Re-wetted peatland management through selection of native species in Sinarmas Forestry

I Wahno, M Nugraheni, B Herdyantara, A Gafur and B Tjahjono
Sinarmas Forestry Corporate Research and Development, Jalan Raya Minas – Perawang KM 26, Perawang, Riau 28772, Indonesia

*E-mail: budi.tjahyono@sinarmasforestry.com

Abstract. Sinarmas Forestry R&D has initiated studies on development of native species in peatland since 2000. This paper describes progress of the research, especially in the last 5 years, which coincided with the implementation of the Government Regulation 71 of 2014 and in collaboration with Asia Pulp and Paper (APP), Forest Research and Development Agency of KLHK, Gadjah Mada University (UGM), Deltares and Euroconsult Mott MacDonald (EMM).

The main objective was to identify alternative local species apart from *Acacia crassicarpa* as pulp and paper raw materials in peat areas with water table of < 40 cm (rewetted areas). Series of different trials have been established, including progeny and species trials. This paper focuses on the species trials. The trials were conducted in Siak Regency, Riau, in a randomized complete block design with 5 replicates and plot size of 6 x 6 trees. Based on the survival rate and growth data, 4 native trees, i.e. Geronggang (*Cratoxylon arborescens*), Gelam (*Melaleuca leucadendra*), Balangeran (*Shorea balangeran*), and Bush Merah (*Lophostemon suaveolens*) were great potentials as alternatives to *A. crassicarpa*. Propagation procedures of these species, including tissue culture techniques, are currently being explored.

1. Introduction

Of the total plantation areas managed by Sinarmas Forestry – Asia Pulp and Paper (APP), around 67 % is lowland area, whereas the other 33 % is mineral soils. *Acacia crassicarpa* is the most suitable commercial species for plantation forests in lowland, while *Eucalyptus pellita* is currently the main species in mineral soils [1].

The Indonesian Government Regulation 71 of 2014 issued on September 15th, 2014 has pointed out that peat ecosystems functioned as plantation areas are categorized as damaged peats if they meet the following standard criteria [2,3]: (1) Peat ground water level is more than 0.4 m below the surface; (2) Pyrite and/or quartz sediments under the peat layer are exposed. Peat areas that fall within these criteria are prohibited to be functioned as plantation forests.

To anticipate the implementation of the regulation, research on the development of native species was initiated. The ultimate goal of this research was to identify local species as alternatives to *A. crassicarpa* as pulp and paper raw materials in peat areas with water table of < 40 cm (rewetted areas). With the enactment of the Indonesian Government Regulation 71 of 2014 which stipulates that the groundwater level in plantation areas in peat areas (water table) should not be more than 40 cm, establishing *A. crassicarpa* plantation has become increasingly challenging. Therefore, research on the development of native species for peat areas has been prioritized in the last 5 years, marked by the agreement of collaborative research between Sinarmas Forestry and other research institutions. To
achieve the goal, several trial series were established, including species trial, demo plantation, and progeny trial. This paper, however, is focusing on one species trial, NT01BB.

2. Methodology
As mentioned earlier, NT01BB was one of progeny trials aimed to identify local species that could be developed as alternatives to A. crassicarpa. The trial was established in December 2016 and involved Sinarmas Forestry - Asia Pulp and Paper (APP), Forest Research and Development Agency (FORDA-Bogor), Gadjah Mada University (UGM), Euroconsult Mott MacDonald and Deltas. The research area was re-wetted and modified, referring to the provisions of the Indonesian Government Regulation 71 of 2014.

2.1. Trial location
This research was conducted by the Native Species Department, Forest Improvement Division, Sinarmas Forestry Corporate R&D, in the Compartment of BBRE327, Siak District, Riau. Previously, the site was planted with A. crassicarpa in the total area of 23 hectares. The NT01BB trial was established in an area of 2.14 hectares with 100 canal blockings and 4 units of Piel Scales (Figure 1).

![Figure 1. The map of trial location and detailed positions of the canal blockings and Piel scales.](image)

