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DRASTIC RECOVERY OF *MELALEUCA*-DOMINANT SCRUB AFTER A SEVERE WILD FIRE: A THREE-YEAR PERIOD STUDY IN A DEGRADED PEAT SWAMP, THAILAND

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Synopsis: The early recovery process of vegetation after a severe wildfire was investigated for three years in a degraded lowland peat swamp in Narathiwat, southern Thailand. At each time of six censuses, fifty quadrats (1 m × 1 m) were set in a burnt site which had been abandoned after a forest reclamation and subjected to major human impacts such as cutting and burning. In August 1997, three months after a severe wildfire that burnt almost all of living plants and peat to about. 25 cm in depth from the ground surface, dense seedlings of *Melaleuca cajuputi* POWELL (mean±SE=52. 7±6. 3 indivs./m²) emerged from the wind-dispersed seeds. Clones of such herbaceous plants as *Blechnum indicum* BURM. f. (mean±SE=0. 7±0. 2 clones/m²) and *Lepironia articulata* (RETZ.) DOMIN. (mean±SE=0. 2±0. 1 clones/m²) also regenerated sparsely from the survived subterranean fragments. Until August 2000, the mean (±SE) height and coverage of vegetation increased sharply (29. 0±7. 7-187. 4±5. 1 cm and 4. 1±1. 1-77. 0±2. 2%, respectively), especially around the rainy seasons, although species composition didn't show clear change (range of mean species density=1. 5-2. 8 spp./m²). Such a recovery pattern was greatly affected by the population development of *M. cajuputi*: *i.e.*, the mean (±SE) maximum height and the mode of the frequency distribution of cover class of the BRAUN-BLANQUET scale for *M. cajuputi* increased 9. 1±2. 1-179. 8±6. 0 cm and 1-4, respectively, and the high density differed scarcely (33. 1±3. 6-73. 8±12. 5 indivs. /m²) for three years. Consequently, a cohort of *M. cajuputi* germinated simultaneously, overcame other species within 1. 5 years and succeeded in the reconstruction of *Melaleuca*-dominant scrub.

Key words: a three-year period study, degraded tropical peat swamp, *Melaleuca cajuputi* POWELL, population development, recovery process, wildfire.

INTRODUCTION

It has been estimated that, by 1990, 24% of the Earth's lowland tropical rain forest had vanished (FAO, 1993), largely due to the agricultural utilization (TURNER & CORLETT, 1996). With regard to the remaining undisturbed vegetation, tropical peat swamps cover an area of 19.9–32.9 × 10^4 km² in Southeast Asia, mainly in sub-coastal locations (RIELEY *et al.*, 1996). Various human impacts such as logging, drainage and burning have also taken place and large areas of the peat swamps have rapidly changed into degraded peatlands (e.g. SUZUKI & HARA, 1995; RIELEY & AHMAD-SHAH, 1996; IMMIRZI *et al.*, 1996).

The tropical lowland peat swamp in its original form is a tight and fragile ecosystem in which pyrite sediment or marine sand lies at the base and acid, oxygen-deficient and nutrient-poor water fills the peat layer (e.g. DENT, 1986; RIELEY *et al.*, 1996; VIJARNSORN, 1996). Therefore, a fair number of attempts at reclamation have resulted in loss of natural resources and degradation of environments, economy and human life. In degraded lowland peat swamps in Thailand that have been subject to prescribed drainage and burning, grasslands, scrubs or open forests usually expand, and typical plants such as *Melaleuca cajuputi* POWELL, *Blechnum indicum* BURM. f., *Lepironia articulata* (RETZ.) DOMIN, *Scleria sumatrensis* RETZ., *Stenochlaena palustris* (BURM. f.) BEDD. and *Lygodium microphyllum* (CAV.) R. BR. typically dominate (SAMATI, 1989; SUZUKI & NIYOMDHAM, 1992; SUZUKI *et al.*, 1992; SUZUKI, 1999).

In the present paper, we report on the early recovery process of vegetation after a severe wildfire in a degraded peat swamp in southern Thailand. The purpose is to clarify when and how do such key species, particularly *M. cajuputi* (a pioneer tree of rapid and dense growth habits), invade and flourish. This basic information is important for the improvement of rehabilitation and management of degraded tropical lowland swamps.

