	6	5	0	7	20	17	0	23	0.50	0.50	0.00	0.00
17 Jun 09	36	6	6	0	7	20	20	0	23	0.00	1.00	0.00	0.00
18 Jun 09	37	7	6	0	7	23	20	0	23	1.00	0.00	0.00	0.00
22 Jun 09	41	8	6	0	7	27	20	0	23	0.25	0.00	0.00	0.00

	T1	T3	T5	T6
R1	8	6	0	7
R2				
R3				
Total	**8**	**6**	**0**	**7**
Mean	**8**	**6**	**0**	**7**
SD				
MLD	**29**	**21**	**0**	**26**
LSD				

Germination

***The mean is significant at the 0.05 level



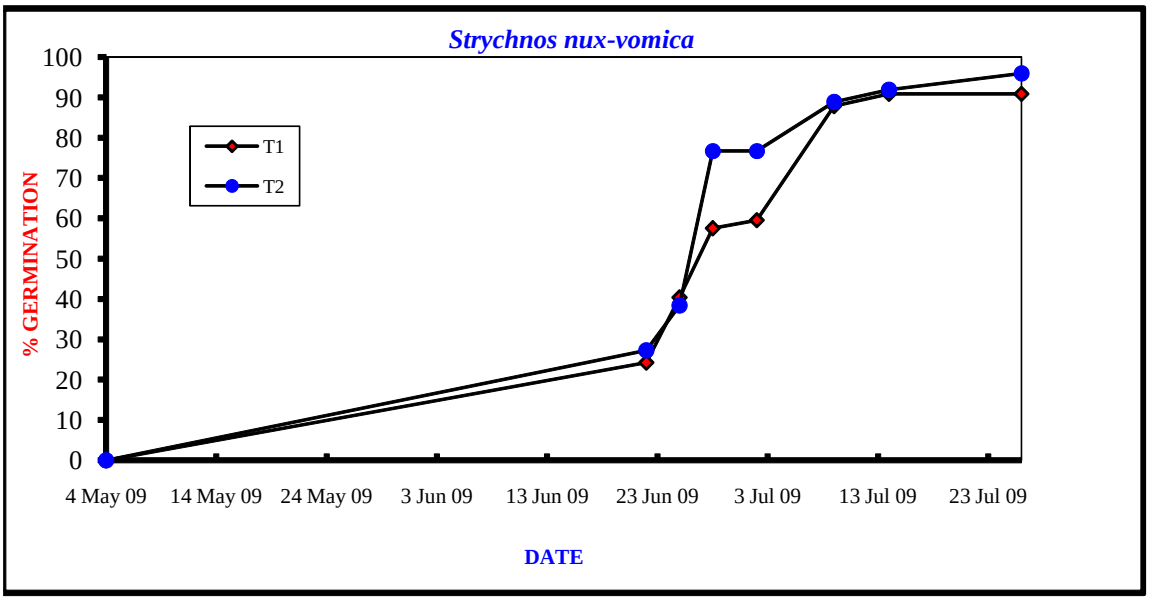
S.NO.	SPECIES	PLANTING DATE
S079	*Strychnos nux-vomica*	4 May 09

N		NO.GERM.				% GERM.				GERM.RATE			
		99	99	0	0								
DATE	DAYS	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
4 May 09	0	0	0			0	0			0.00	1.00		
22 Jun 09	49	24	27			24	27			0.49	0.55		
25 Jun 09	52	40	38			40	38			5.33	3.67		
28 Jun 09	55	57	76			58	77			5.67	####		
2 Jul 09	59	59	76			60	77			0.50	0.00		
9 Jul 09	66	87	88			88	89			4.00	1.71		
14 Jul 09	71	90	91			91	92			0.60	0.60		
26 Jul 09	83	90	95			91	96			0.00	0.33		

	T1	T2	T3	T4
R1	32	31		
R2	30	32		
R3	28	32		
Total	**90**	**95**		
Mean	**30**	**31.67**		
SD	**2**	**0.58**		
MLD	**55**	**55**		
LSD	**a**	**a**		