The site was re-wetted after harvesting the wood, bringing the water table up to 40 cm, resembling the provisions of the Indonesian Government Regulation 71 of 2014. The site was divided into 3 zones: Core area (the planted plot area), the zone with water table of between 0 and 25 cm; Inner buffer, the zone with the water table of between 25 and 40 cm; and Outer buffer, the zone with water table of more than 40 cm (Figure 2, left). To adjust the water table to a certain depth, it was required to develop canal blocking and spillway so that each of the zones had the desired water table [3] (Figure 2, right). The water levels in the canals were measured twice a week during the trial were 15 - 64 cm.
2.2. Treatment list
The treatments were arranged in a Split-plot Randomized Complete Block Design (RCBD) with 5 replications and the plot size of 6 x 6 trees with the spacing of 3 x 2 meters. The species tested included *Cratoxylon arborescens* (Geronggang) from 3 plus trees, *Melaleuca leucadendra* (Gelam) from 6 plus trees, *Shorea balangeran* (Balangeran) from 4 plus trees, *Camnosperma coriaceum* (Terentang) from 2 plus trees [3,4], and *A. crassicarpa* as the control treatment (Table 1). All propagation materials were obtained from the seeds, collected in collaboration with the UGM team through joint exploration. Fertilizers, applied at planting time, were CIRP (250 g per plant), NPK (15:15:15, 100 g per plant) and ameliorant (in-house product, 2 kg per plant). Assessment was conducted at the plant ages of 1, 6, 12, 24, 36, and 48 months to observe the tree survival and growth (height and diameter). The tree height was measured within 1 to 48 months of their ages, and the tree diameter was assessed at the plant ages of 36 to 48 months. In the meantime, survival was observed within 2 to 48 months of the ages.

2.3. Calculation and statistical analysis
The survival, height, DBH, and volume, plot survival, and plot volume per hectare were used in the analysis. Volume was estimated differently for *A. crassicarpa* (V-Acr) and for non *A. crassicarpa* (V-Nac) with the following formula [1].

\[ V_{-\text{Acr}} = e^{-10.278} \times D^{1.6726} \left( \frac{H^2}{H-1.3} \right)^{1.3055} \]
\[ V_{-\text{Nac}} = e^{-10.2516} \times D^{1.7243} \left( \frac{H^2}{H-1.3} \right)^{1.2347} \]

where:
- \( e \) = EXP function
- \( V_{-\text{Acr}} \) = Estimated standing tree volume for Acr (m³)
- \( V_{-\text{Nac}} \) = Estimated standing tree volume for non Acr species (m³)
- \( D \) = Tree diameter (cm)
- \( H \) = Tree height (m)

Plot survival was measured as the average of survival for each treatment within replication. Plot volume per hectare (Plot_VolHa) was calculated for each treatment within replication using the following formula.
Plot_VolHa = Plot survival x Plot volume x 1666, in which plot volume is the volume average within replication.

**Table 1.** The list of the tested species and their provenances.

| Treat no. | Species name          | Provenance | Plus tree code |
|-----------|-----------------------|------------|----------------|
| 1         | *Cratoxylon arborescens* 1 | Bukit Batu | CTNBBBD001     |
| 2         | *Cratoxylon arborescens* 2 | Bukit Batu | CTNBBBD002     |
| 3         | *Cratoxylon arborescens* 3 | Bukit Batu | CTNBBBD003     |
| 4         | *Melaleuca leucadendra* 1 | Palembang  | MLCOKI001      |
| 5         | *Melaleuca leucadendra* 2 | Palembang  | MLCOKI002      |
| 6         | *Melaleuca leucadendra* 3 | Palembang  | MLCOKI003      |
| 7         | *Melaleuca leucadendra* 4 | Palembang  | MLCOKI004      |
| 8         | *Melaleuca leucadendra* 5 | Palembang  | MLCOKI005      |
| 9         | *Melaleuca leucadendra* 6 | Palembang  | MLCOKI006      |
| 10        | *Shorea balangeran* 1    | RasauKuning| SBNRSK001      |
| 11        | *Shorea balangeran* 2    | RasauKuning| SBNRSK002      |
| 12        | *Shorea balangeran* 3    | RasauKuning| SBNRSK003      |
| 13        | *Shorea balangeran* 4    | RasauKuning| SBNRSK004      |
| 14        | *Camnosperma coriaceum* 1 | Siak-Zamrut | CMSBBR001    |
| 15        | *Camnosperma coriaceum* 2 | Bengkalis-BBD | CMSBBD001 |
| 16        | *Acacia crassicarpa*     |            | CONTROL        |

Microsoft Excel and Agricole Package in R Statistical Software were used for statistical analysis. To identify significant differences between treatments and between species, Analysis of Variance (ANOVA) was employed (p-value < 0.05), followed with Duncan's Multiple Range Test once significant differences were observed.

### 3. Results and discussion

The results showed that *A. crassicarpa* had the lowest survival rate and continued to decrease from early ages to the latest assessment. The survival of *A. crassicarpa* dropped drastically (39.6%) at 6 months, while the other species survived better (more than 60%) at the same age. This indicated that *A. crassicarpa* could not perform well on peat areas with water table of < 40 cm. At the age of 48 months, the highest survival was achieved by Gelam, with the survival of 80.7%, followed by Balangeran (64.3%), Terentang (41.9%) and Geronggang (39.8%), while the survival of *A. crassicarpa* as the control species was 8.3% at the end of the observation (Figure 3).

