PERFORMANCE OF SIX NATIVE TREE SPECIES, PLANTED TO RESTORE DEGRADED FORESTLAND IN NORTHERN THAILAND AND THEIR RESPONSE TO FERTILISER

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ABSTRACT

The performance of six native forest tree species, planted to restore forest in a degraded watershed in Doi Suthep-Pui National Park, Thailand and their responses to four fertiliser treatments are reported. The species were chosen for their potential to i) shade out competing weeds rapidly and ii) enhance tree species richness by attracting seed-dispersing wildlife.

All species planted, except *Gmelina arborea*, performed well. Relative performance indices, which combined survival and relative growth rate, were 87.5 for *Erythrina subumbrans*, 45.3 for *Melia toosendan*, 36.9 for *Prunus cerasoides*, 32.5 for *Sapindus rarak*, 22.2 for *Hovenia dulcis* and 3.5 for *Gmelina arborea*.

Application of fertiliser at the time of planting and twice during the first rainy season after planting resulted in much higher performance than application of fertiliser only at the time of planting, for all species except *Prunus cerasoides*. Although the highest dosage of fertiliser (200 g at the time of planting and twice during the rainy season) resulted in the highest growth rates, it also lowered survival of planted saplings. For planting mixtures of native tree species, the recommended fertiliser treatment is therefore 50-100 g fertiliser, applied at the time of planting and at least twice during the first rainy season after planting. Further research is needed to determine whether more frequent fertiliser application would further improve performance.

Key words: forest restoration, reforestation, silviculture, fertiliser

INTRODUCTION

Deforestation is probably the greatest threat to Thailand's biodiversity. Whilst increased protection of remaining forest must remain an essential part of any policy for biodiversity conservation, protection alone is clearly not enough. Since Thailand's first conservation areas were established in the early 1960's, forest cover has been reduced from 53% of the country (BHUMIBAMON, 1986) to 22.8% or 111,010 km^2 (FAO, 1997). Now, more than a decade since a ban on commercial logging was introduced, the annual rate of deforestation

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remains approximately 1,000 km^2 (CHATWIROON, 1997) or just under 1%. To counteract this apparently unstoppable deforestation, restoring forest to degraded forestland must complement stricter protection of remaining forest.

Forest restoration within wildlife sanctuaries and national parks should aim to recreate the original forest ecosystems that were present before deforestation occurred. This would provide optimal habitat for wildlife and help to restore original levels of biodiversity. One way to achieve this might be to complement natural regeneration by planting native forest tree species that grow rapidly, shade out weeds and attract seed-dispersing animals into planted areas. Wildlife, especially birds and bats, attracted by the planted trees, would disperse the seeds of other, non-planted tree species into replanted sites and thus accelerate the recovery of biodiversity. This is the so-called 'framework species' method of forest restoration, which has been used very successfully to restore forest in Queensland's Wet Tropics World Heritage Area (GOOSEM & TUCKER, 1995; LAMB *et al*. 1997, TUCKER & MURPHY, 1997). In Queensland, 30-60 cm tall saplings of 20-30 framework tree species are planted, spaced 1.6-1.8 m apart. In addition to careful species selection, the method includes intensive care for the trees after planting i.e. weeding and application of fertiliser. Such practices maximise the performance of the planted trees and bring about rapid canopy closure. Once canopy closure occurs, no further maintenance is required and the replanted forest becomes self-sustaining.

In collaboration with Doi Suthep-Pui National Park, Chiang Mai University's Forest Restoration Research Unit (FORRU) has been carrying out research since 1997 to identify potential framework tree species from amongst the native tree flora of the national park and to develop effective methods to propagate them. With sponsorship from the Biodiversity Research and Training Programme (BRT 240002), FORRU established experimental field plots in 1998, to assess whether the framework species method could be adapted to restore deforested sites in northern Thailand.

Within these plots, the performance of 29 indigenous species of forest tree is being monitored. Here we report on the early performance of six of the fastest-growing species. In many degraded upland areas, applying fertiliser can accelerate tree growth, since soil nutrients are often depleted following cultivation. For forest restoration projects in Australia, GOOSEM & TUCKER (1995) recommend applying 100 g of inorganic fertiliser when trees are planted and subsequently every 4 weeks during the rainy season. However, for native forest trees in Thailand, the optimal dosage and frequency of fertiliser application have not yet been determined. Therefore, in the experiments reported here, four different fertiliser treatments were also tested.

