Fellowship report

An ITTO fellowship grant helps show potential of mixed local tree species for revegetating tin mine tailings in Indonesia

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Reliance on natural succession to restore sand tin tailings without any human aid can be very slow (Mitchell 1959; Nurtjahya *et al.* 2007a). Natural regeneration after up to 11 years on tin-mined land in Indonesia was dominated by shrub species of the Cyperaceae and Poaceae families while shrub species of the Myrtaceae family were still common on 38-year old tin-mined lands. The cation exchange capacity and concentrations of soil nutrients (Ca, Mg, K, and Na) of tin-mined lands were lower than undisturbed land, and the carbon to nitrogen ratio of tin-mined lands was higher than undisturbed lands (Nurtjahya *et al.* 2007a), inhibiting natural regeneration of tree species.

A number of exotic tree species are widely used in rehabilitation programs but it is unwise to continue to rely on such a limited mix for all future rehabilitation efforts (Lamb and Tomlinson 1994) as they may inhibit natural recolonization. Besides standard soil amendment practices to promote natural regeneration (Nurtjahya 2001), various organic/non-organic materials and microorganisms have been examined (Puryanto 1983; Awang 1988; Sastrodihardjo 1990; Madjid *et al.* 1994; Naning *et al.* 1999; Nurtjahya 2001; Setiadi 2002; CBR 2002), although systematic scientific studies are considered inadequate (Ang *et al.* 2003). Selection of native tree species has been guided by information from natural succession observation (Nurtjahya *et al.* 2007a) in ecosystems which are similar to tin-mined lands. Improving microclimates, by using methods such as alternating rip cultivation with high planting density and high species richness, is one technique that has had some success (Rachmawati *et al.* 1996; Parrotta and Knowles 2001).

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Various indicators have been used to evaluate the success of revegetation (Tongway *et al.* 2001, pers. comm.; Setiadi 2002, pers. comm.; Ludwidg *et al.* 2003), including the measurement of fauna (Andersen and Sparling 1997; Passel 2000; Yin *et al.* 2000; Nurtjahya *et al.* 2007b). Survival rate, however, is viewed as the most critical indicator (Lamb and Tomlinson 1994). The aim of this study was to study the growth of ten selected local tree species in amended sand tin tailings, and to identify cultivation practices which support the best growth of local tree species and encourage natural colonization.

Study site and methodology

The two hectare tin-mined study site (barren prior to this study) is located at Riding Panjang village, in the Province of Bangka Belitung (01° 59' 53.46"S and 106° 06' 45.32"E), at an altitude of 30 m.a.s.l., with annual rainfall of 2400 mm, and temperatures ranging from 23.8 to 31.5°C. The experiment consisted of a factorial randomized complete block design with two factors and three replicates. 3345 seedlings were planted at three densities (10 000 seedlings ha^{-1}, 2500 seedlings ha^{-1}, and 625 seedlings ha^{-1}) in 45 plots of 12 x 12 m. Each planting density treatment plot had ten species. The five soil treatments were: (1) control, (2) 500 grams powdered slime tailing under *Lepironia articulata*, (3) equal composition (1:1) 30 kg ha^{-1} of legume cover crops (LCC) *Calopogonium mucunoides* and *Centrosema pubescens*, (4) LCC and 2.5% humic acid, and (5) LCC and top soil. The ten species were: *Calophyllum inophyllum* (Clusiaceae), *Hibiscus tiliaceus* (Malvaceae), *Macaranga* spp. (Euphorbiaceae), *Mallotus paniculatus* (Euphorbiaceae), *Schima wallichii* (Theaceae), *Vitex pinnata* (Verbenaceae), *Ficus superba* (Moraceae), *Syzygium grande* (Myrtaceae), *Aporosa* spp. (Euphorbiaceae), and *Syzygium polyanthum* (Myrtaceae). Pieces of coconut shell were placed around the root collar of each plant at planting to improve the microclimate. The plants were watered from a nearby pond.