METHODS

Study site

The study was conducted in a degraded peat swamp in Bacho, Narathiwat Province (6°30'22"N, 101°44'42"E). The site is in a back swamp of located approximately 2.5 km inland from the seashore. According to meteorological records at Narathiwat, the annual mean temperature is 27.6℃, annual precipitation is 2560 mm (NAGANO *et al.*, 1996) and the mean number of rain days is 171 (IMMIRZI *et al.*, 1996). This region has two seasons, a moderate dry season (from January to September) and a rainy season (from October to December).

The study site was subjected to wildfire at the end of May 1997, and almost every living plant (including subterranean organs) was killed. It was estimated that the upper peat layer was lost (about 25 cm in a roughly 90 cm thick layer). The previous vegetation was scrub of about 3 m in height and *M. cajuputi, B. indicum, L. articulata* and *S. sumatrensis* densely grew. Water levels changed remarkably along with the progress of seasons. The maximum water level ranged from below −70 cm to 70 cm during the observation period of June 1997 to December 1999 (NAGANO *et al.*; per. com.).

Field measurements

To clarify the establishment process of vegetation and the *M. cajuputi* population after the wildfire, field censuses were carried out at six different times: late August 1997 (AUG97, late dry season), late February 1998 (FEB98, period following rainy season), early August 1998 (AUG98), late January 1999 (JAN99, period following rainy season), late August 1999 (AUG99) and 2000 (AUG00). In each census, we randomly set 50 quadrats (1m×1m) around the study site, and surveyed (1) height and coverage of vegetation, (2) species name, maximum height and cover for each species by the BRAUN-BLANQUET scale (BRAUN-BLANQUET, 1964) for each species and (3) number of individuals (ramets) and flowering performances (including fruiting individuals) for each woody species at each quadrat (Note: on AUG97, some categories were recorded only in 15 quadrats). Notations regarding botanical name were determined in accordance with PHENGKLAI & NIYOMDHAM (1991).