Study area

Experimental plots were established in the north of Doi Suthep-Pui National Park, in a degraded watershed (18° 52'N, 94° 51'E), 1,207-1,310 m above sea level. The locations of the plots were decided in collaboration with the villagers of Ban Mae Sa Mai, an Hmong hill tribe community about 2 km from the plots. The villagers were also closely involved with planting, maintaining and monitoring the plots.

The area has two main seasons: the wet season (May - October) and the dry season (mean monthly rainfall below 100 mm, November - April). The dry season is subdivided into the cool-dry season (November to January) and the hot- dry season (February to April). Average annual rainfall, recorded at the nearest weather station to the study site at similar elevation (Kog-Ma Watershed Research Station), was 2,094.9 mm. Temperatures varied from a minimum of 4.5°C in December to a maximum of 35.5°C in March (Fig. 1).

Originally the study site had been covered in evergreen forest, but the forest was cleared approximately 20 years ago and the area cultivated for cabbages, corn, potatoes etc. Frequent fires have caused additional degradation. Compared with soil in undisturbed evergreen forest at a similar elevation, soil in the study site was significantly more acidic and it had significantly less organic matter, less nitrogen, more sand and less silt and clay (Table 1, $p<0.05$). Although a few scattered mature trees remain, the area is now dominated by herbaceous weedy vegetation such as *Pteridium aquilinum* (L.) Kuhn (Dennstaedtiaceae), *Bidens pilosa* L. var. *minor* (Bl.) Sherf, *Ageratum conyzoides* L., *Eupatorium odoratum* L. and *E. adenophorum* Spreng. (all Compositae), *Commelina diffusa* Burm. F. (Commelinaceae) and grasses e.g. *Phragmites vallatoria* (Pluk. ex L.) Veldk., *Imperata cylindrica* (L.) P. Beauv. var. *major* (Nees) C.E. Hubb. ex Hubb. & Vaugh. and *Thysanolaena latifolia* (Roxb. ex Horn.) Honda (both Gramineae).

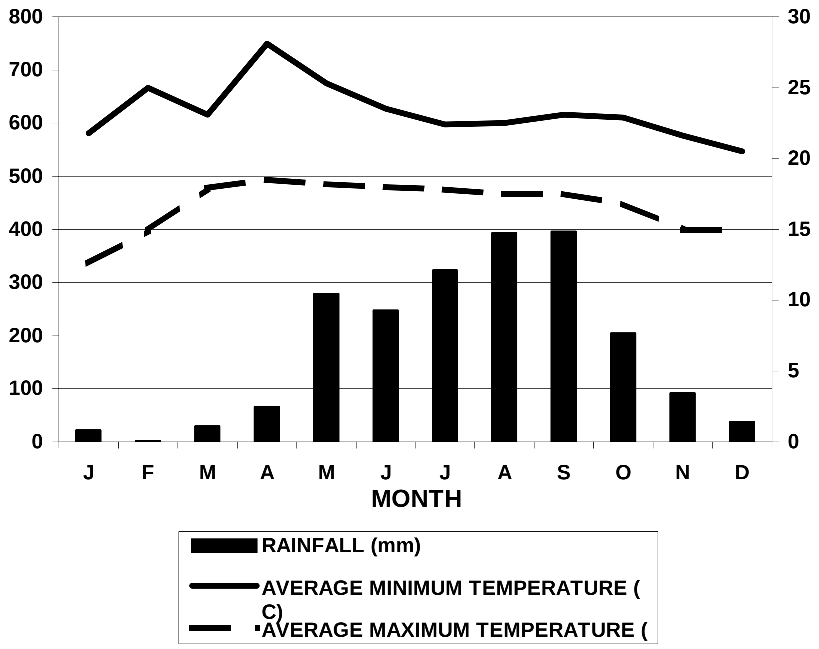

Figure 1. Average monthly rainfall, minimum and maximum temperature at Kog-ma Watershed Research Station (elevation 1,400 m) approximately 9 km from the study site (1966-83).