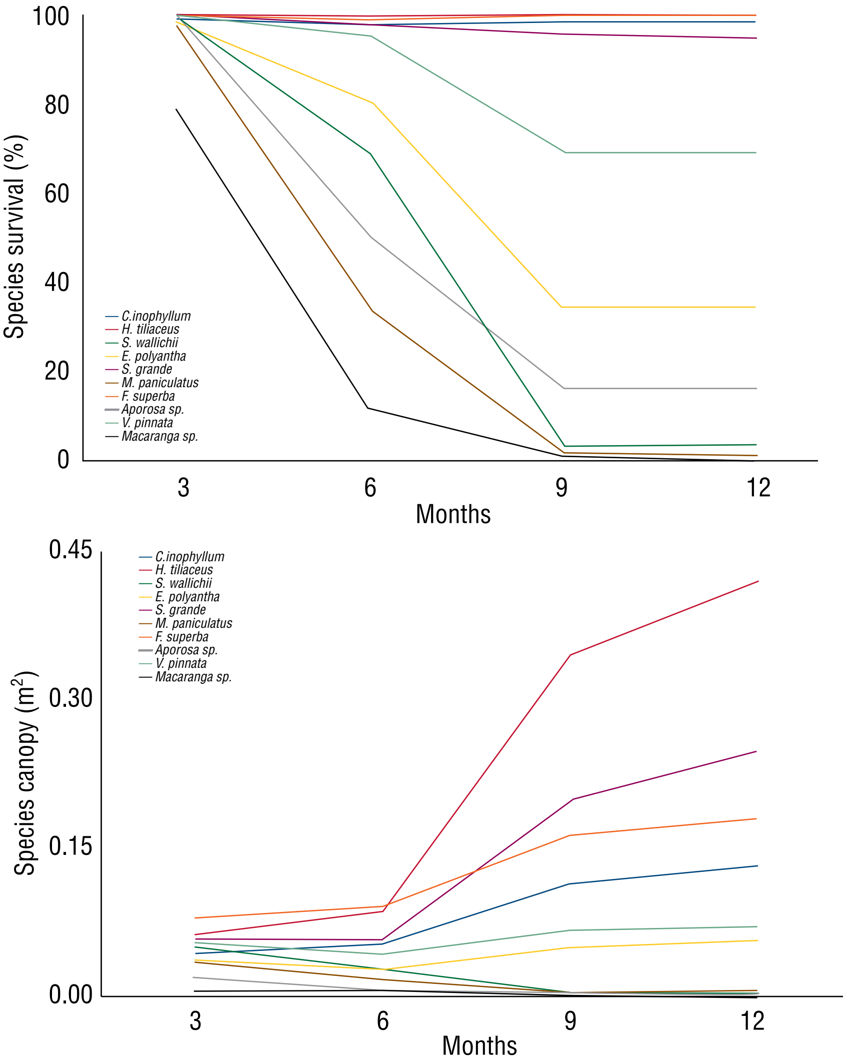
Soil temperature and humidity, inside and outside the coconut shells, was measured at nine months (wet season) and twelve months after planting (dry season). Survival and canopy cover diameter of all individuals in each plot were measured at three, six, nine, and twelve months after planting. Fallen litter in each plot was collected and weighed twelve months after planting. Population density of ants and *Collembola* spp. was determined using pitfall traps (Suhardjono 2004) at three, six, nine, and twelve months after planting. The number of plant species which invaded each plot was determined at the end of the experiment. All data was tested for significance ($p<0.05$) using standard analysis of variance techniques.

Results

The coconut shells significantly reduced soil temperatures near the seedlings in the late dry season (by 4.3°C) and in the wet season (by 2.1°C) in all plots. They significantly increased soil humidity inside the coconut shell in the dry season (by 7.6% – 12.2%) and in the wet season (by 0.8% – 7.8%) in all plots except the controls and those treated with slime tailing powder (Nurtjahya *et al.* 2007c).