Statistical analysis

To evaluate the vegetation recovery process during

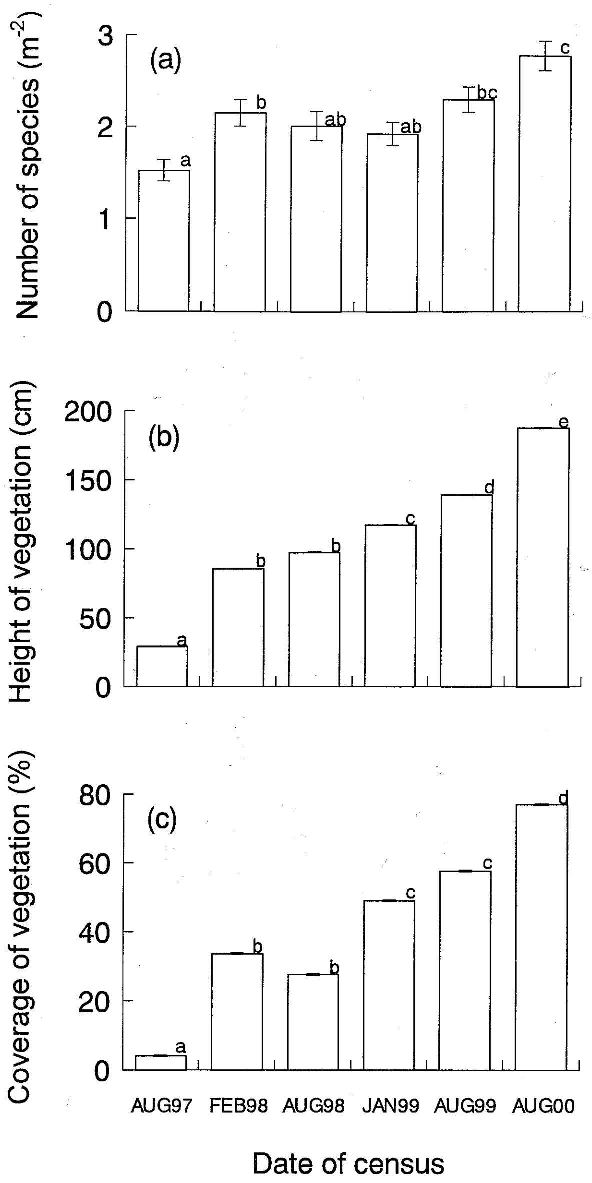

Fig. 1. Comparisons of number of species (a), height of vegetation (b) and coverage of vegetation (c) among field censuses. Different letters indicate a significant difference ($P<0.05$ and $P<0.0033$) by TUKEY-KRAMER HSD after ANOVA for (a) and DUNN's test after KRUSKAL-WALLIS test for (b) and (c), respectively. Data shown are means ±SE. Number of samples are 50 except for AUG97 in (b) and (c). For (b) and (c), number of samples is 15 for only AUG97. See text for abbreviations of date of census.

the three-year period, one-way analyses of variance (ANOVAs) were used to compare number of species, height and coverage of vegetation, and density and maximum height of *M. cajuputi* among the field censuses. The data were square root transformed to meet assumptions of normality. When an overall significant difference was found by ANOVA, comparisons for all pairs were performed using TUKEY-KRAMER HSD test ($P<0.05$). For data measured on an ordinal scale such as cover of each species, or when data do not meet assumptions of normality after transformations, KRUSKAL-WALLIS tests were used. When an overall significant difference was found by the KRUSKAL-WALLIS test, comparisons for all pairs were performed using DUNN's test, in each of which the overall $\alpha=0.05$ was divided by the total number of comparisons.

Statistical analyses were performed using "JMP" (SAS Institute Inc., 1999) for ANOVAs and using "StatView" (SAS Institute Inc., 1998) for KRUSKAL-WALLIS tests.

RESULTS

Early recovery of vegetation

The mean (± SE) number of species in AUG97 was as small as 1.5 (±0.1) m^{-2} and it gradually increased until AUG00, mean±SE = 2.8±0.2 m^{-2} (Fig. 1a, $P<0.05$ after ANOVA $F=8.7$, $P<0.0001$). The overall mean (±SE) number of species throughout the censuses was 2.1 (±0.2) m^{-2}. The dominant species were *M. cajuputi*, *B. indicum*, and *L. articulata*, and *Melastoma malabathricum* LINN., *S. sumatrensis*, *Cyperis procerus* ROTTB. and *Fimbristylis nutans* (RETZ.) VAHL occasionally appeared. The recovered vegetation consisted of a small number of species, the total number of emerged species for the three years was only about 18.

In contrast with minor change in species density, the height and coverage of vegetation clearly increased along with the progress of the seasons (Fig. 1b, $P<0.0033$ after KRUSKAL-WALLIS test $H=193.7$, $P<0.0001$; Fig. 1c, $P<0.0033$ after KRUSKAL-WALLIS test $H=161.9$, $P<0.0001$). In AUG97, the mean (±SE) height and coverage of vegetation was 29.0 (±7.7) cm and 4 (±1) %, respectively ($n=15$; Figs. 1b, c), and those in AUG00 reached 187.4 (±5.1) cm and 77 (±2) %, respectively ($n=50$; Figs. 1 b, c). The expansion of vegetation was comparatively large around the rainy season.

The cover-class of *M. cajuputi*, *B. indicum* and *L. articulata* also increased along with the progress of the seasons, although the population development rate was different among these three dominant