Table 1. Soil characteristics of the study site (degraded area) (n=16) compared with those in undisturbed evergreen forest (Tum Reusi, elevation 1,100 m about 9 km from the study site) (n=20).

	Degraded Area		*Evergreen Forest*		t-test[1] p values
	Mean	*SD*	Mean	*SD*	
ph	5.44	0.423	6.22	0.545	0.001
Organic Matter (%)	5.35	0.997	7.30	2.480	0.010
Nitrogen (%)	0.26	0.045	0.37	0.121	0.002
Potassium (ppm)	274.84	137.637	295.67	72.093	ns[2]
Moisture at field capacity (%)	34.76	2.571	35.35	4.363	ns[2]
Sand (%)	68.52	6.290	52.13	17.872	0.010
Silt (%)	18.26	3.090	22.04	5.473	0.020
Clay (%)	13.22	3.880	25.83	16.343	0.010

[1]Two-tailed Student's t-test, variances assumed equal, [2]ns = not significant at p>0.05

METHODS

Trees planted

The saplings planted were grown from seed, collected within Doi Suthep-Pui National Park. Seeds were germinated in open plastic trays and potted into 9 x 2.5 inch black plastic bags in a medium of forest soil, coconut husk and peanut husk mixed in the ratio of 2:1:1. Saplings were grown for 3-18 months (depending on species) at FORRU's research nursery at the national park HQ (at about 1,000 m above sea level). They were 30-100 cm tall at the time of planting. Brief information about the six species covered in this report is provided below. For further details see Forest Restoration Research Unit (1998 & 2000).

Erythrina subumbrans (Hassk.) Merr. (Leguminosae, Papilionoideae) is an exceptionally fast-growing, deciduous tree, up to 25 m tall, with a dense, spreading crown, branching near the base. It is found in evergreen forest and mixed evergreen-deciduous forests from 350 to 1,700 m elevations, especially along stream valleys at lower elevations (CMU Herbarium Database). The stem is thorny which may protect saplings from herbivores. The attractive red flowers produce copious quantities of nectar, which attract wildlife, and the seeds are eaten by various bird species.

Gmelina arborea Roxb. (Verbenaceae) is a common, fast-growing, medium-sized (up to 30 m tall), deciduous tree, found in all forest types, especially in disturbed areas at elevations ranging from 350 to 1,500 m (CMU Herbarium Database). Its dense spreading crown is particularly effective at shading out weeds. About 3-4 years after planting, it produces fleshy fruits (drupes) which are avidly eaten by deer and cattle. This species is widely used as a plantation tree for pulp and paper production.

Hovenia dulcis Thunb. (Rhamnaceae) is a rare, exceptionally fast-growing, deciduous tree, up to 20-30 m tall, with a spreading crown, restricted to evergreen forest, especially near streams, from 1,000 to 1,300 m elevations (KOPACHON *ET AL.*, 1996). The fruits (capsules) are very attractive to birds (pigeons and bulbuls) (HITCHCOCK & ELLIOTT, in press) and rodents and it rapidly resprouts after fire damage. The fruit stalks are used in a traditional treatment of hangovers (MABBERLY, 1987).

Melia toosendan Sieb. & Zucc. (Meliaceae) is a common, fast-growing, deciduous tree, up to 30 m tall, capable of rapid regeneration after damage, found in evergreen forest and mixed evergreen-deciduous forest, at elevations of 550 to 1,450 m (CMU Herbarium Database). Fruiting can occur on saplings as young as 2-3 years old.

Prunus cerasoides D. Don (Rosaceae) is a medium-sized, fast-growing, deciduous tree, up to 20 m tall, with conspicuous pinkish-purple flower petals and small red fruits, which are attractive to birds. It grows in evergreen forest and disturbed areas, at 1,000-2,000 m elevation (CMU Herbarium Database). This species has become particularly popular for tree planting projects, mostly because of its attractive flowers. It is often planted as an ornamental, especially along roadsides. The fruits are edible but rather acidic (Bunyadit, pers. com.).

Sapindus rarak DC. (Sapindaceae) is an uncommon, medium-seized, deciduous, fast-growing, resilient, canopy tree, reaching heights of 10-25 m. It grows in evergreen forest and mixed evergreen-deciduous forest, often in disturbed areas at elevations ranging from 625 to 1,620 m (CMU Herbarium Database). Soapy substances, extracted from the fruits, are used to make soaps and shampoos. The wood is used for general construction, furniture, boards and combs.