Based on growth performance alone, *A. crassicarpa* performed better than the other species tested. However, the survival rate was insubstantial, in which tree volume and plot volume per hectare were among the lowest (Table 2). *S. balangeran*, *M. leucadendra*, and *C. arborescens* were the best three species with the plot volumes per hectare of up to 45.82 m³/ha, 39.77 m³/ha, and 35.01 m³/ha, respectively. The growth performance was significantly different between species, indicating that some species are superior to the others (Table 3, Table 4, Table 5). These results reflect the suitability of each species to the site, which in this study was peat areas with the water table of no more than 40 cm. Nevertheless, the above productivities are not comparable to the productivity of *A. crassicarpa* in peat areas with the water table of 80 cm, which is ca. 120 m³/ha at 48 months.
Figure 3. Survival rates of the species tested from age 2 to 48 months.

Table 2. Survival and growth of each species tested at the age of 48 months, from the highest to the lowest.

| Species                   | SR48 | H48 (m) | D48 (cm) | V48 (m³) | Plot_VolHa (m³/ha) |
|---------------------------|------|---------|----------|----------|-------------------|
| Shorea balangeran        | 0.643| 8.732   | 10.015   | 0.044    | 45.82             |
| Melaleuca leucadendra    | 0.808| 7.828   | 9.639    | 0.030    | 39.77             |
| Cratoxylon arborescens   | 0.398| 8.538   | 13.009   | 0.053    | 35.01             |
| Acacia crassicarpa       | 0.083| 12.593  | 24.227   | 0.232    | 32.25             |
| Camnosperma coriaceum    | 0.422| 6.689   | 9.613    | 0.026    | 18.32             |

Note: SR48 = survival, H48 = tree height, D48 = diameter, V48 = tree volume, Plot_VolHa= plot volume per hectare.

Table 3. Statistical analysis for survival rate at the age of 48 months.

| Source          | SS    | DF | F value | p       |
|-----------------|-------|----|---------|---------|
| Rep.            | 17.887| 4  | 23.924  | 1.713E-19|
| Species         | 129.347| 4  | 173.007 | 6.857E-133|
| Sp. : Treat.    | 10.824| 4  | 14.478  | 1.042E-11|
| Residuals       | 535.874| 2867|        |         |

Table 4. Statistical analysis for tree height at the age of 48 months.

| Source          | SS    | DF | F value | p       |
|-----------------|-------|----|---------|---------|
| Rep.            | 241.638| 4  | 26.397  | 2.884E-21|
| Species         | 851.866| 4  | 93.061  | 1.229E-71|
| Sp. : Treat.    | 2417.021| 4  | 264.044 | 1.298E-176|
| Residuals       | 3892.678| 1701|        |         |
Table 5. Statistical analysis for diameter at the age of 48 months.

| Source        | SS     | DF | F value | p       |
|---------------|--------|----|---------|---------|
| Rep.          | 61.431 | 4  | 2.564   | 3.669E-02 |
| Species       | 4914.353 | 4  | 205.137 | 1.095E-143 |
| Sp.: Treat.   | 1572.588 | 4  | 65.644  | 1.088E-51 |
| Residuals     | 10187.463 | 1701 |         |         |

Research on propagation methods was also carried out for all the species. Besides being propagated generatively (by seeds), vegetative propagation methods (cutting and tissue culture) were also attempted. *M. leucadendra* and *C. arborescens* were successfully propagated by seedlings, cutting and tissue culture. Meanwhile, *S. balangeran* propagation is currently relying on seedlings and cuttings only as tissue culture propagation method for this species is still developed in the Biotech Laboratory of the Sinarmas Forestry Corporate R&D. On the other hand, propagation research of Terentang (*C. coriaceum*) was discontinued due to its inferior growth performance.

Apart from this experiment, Bush Merah (*Lophostemon suaveolens*) was studied separately in the LP03AB trial, established in April 2019. The species shows a comparable survival and growth performance to *S. balangeran, M. leucadendra*, and *C. arborescens* (unpublished data). Therefore, in addition to the other three species, Bush Merah is also considered as a potential alternative species. The species has been successfully propagated, both generatively and vegetatively.