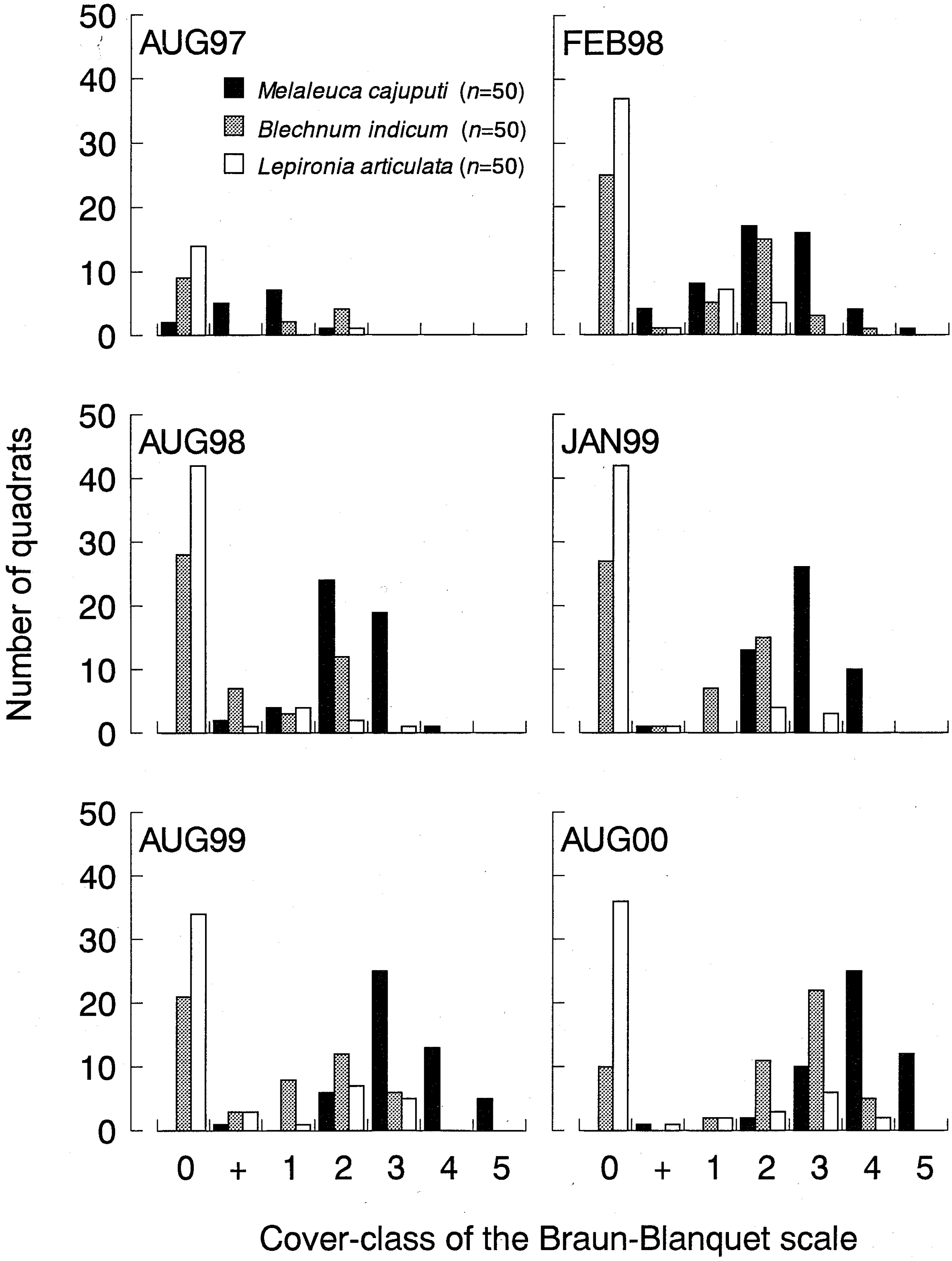

Fig. 2. Comparisons of cover-class among *Melaleuca cajuputi, Blechnum indicum* and *Lepironia articulata* in each field census. Cover-class scale is in accordance with the BRAUN-BLANQUET scale (1964).