There was a significant interaction between planting density and soil treatment on survival rate, plant cover, and litter production. The combination treatment of highest planting

Tailing off: Tin mine tailings are inhospitable to tree regeneration and growth *Photo: E. Nurtjahya*



Hibiscus on top: Average survival and canopy cover at 3–12 months after planting (Nurtjahya *et al.* 2008)

density and LCC plus top soil gave the highest survival rate at 78.7%. The highest planting density and LCC resulted in the highest average canopy cover (31.4 m²). The highest density and LCC treatment also produced the highest litter production (459.7 kg ha^{-1}year^{-1}). LCC supplied a major percentage of litter production with about 90% from *C. mucunoides*.

Survival rates above 90% at the end of the experiment were recorded for *H. tiliaceus* (100%), *F. superba* (99.9%), *C. inophyllum* (99.3%), and *S. grande* (90.2%). The four species with the highest average canopy cover at the end of the experiment were *H. tiliaceus* (0.42 m²), *S. grande* (0.25 m²), *F. superba* (0.18 m²), and *C. inophyllum* (0.13 m²) (see charts). The species with the highest survival rates and canopy cover were the same at three months and at the end of the 12-month study (Nurtjahya *et al.* 2008). The higher survival rates and canopy cover for these four species are explained by their morphological adaptability to environmental conditions, including thicker cuticle and/or suberin. Some adaptations of leaves and roots of these species to environmental stress have been reported (Nurtjahya and Juairiah 2006).

Although the interaction between planting density and soil treatments on ants and collembolan populations was not statistically significant (Nurtjahya *et al.* 2007b), the tendency towards higher ant and collembolan population at higher plant densities may be due to improved microclimate, especially humidity. The collembolan population on the site, which increased from six to nine months and from nine to 12 months (when it averaged 375 individuals/m²), appeared to reflect increasing soil fertility. While ant populations were not a good indicator of restoration on this site (contrary to the findings of Andersen and Sparling 1997), *Collembola* appears to be a good potential bio-indicator for revegetation of tin-mined land (Nurtjahya *et al.* 2007b; Nurtjahya *et al.* 2007d).

There were 41 invading species recorded on plots with a domination of species from Cyperaceae, Melastomataceae, Leguminosae, and Poaceae families. As plots treated with top soil plus legume cover crops showed the highest number of invading species, top soil appeared to be the primary seed source (Zhang *et al.* 2001). Comparing parameters of soil properties, the number of tree species, total number of plant

Greened: Study site shortly after planting (left) and at fourteen months after planting (right) *Photo: E. Nurtjahya* species and plant cover from this experiment to those of natural regeneration on nearby sites shows that regeneration of tin mine tailings can be significantly accelerated by using appropriate native tree species. A tradeoff needs to be made between planting density and cost, however, with higher densities incurring higher costs (revegetation costs at 625 seedlings ha^{-1}, 2500 seedlings ha^{-1} and 10 000 seedlings ha^{-1} are US$1700, 2600, and 5300 ha^{-1} respectively).

Comparing parameters of soil properties, the number of tree species, total number of plant species and plant cover from this experiment to those of natural regeneration on nearby sites shows that regeneration of tin mine tailings can be significantly accelerated by using appropriate native tree species

Conclusion

The highest planting density (10 000 seedlings ha^{-1}) plus treatment with LCC *Calopogonium mucunoides* at 30 kg ha^{-1} gave the highest survival rate (73-79%), highest average canopy cover and highest litter production (460 kg ha^{-1} $year^{-1}$). *H. tiliaceus*, *F. superba*, *C. inophyllum*, and *S. grande* are the most promising of the ten native tree species for revegetating tin-mined lands. Treating plots with legume cover crops and/or top soil showed highly significant effects on recolonization. This study shows that planting appropriate native species and treating with topsoil or legume cover can accelerate succession significantly compared to natural regeneration. Although a planting density of 10 000 seedlings ha^{-1} showed the best performance, lower densities would also show marked improvements over natural regeneration at lower costs.

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