Establishment and monitoring of planting trials

Three replicated blocks of sub-plots were established on gently sloping sites on ridge tops above Ban Mae Sa Mai. The blocks were spaced approximately 0.5-1 km apart, to encompass natural variability in soil conditions, slope, aspect etc. Sub-plots were prepared by weeding with hand tools, followed by a single application of the non-residual herbicide, glyphosate, care being taken not to spray naturally established trees. On 28th June 1998, the sub-plots were planted randomly with 29 potential framework tree species at a density of 3,125 trees per ha (approximately 1.8 x 1.8 m spacing). For each species, the same number of trees was planted in each sub-plot.

In the sub-plots, four fertiliser treatments were applied. The fertiliser used was “Rabbit Brand” NPK 15-15-15. The treatments were: i) 100 g fertiliser mixed with soil in the planting hole at planting time, but no subsequent fertiliser application; ii) 50 g fertiliser at planting and two further 50 g applications during the rainy season; iii) 100 g fertiliser at planting and two further 100 g applications during the rainy season and iv) 200 g fertiliser at planting and two further 200 g applications during the rainy season. Hereafter, these treatments are referred to as FP, F50 F100 and F200 respectively. Sub-plots were 20 x 20 m for each treatment. The sub-plots were weeded as necessary during the rainy season. Fertiliser was spread in a ring at least 30 cm from the stem of each sapling immediately after weeding in September and December (except for the FP treatment). The plots were monitored 2 weeks after planting on 15th July 1998 and on 5th March 1999. Monitoring included recording numbers of surviving trees and their heights (measured from root collar to apical meristem).

RESULTS

Survival

Overall, the mean survival of planted saplings was 81.9%. The mean values for individual species ranged from 72.4% for *Gmelina arborea* to 93.2% for *Erythrina subumbrans*. Within individual treatment sub-plots, however, the range was 58.3 to 100.0% (Table 2.). The effects of the fertiliser treatments on survival varied among the species. With the exception of *Gmelina arborea*, there was no difference in survival percentages obtained with the FP treatment for the other 5 species, all between 80 and 87.5%; with the F50 treatment, the highest survival of >95% was recorded for *Sapindus rarak*, *Melia toosendan* and *Erythrina subumbrans*; similarly for the F100 treatment, the latter species also had survival percentages of >93.3%. Averaging across all species, the F100 treatment gave the highest survival and the F200 treatment gave the lowest. A Mann-Whitney U-test revealed significant differences in treatment medians only between F100 and F200 ($p<0.05$).

Table 2. Percentage survival of 6 native forest tree species over the first growing season with 4 fertiliser application treatments (initial sample sizes ranged from 9 to 21 saplings per treatment).

Species	Treatments				Species means
	FP	F50	F100	F200	
Erythrina subumbrans	80.0	100.0	100.0	92.9	93.2
Gmelina arborea	58.3	66.7	91.7	72.7	72.3
Hovenia dulcis	87.5	60.0	80.0	76.9	76.1
Melia toosendan	84.6	100.0	93.3	85.7	90.9
Prunus cerasoides	85.7	61.5	80.0	62.5	72.4
Sapindus rarak	84.2	95.0	95.2	70.0	86.1
Treatment means	80.1	80.5	90.0	76.8	81.9

Growth Rates

Relative height growth rate (%RGR month^{-1}) was calculated for each individual sapling that survived the period July 1998 to March 1999. An analysis of variance, performed on the mean %RGR of each species and of each treatment showed no significant differences among the three blocks ($p<0.05$). Therefore, %RGR’s for all individual saplings were pooled across all blocks for each treatment. Averaging over all species and treatments, the mean relative growth rate was about 8% month^{-1}. The effects of the fertiliser treatments on mean %RGR varied among the species. *Erythrina subumbrans* gave the highest mean %RGR in all treatments, followed by *Prunus cerasoides* (Table 3). With the exception of the FP treatment, relatively high growth rates were also obtained with *Melia toosendan* and *Sapindus rarak.*

Table 3. Mean relative height growth rates (% month^{-1}) of 6 native forest tree species over the first growing season with 4 fertiliser application treatments.