*Gelam* (*M. leucadendra*) is known not only for its excellent performance on degraded peat lands [5], but also considered as one of six commercial species for peat areas [3]. In addition, *Gelam* also continuously produces seeds throughout the year. On the other hand, it is difficult to obtain seeds of *Balangeran* (*S. balangeran*). Flowering and fruiting season does not occur every year. The fruiting season is strongly influenced by local conditions [6]. The seeds, which are recalcitrant, are almost impossible to be stored for a long time. However, its growth and survival rates in peat areas are among the fastest. Therefore, Balangeran is included in the list of alternative species. Among the selected species list, Geronggang (*C. arborescens*) is the most well-studied species for pulpwood plantation in peat areas in Sumatra and Kalimantan [7–9]. A 2018 study reported that Geronggang’s survival percentage was up to 80% at 5.5 years after planting [7]. Another study found that Geronggang has promising growth and yield as its height, diameter and yield increment are relatively comparable to those of *A. crassicarpa* [9]. Meanwhile, information on the performance of Bush Merah (*L. suaveolens*) for pulpwood plantation in peatland areas is not readily available. Its inclusion in the current progeny trial was merely based on the consideration that it belongs to the same family as *Melaleuca*, Myrtaceae. Even though Terentang (*C. coriaceum*) is a well-known native species of Riau [10,11] and among the most dominant species to cover degraded or burned peat forests [10], it is not selected as an alternative species due to its inferior growth performance compared to that of the others.

4. Conclusion
Based on the survival and growth performance in the peat area with the water table of less than 40 cm, as well as the propagation method, four prospective alternative species for *A. crassicarpa* in peat areas are identified. They are *S. balangeran, M. leucadendra, C. arborescens*, and *L. suaveolens*. However, the above productivities are not comparable to the productivity of *A. crassicarpa* in peat areas with the water table of 80 cm, which is ca. 120 m3/ha at 48 months. Further work is continuing for the development of improved seeds and the production of propagation materials of these species.
Acknowledgments
This research was fully funded by Asia Pulp and Paper (APP). The authors wish to thank all team members of the Native Species Department, Biotech Laboratory, Data Science Management Department, Siak District, and all institution partners. Research fellowship granted by the Alexander von Humboldt Foundation of the Government of the Federal Republic of Germany to AG is also gratefully acknowledged.

References
[1] Sinarmas Forestry 2016 Sinarmas Forestry Planning Project Ivory – Phase II Growth and Yield (Jakarta: Margules Groome Consulting Pty Ltd)
[2] Pemerintah Republik Indonesia 2014 PP No. 71 Tahun 2014 tentang Perlindungan dan Pengelolaan Ekosistem Gambut
[3] Giesen W and Sari E N N 2018 Tropical Peatland Restoration Report: The Indonesian Case (Jakarta: Kehijau Berbak)
[4] APP 2017 Tantangan dan peluang uji coba jenis alternatif pengganti akasia di HTI pulp dan paper di lahan gambut Workshop Potensi Bisnis Alternatif di Lahan Gambut (Bogor)
[5] Widiana A, Taufikurahman, Limin S H and Manurung R 2015 The potential of gelam leaves as non-timber product of the trees for reforestation of the degraded peat land in Central Kalimantan–Indonesia Adv. Environ. Biol. 9 13–7
[6] Balai Penelitian Kehutanan Banjarbaru 2012 Budidaya Shorea balangeran di Lahan Gambut ed Suryanto et al (Banjarbaru: Balai Penelitian Kehutanan Banjarbaru - Balitbang Kehutanan - Kmenterian Kehutanan)
[7] Junaedi A 2018 Growth performance of three native tree species for pulpwood plantation in drained peatland of Pelalawan District, Riau Indones. J. For. Res. 5 119–32
[8] Alimah D 2016 Kandungan bahan aktif geronggang (Cratoxylon arborescens (Vahl.) Blume) dan potensi pemanfaatannya Galam 2 33–9
[9] Junaedi A, Danu, Pribadi A, Aprianis Y, Novriyanti E, Sutrisno E, Akbar O T, Daru M, Enggar W and Kurniawan H 2019 Bunga Rampai Geronggang: Jenis Lokal Potensial Bumi Lancang Kuning ed Y Rochmayanto and E Novriyanti (Yogyakarta: Diandra Kreatif)
[10] Qirom M, Halwany W, Rachmanadi D and Tampubolon A P 2019 The study on biophysical peatland landscape in Sebangau National Park: Case in Mangkok Resort J. Ilmu Pertan. Indones. 24 188–200
[11] Nugroho N P 2014 Developing site-specific allometric equations for above-ground biomass estimation in peat swamp forests of Rokan Hilir district, Riau Province, Indonesia Indones. J. For. Res. 1 47–65