Germination

***The mean is significant at the 0.05 level



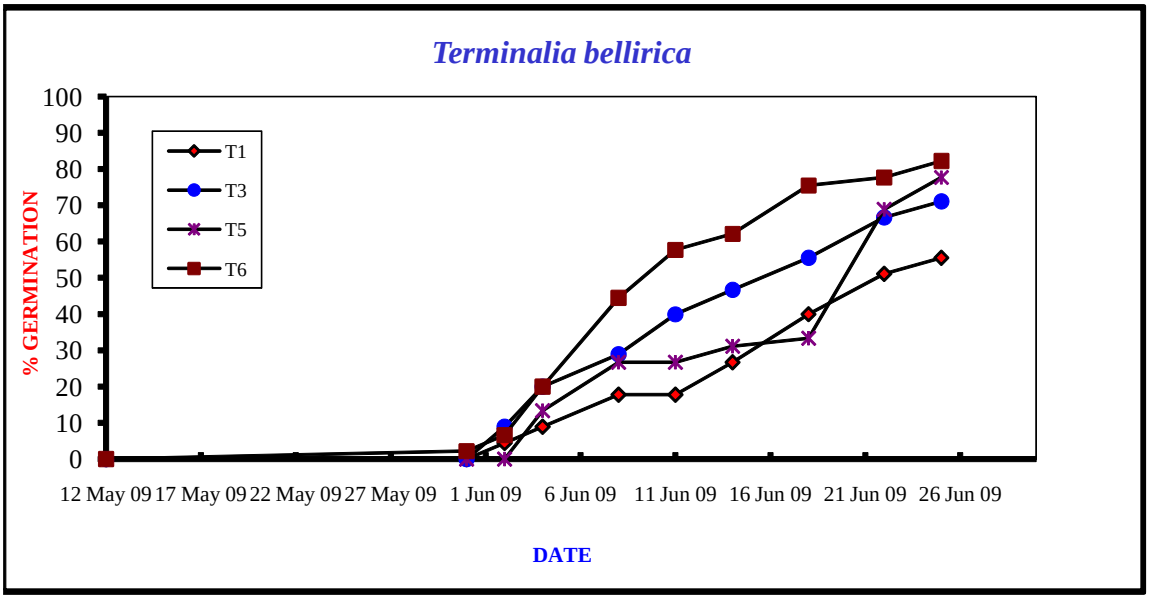
S.NO.	SPECIES	PLANTING DATE
S195	*Terminalia bellirica*	12 May 09

N		NO.GERM.				% GERM.				GERM.RATE			
		45	45	45	45								
DATE	DAYS	T1	T3	T5	T6	T1	T3	T5	T6	T1	T3	T5	T6
12 May 09	0	0	0	0	0	0	0	0	0	0.00	1.00	2.00	3.00
31 May 09	19	0	0	0	1	0	0	0	2	0.00	0.00	0.00	0.05
2 Jun 09	21	2	4	0	3	4	9	0	7	1.00	2.00	0.00	1.00
4 Jun 09	23	4	9	6	9	9	20	13	20	1.00	2.50	3.00	3.00
8 Jun 09	27	8	13	12	20	18	29	27	44	1.00	1.00	1.50	2.75
11 Jun 09	30	8	18	12	26	18	40	27	58	0.00	1.67	0.00	2.00
14 Jun 09	33	12	21	14	28	27	47	31	62	1.33	1.00	0.67	0.67
18 Jun 09	37	18	25	15	34	40	56	33	76	1.50	1.00	0.25	1.50
22 Jun 09	41	23	30	31	35	51	67	69	78	1.25	1.25	4.00	0.25
25 Jun 09	44	25	32	35	37	56	71	78	82	0.67	0.67	1.33	0.67

	T1	T3	T5	T6
R1	11	8	10	12
R2	10	12	12	12
R3	4	12	13	13
Total	**25**	**32**	**35**	**37**
Mean	**8.333**	**10.67**	**11.67**	**12.33**
SD	**3.79**	**2.31**	**1.53**	**0.58**
MLD	**37**	**30**	**37**	**27**
LSD	a	a	a	a