Species	Treatments								Species means	
	FP		F50		F100		F200			
	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
Erythrina subumbrans	17.80	6.39	14.29	10.57	17.99	5.23	17.74	7.70	16.95	7.47
Gmelina arborea	-0.71	4.39	3.81	1.86	0.05	1.97	0.49	4.14	0.91	3.09
Hovenia dulcis	3.52	3.82	5.25	7.87	6.45	3.16	5.98	3.67	5.30	4.63
Melia toosendan	2.35	9.24	10.82	3.41	9.71	4.52	12.49	5.25	8.84	5.61
Prunus cerasoides	9.33	4.45	8.76	2.79	7.80	9.12	11.12	3.80	9.25	5.04
Sapindus rarak	2.92	7.59	8.10	3.60	7.91	11.61	8.18	7.37	6.78	7.54
Treatment means	5.87	5.98	8.50	5.02	8.32	5.94	9.33	5.32	8.01	5.56

Averaging across the species, the highest growth was obtained with the F200 treatment and lowest with the FP treatment. However, an analysis of variance performed on pooled %RGR's from all blocks, for each species, failed to show that differences in mean %RGR among fertiliser treatments were statistically significant, except for *Melia toosendan.* For this species alone, differences among fertiliser treatments were highly significant ($F=6.45$, $p=0.001$), but this was due entirely to the differences between FP and the other treatments. T-tests showed that the FP treatment significantly reduced %RGR compared with all other treatments (F50, $t=3.16$, $p<0.01$; F100, $t=2.59$, $p<0.02$; F200, $t=3.13$, $p<0.01$). There were no significant differences among the treatments involving application of fertiliser twice during the rainy season for *Melia toosendan*.

Performance

Combining survival with %RGR provides an index of relative performance and enables comparisons among species. Therefore, a relative performance index (RPI, no units), with a maximum value of 100, was calculated to determine the optimal fertiliser treatment:

$$\text{RPI} = \frac{\text{mean \% survival x 10}}{\text{max. mean \% survival}} \quad \text{x} \quad \frac{\text{mean \%RGR x 10}}{\text{max. mean \%RGR}}$$

Averaging across fertiliser treatments, differences among species were statistically significant (Table 4, $p<0.05$). *Erythrina subumbrans* was significantly the best-performing species, followed by *Melia toosendan*, *Prunus cerasoides*, *Sapindus rarak* and *Hovenia dulcis* (Table 4). *Gmelina arborea* performed inadequately in this experiment. Applying fertiliser only at the time of planting clearly resulted in the poorest performance compared with application of fertiliser at planting and twice during the rainy season. All species tested, except *Prunus cerasoides*, showed minimum performance with the FP treatment. Averaging across species, mean RPI was lowest with the FP treatment. However, differences among all treatment means were not statistically significant (at $p<0.05$) and were only marginal among the other three treatments. Three of the species tested attained maximum RPI with the F50 treatment (*Melia toosendan*, *Sapindus rarak* and *Gmelina arborea*), two (*Hovenia dulcis* and *Erythrina subumbrans*) with the F100 treatment and one (*Prunus cerasoides*) with the FP treatment.

Table 4. Mean RPI of 6 native forest tree species over the first growing season with 4 fertiliser application treatments.

Species	Treatments				Species means[1]
	FP	F50	F100	F200	
Erythrina subumbrans	79.1	79.4	100.0	91.6	87.5[a]
Gmelina arborea	-2.3	14.1	0.3	2.0	3.5[c]
Hovenia dulcis	17.1	17.5	28.7	25.6	22.2[b]
Melia toosendan	11.1	60.1	50.4	59.5	45.3[b]
Prunus cerasoides	44.4	30.0	34.7	38.6	36.9[b]
Sapindus rarak	13.7	42.8	41.9	31.8	32.5[b]
Treatment means	27.2	40.7	42.6	41.5	

[1] Means not sharing same superscripts are significantly different (Student's t-test, two tailed, $p<0.05$, variances assumed equal).

DISCUSSION

All species, except *Gmelina arborea,* performed well in this experiment and can be recommended for planting to restore forest ecosystems in highland areas in northern Thailand. Three of the species can also be grown at lower elevations e.g. *Erythrina subumbrans* (down to 350 m), *Melia toosendan* (550 m) and *Sapindus rarak* (625 m). The poor performance of *Gmelina arborea* can probably be attributed to various insect pests that attacked the leaves. This problem seems to vary from year to year, since *Gmelina arborea* saplings planted by FORRU in the same watershed in 1997 grew very well.