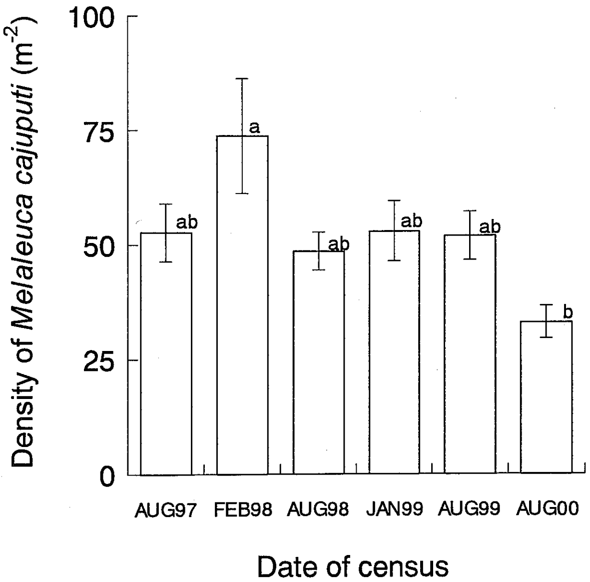

Fig. 3. Comparisons of population density of *Melaleuca cajuputi* among field censuses. Different letters indicate a significant difference ($P<0.0033$) by DUNN's test after KRUSKAL-WALLIS test. Data shown are means±SE. Number of samples are 50 in each field census. See text for abbreviations of date of census.

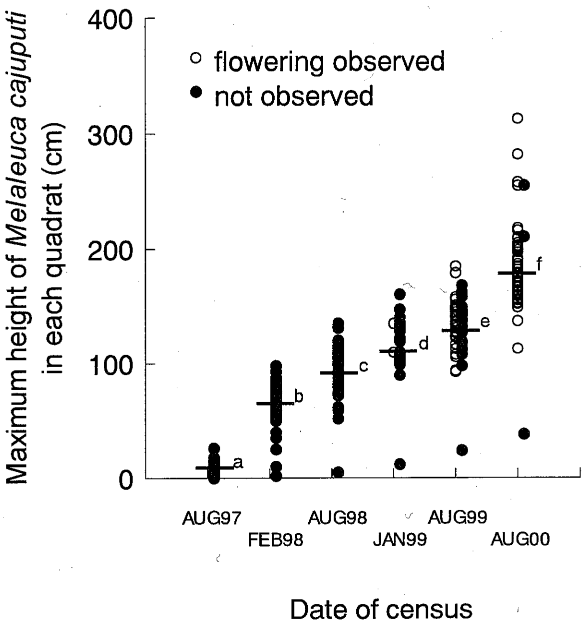

Fig. 4. Comparisons of maximum height of *Melaleuca cajuputi* in each quadrat among field censuses. Different letters indicate a significant difference ($P<0.05$) by TUKEY-KRAMER HSD test after ANOVA. Open and closed circles represent the quadrats where flowering individual is observed and not observed, respectively. Horizontal lines show mean maximum height. Number of samples are 50 for FEB98, AUG98, JAN99, AUG99 and AUG00. Number of samples is 15 for only AUG97. See text for abbreviations of date of census.

species (Fig. 2). In AUG97, the cover-class of each species did not differ among one another (Fig. 2, $P \geqq 0.0167$ after KRUSKAL-WALLIS test $H=11.4$, $P<0.0033$), but *M. cajuputi* soon became the most dominant species and the differences among species increased (Fig. 2). The cover-class of *M. cajuputi* was significantly greater than the other two herbaceous species in FEB98 ($P<0.0167$ after KRUSKAL-WALLIS test $H=65.5$, $P<0.0001$), nine months after the wildfire, and it overcame others from AUG98 ($P<0.0167$ after KRUSKAL-WALLIS test $H=89.5$, $P<0.0001$), JAN99 ($P<0.0167$ after KRUSKAL-WALLIS test $H=95.1$, $P<0.0001$), AUG99 ($P<0.0167$ after KRUSKAL-WALLIS test $H=84.7$, $P<0.0001$) through AUG00 ($P<0.0167$ after KRUSKAL-WALLIS test $H=86.1$, $P<0.0001$). In AUG 00, the cover-class of the three most dominant species differed significantly from each other, in which the greatest one was *M. cajuputi* and the lowest was *L. articulata* (Fig. 2).