Germination

***The mean is significant at the 0.05 level



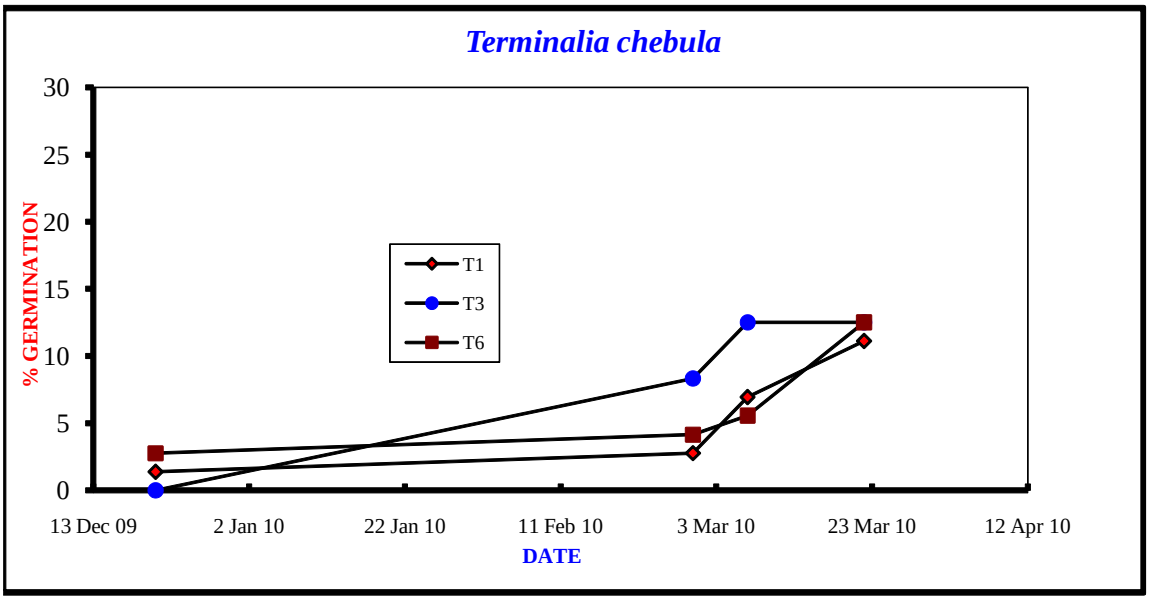
S.NO.	SPECIES	PLANTING DATE
S183	*Terminalia chebula*	2 Nov 09

N		NO.GERM.				% GERM.				GERM.RATE			
		72	72	72	72								
DATE	DAYS	T1	T3	T5	T6	T1	T3	T5	T6	T1	T3	T5	T6
21 Dec 09	49	1	0	0	2	1	0	0	3	0.00	0.00	0.00	0.00
28 Feb 10	118	2	6	0	3	3	8	0	4	0.01	0.09	0.00	0.01
7 Mar 10	125	5	9	0	4	7	13	0	6	0.43	0.43	0.00	0.14
22 Mar 10	140	8	9	0	9	11	13	0	13	0.20	0.00	0.00	0.33

	T1	T3	T5	T6
R1	1	4	0	3
R2	2	2	0	3
R3	5	3	0	3
Total	**8**	**9**	**0**	**9**
Mean	2.667	3	0	3
SD	2.08	1	0	0
MLD	125	118	0	140
LSD	a	a	a	a

Germination

***The mean is significant at the 0.05 level



APPENDIX 3

Framework Tree Species - with scores predicting suitability for restoring deciduous forest ecosystems, based on best currently available data.

E/D = evergreen (E) or deciduous (D) (source: CMU Herbarium Database)

ABUNDANCE recorded for Doi Suthep-Pui National Park (CMU Herbarium Database):

0	Probably extirpated
1	Down to a few individuals, in danger of extirpation
2	Rare
3	Medium abundance
4	Common, but not dominant
5	Abundant (source: CMU Herbarium Database)

HABITAT recorded for Doi Suthep-Pui National Park (CMU Herbarium Database):

deciduous dipterocarp/oak	dof
pine dipterocarp	do/pine
bamboo/deciduous forest	bb/df
mixed deciduous/evergreen	mxf
evergreen forest	egf
evergreen with pine	eg/pine
disturbed areas, roadsides	da
secondary growth	sg

ELEVATION RANGE recorded for Doi Suthep-Pui National Park (CMU Herbarium Database): metres above mean sea level.

FRUITING MONTHS recorded for Doi Suthep-Pui National Park (CMU Herbarium Database):- ja = January; fb = February; mr = March; ap = April; my = May; jn = June; jl = July; ag = August; sp = September; oc = October; nv = November; dc = December.

FRUIT CLASS (Pakkad, 1996; Wong 1992): FIG = fig; F = fleshy; DD = dry dehiscent; DI = dry indehiscent.

GERMINATION PERCENT (FORRU data): E = excellent (>75%); A = acceptable (50-75%); M = marginal (25-50%) R = rejected (<25%).