Compared with a single application of fertiliser at planting time, applying fertiliser twice during the rainy season marginally or substantially increased the performance of five of the six species of planted saplings and significantly increased growth rate of *Melia toosendan*. Only *Prunus cerasoides* appeared to fair better without repeated applications of fertiliser during the rainy season.

Although the maximum fertiliser dosage (F200) resulted in the highest %RGR, averaged across the species, it increased %RGR only marginally, by 9.7% and 12.1%, compared with the F50 and F100 treatments respectively. Therefore, in view of the high sapling mortality caused by the F200 treatment and its high expense, it cannot be recommended.

The recommended fertiliser treatment, when planting mixtures of native tree species in degraded upland watersheds in northern Thailand, is therefore 50-100 g fertiliser applied at the time of planting and at least twice during the first rainy season after planting. The advantages of using 100 g, compared with 50 g, however, appear to be marginal. Therefore, 50 g is probably the most cost-effective treatment. Further research is needed to determine whether more frequent applications of fertiliser would yield further benefits. A possible exception to this general guideline is *Prunus cerasoides*, which performed best with minimal fertiliser application. This species had higher survival and growth rates with the FP treatment than with both the F50 and F100 treatments.

%RGR of height was a highly variable measure of growth. This may have reflected variability in site conditions or genetic variation among the saplings planted. Further research is needed to attain a more uniform response from the planted saplings.

The experiment is still being monitored and we hope to report on the performance of the planted trees after 2-3 years of growth in a subsequent paper.

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REFERENCES

BHUMIBAMON, S., 1986. *The environmental and socio-economic aspects of tropical deforestation: a case study of Thailand*. Department of Silviculture, Faculty of Forestry, Kasetsart University. 102 pp.

CHATWIROON, P., 1997. Forest situation and some responses in Thailand. Paper presented at the workshop "*From Reforestation to Rehabilitation*", Kuranda, Queensland, Australia.

FAO, 1997. *State of the World's Forests 1997*.

FOREST RESTORATION RESEARCH UNIT, 1998. *Forests for the Future: Growing and Planting Native Tress for Restoring Forest Ecosystems*. Biology Department, Science Faculty, Chiang Mai University, Thailand. 60 pp.

FOREST RESTORATION RESEARCH UNIT, 2000. *Tree Seeds and Seedlings for Restoring Forests in Northern Thailand.* Biology Department, Science Faculty, Chiang Mai University, Thailand. 151 pp.

GOOSEM, S. and N. I. J. TUCKER, 1995. *Repairing the Rainforest*. Cassowary Publications, Cairns, Australia.

HITCHCOCK, D. and S. ELLIOTT, (in press). Forest restoration research in northern Thailand, III: Observations of birds feeding in mature Hovenia dulcis Thunb. (Rhamnaceae). *Nat. Hist Bull. Siam Soc.* in press.

KOPACHON, S, K. SURIYA, K. HARDWICK, G. PAKAAD, J. MAXWELL, V. ANUSARNSUNTHORN, D. BLAKESLEY, N. GARWOOD and S. ELLIOTT, 1996. Forest restoration research in northern Thailand: 1. The fruits, seeds and seedlings of Hovenia dulcis Thunb. (Rhamnaceae). *Nat. Hist. Bull. Siam Soc.* 44: 41-52.

LAMB. D., J. PARROTTA, R. KEENAN and N. I. J. TUCKER, 1997. Rejoining habitat fragments: restoring degraded forest lands. pp. 366-385 in LAURANCE, W. F. and BIERREGAARD, R. O. *Tropical Forest Remnants: Ecology, Management and Conservation of Fragmented Communities*. The University of Chicago Press, Chicago.

MABBERLY, D. J. 1987. *The Plant Book*. Cambridge University Press. Cambridge; p 281.

TUCKER, N. and T. MURPHY, 1997. The effects of ecological rehabilitation on vegetation recruitment: some observations from the Wet Tropics of North Queensland. *For. Ecol. Manage.* 99: 133-152.