Changes in *Melaleuca* population during three-year period

In AUG97, three months after the wildfire, the mean (±SE) population density of *M. cajuputi* was 52.7 (±6.3) indivs./m², and the final one in AUG00 was 33.1 (±3.6) indivs./m² (Fig. 3). The latter was significantly smaller than the mean population density in FEB98 but not significantly smaller than the one in AUG97, AUG98, JAN99 and AUG99 (Fig. 3, $P<0.0033$ after KRUSKAL-WALLIS test $H=12.7$, $P<0.0265$). Moreover, the mean population density of all the field censuses except for the AUG00 also showed no significant differences. The fluctuation of the population density of *M. cajuputi* was small for the three years.

Contrary to the population density, there was a great difference in the mean maximum height of *M. cajuputi* among the field censuses. The mean maximum height in AUG00 was the highest of all (mean±SE=179.8±6.0 cm) and was 20 times larger than the one in AUG97 (Fig. 4, mean±SE = 9.1±2.1 cm), and every pair of the mean maximum height differed significantly (Fig. 4, $P<0.05$ after ANOVA $F=152.4$, $P<0.0001$).

Flowering individuals of *M. cajuputi* were first observed in JAN99, twenty months after the wildfire, and sharply increased corresponding with rapid growth in the height of saplings (Fig. 4).

DISCUSSION

This study illustrated the recovery process of vegetation after a severe wildfire in a degraded peat swamp in Thailand. The study revealed that the recovery was carried out mainly by a *M. cajuputi* population, which was characterized by invasion by seeds and vigorous growth with high density and low mortality of component individuals.

In this study site, the total number of observed species for three years was only about 18; *M. cajuputi, M. malabathricum* as woody plants, *B. indicum* as a fern, and *L. articulata, S. sumatrensis, C. procerus* and *F. nutans* as grasses. Therefore, the species density scarcely increased (three months after the wildfire: range=0–3 spp. m^{-2}, $n=50$; thirty-nine months after the wildfire: range=1–5 spp. m^{-2}, $n=50$; respectively), although the height and coverage of vegetation increased greatly (Fig. 1). These trends were mainly due to the development of the *M. cajuputi* population, resulting from vigorous and dense growth of *M. cajuputi* seedlings in contrast to the other species. Concretely, the cover-class and the maximum height of *M. cajuputi* increased drastically, and *M. cajuputi* succeeded in occupation of the canopy of recovered vegetation, while the high density of population changed scarcely during three-years (Figs. 2–4).

Almost all of individuals of *M. cajuputi* originated from seeds rather than from vegetative propagules. This result is supported by the following observations: 1) severe wildfire burned not only the peat layer (about 25 of the 90 cm-thick layer) but also *M. cajuputi* including subterranean organs, 2) at the first census (three months after the wildfire) most individuals of *M. cajuputi* were small rosettes or erected seedlings with poor root-systems. Therefore, the recovery of vegetation in this study site must depend on both rapid invasion of a large number of *M. cajuputi* seeds and vigorous growth of the seedlings after germination. Seeds of *M. cajuputi* are dusty and are easily dispersed by wind. In addition to these characteristics, periods from establishment to beginning of reproduction are very short as our observation showed. Furthermore, Sasaki *et al.* (1995) demonstrated that the *M. cajuputi* seeds germinated under flooding conditions and did not lose germination capacity even after heating to 100℃ for one hour. Such characteristics may allow this species to invade rapidly into disturbed locations that have been subjected to major human impact such as cutting and burning. In addition, growth of *M. cajuputi* juveniles shows greater increase under conditions such as high soil water content (Sasaki *et al.*, 1995) and the rainy season (Hirabuki *et al.*, unpubl. data). These traits may also allow this species to dominate in this study site. Consequently, in Narathiwat, frequent disturbances by burning and cutting, in combination with the physiological abilities of *M. cajuputi* (such as forward reproduction, high germination capacity and vigorous growth in rainy season) may maintain the *Melaleuca*-dominant scrub.

Knowledge of these traits may be useful for the improvement of rehabilitation of degraded tropical lowland peatlands. At the same time, this species has been used by humans as firewood, as a building material, and for medicinal purposes. The typical characteristics of *M. cajuputi* as a pioneer tree, *i.e.* rapid invasion and domination of disturbed sites and high productivity, may be important factors that make this species is useful to humans.

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