MLD (FORRU data): median length of dormancy (days)

DISPERSAL (Pakkad, 1996; Wong, 1992): A = animal-dispersed; W = wind-dispersed.

FIELD PERFORMANCE (FORRU data) survival and growth in first growing seasons and fire resilience: E = excellent; A = acceptable; M = marginal; R = rejected.

SUITABILITY SCORE: 0-100, percentage of maximum possible score with available data, based on field performance (6 points); ease of propagation (4); fire resilience (4); animal-dispersed (3); fleshy fruits (3); habitat suitability (3) and evergreen habit (1.5)

.

SPECIES	FAMILY	E/D	ABUN-DANCE	HABITAT	ELEVATION RANGE	FRUITING MONTHS	FRUIT CLASS	EASE OF PROPA-GATION	MLD (DAYS)	DISPER-SAL	FIELD PERFOR-MANCE	FIRE RESIL-IENCE	SUITABILITY SCORE
Actinodaphine henryi Gamb.	Lauraceae	E	3	mxf egf	650-1425	ap my	F	E	75	A	E	-	**90**
Adenanthera microsperma Teijm & Binn.	Leguminosae M	D	3	dof bb/df	350-700	(my) sp-nv	DD	E	33-60	A	A	R	**57**
Afzelia xylocarpa (Kurz) Craib	Leguminosae C	D	2	bb/df	350-500	jn-fb	DD	E	19-29	A?	E	R	**61**
Alangium salvifolium (L.f.) Wang. ssp. hexapetalum (Lmk.) Wang.	Alangiaceae	D	3	bb/df	350-800	ap-my	F	E	16	A	A	A	**80**
Albizia chinensis (Osb.) Merr.	Leguminosae M	D	3	mxf da in egf and eg/pine	450-1325	ja fb	DI	E	7	W	E	-	**66**
Albizia lebbeck	Leguminosae M	D	3	bb/df sg	350-500	ja-ap	DI	E	3-16	W	E	M	**65**
Alstonia scholaris (L.) R. Br. var. scholaris	Apocynaceae	D	3	mxf egf	350-1200	fb mr ap	DD	E	14-40	W	E	-	**61**
Aphanamixis polystachya (Wall.) R. Parker	Meliaceae	E	3	egf and streams in mxf	375-1300	ja-my	F	E	9	A	M	-	**76**
Artocarpus lakoocha Roxb.	Moraceae	D	3	dof bb/df	550-1500	mr-my	F	E	21-35	A	M	R	**59**
Bauhinia purpurea L.	Leguminosae C	ED	3	dof da	350-930	jl-ap	DD	E	14-28	W	E	R	**57**
Careya arborea Roxb.	Lecythidaceae	D	3	dof bb/df	350-850	my jn	F	E	14-37	A	A	E	**86**
Casearia grewiifolia Vent. var. grewiifolia	Flacourtiaceae	D	3	mxf egf	350-500	jn jl	F	E	74	A	A	-	**78**
Dalbergia cultrata Grah. ex Bth.	Leguminosae P	D	4	da dof bb/df mxf eg/pine egf	350-1400	jl ag sp oc nv dc ja fb mr	F	E	30	W	M	-	**59**
Dalbergia oliveri Gamb. Ex Pain	Leguminosae P	D	3	dof bb/df mxf	350-1500	jn-ag	DD	E	50	W	E	-	**63**
Erythrina stricta Roxb.	Leguminosae P	D	3	bb/df egf eg/pine	400-1680	ap my	DD	A	30-37	W	A	-	**54**
Eugenia fruticosa (DC.) Roxb.	Myrtaceae	E	2	eg/pine dof bb/df	350-1525	my-jl	F	E	23-37	A	A	A	**88**
Eugenia grata Wight	Myrtaceae	E	4	streams dof bb/df	400-900	jn jl	F	A	18-56	A	E	-	**80**
Ficus altissima Bl.	Moraceae	E	3	bb/df mxf	350-1050	all year	FIG	E	25-58	A	M	-	**78**
Ficus benjamina L. var. benjamina	Moraceae	E	3	mxf egf	350-1400	all year	FIG	E	22-67	A	E	R	**73**
Ficus callosa Willd.	Moraceae		2	egf	790-1100	ag oc nv dc ja fb mr		E	11		E	-	**83**
Ficus capillipes Gagnep.	Moraceae	ED	2-3	bb/df mxf streams	475-1100	dc-ag	F	E	60-80	A	A	-	**88**
Ficus fistulosa Reinw. ex Bl. var. fistulosa	Moraceae	ED	3	da open bb/df mxf egf sg	350-1400	all year	FIG	A	13-84	A	A	-	**80**

SPECIES	FAMILY	E/D	ABUN-DANCE	HABITAT	ELEVATION RANGE	FRUITING MONTHS	FRUIT CLASS	EASE OF PROPA-GATION	MLD (DAYS)	DISPER-SAL	FIELD PERFOR-MANCE	FIRE RESIL-IENCE	SUITABILITY SCORE
Ficus glaberrima Bl. var. glaberrima	Moraceae	E	4	streams rocks in bb/df mxf egf	450-1200	all year	FIG	E	22-40	A	E	-	**95**
Ficus hispido L. f. var. hispida	Moraceae	E	3	da in bb/df sg	350-1525	all year	FIG	E	14-23	A	A	R	**71**
Ficus microcarpa L. f. var. microcarpa forma microcarpa	Moraceae	E	3	dof bb/df mxf egf eg/pine	350-1050	all year	FIG	E	17-25	A	E	R	**84**
Ficus racemoso L. var. racemosa	Moraceae	D	3	mxf often along streams	350-500	nv-jl	FIG	E	8-27	A	E	-	**88**
Ficus rumphii Bl.	Moraceae	D	2	bb/df streams	450-550	ap my	FIG	E	18-65	A	E	A	**86**
Ficus semicordata B.-H. ex J.E. Sm. var. semicordata	Moraceae	D	3	sg da in bb/df egf eg/pine	350-1550	fb-my	FIG	E	21-52	A	A	-	**80**
Gardenia obtusifolia Roxb. Ex Kurz	Rubiaceae	D	3	dof	400-750	sp-mr	F	E	25	A	E	R	**78**
Gmelina arborea Roxb.	Verbenaceae	D	3	dof bb/df mxf egf eg/pine	350-1475	mr-jn	F	E	9-19	A	E	R	**78**
Irvingia malayana Oliv. ex Benn.	Irvingiaceae	E	3	mxf	350-750	sp-nv	F	A	76	A	A	A	**80**
Lithocarpus polystachyus (A.DC.) Rehd.	Fagaceae	E	3	dof bb/df	550-1300	sp-dc	DI	A	258	A	A	R	**63**
Oroxylum indicum (L.) Kurz	Bignoniaceae	D	3	bb/df mxf	350-1400	ja-mr	DD	E	12-40	W	E	-	**61**
Phyllanthus emblica L.	Euphorbiaceae	D	4	da sg da bb/df mxf	600-1620	sp-mr	F	E	13-16	A	E	A	**86**
Protium serratum (Wall. ex Colebr.) Engl.	Burseraceae	D	3	mxf egf	350-1500	jn jl ag sp oc	F	M	29	W	A	-	**71**
Rhus chinensis Mill.	Anacardiaceae	D	3	eg/pine bb/df mxf da sg	500-1550	ja fb	F	R	28-73	A	A	-	**59**
Sindora siamensis Teysm. ex Miq. var. siamensis	Leguminosae C	D	2	dof streams bb/df	350-460	(jn) dc-ja	DD	E	14-15	W	E	A	**65**
Spondias pinnata (L. f.) Kurz	Anacardiaceae	D	3	dof bb/df	375-750	oc-mr	F	M	8-29	A	A	A	**69**
Strychnos nux-vomica L.	Loganiaceae	D	3	dof bb/df	350-900	dc-my	F	E	38-53	A	A	R	**83**
Terminalia alata Hey. ex Roth	Combretaceae	D	3	dof bb/df	350-900	ag-mr	DI	R	17	W	E	-	**49**
Terminalia bellirica (Gaertn.) Roxb.	Combretaceae	D	3	bb/df mxf	350-1150	oc-fb	F	E	27-37	A	A	A	**80**
Terminalia chebula Retz. var. chebula	Combretaceae	D	3	dof bb/dg mxf	350-850	nv-fb	F	A	60-140	A	E	-	**88**
Trewia nudiflora L.	Euphorbiaceae	D	3-4	streams in mxf bb/df da sg	60-1050	jn-fb	F	E	4-14	A	A	-	**88**