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Role of watering interval and media composition on the growth of exotic fast growing species on coal mining soil

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Abstract. Open mining of non-renewable energy from coal in tropical regions causes land degradation, temperature stress, water stress, high acidity, aluminum toxicity, and other poor soil characteristics. Kranji (*Pongamia pinnata*) is an exotic fast-growing species whose tolerance to drought conditions and marginal soils are potential for the revegetation of degraded areas. This research aimed to analyze the effect of coal mining media, watering interval, and their interaction on the growth of kranji seedlings. This research was conducted in October 2015 with a 4-months observations period. The research used a completely randomized factorial design comprising soil media and watering interval. Three soil media treatments comprising secondary forest soil, disposal, and overburden in coal mining media were performed in PT Berau Coal, Berau, East Kalimantan. The watering interval was every 3 and 7 days. Organic pot made from leaf litter was used as basic treatment in this research, and kranji seedlings were obtained from Banyuwangi Protected Forest. The total chlorophyll, height, diameter, shoot dry weight, root dry weight, and top/root ratio parameters were measured. Soil media and watering interval significantly affected the height, shoot dry weight, and top/root ratio of kranji seedlings. The interaction between watering interval and soil media was not significant for all parameters. *P. pinnata* was tolerance to drought and poor nutrient of post-coal mining soil. Exotic fast-growing species of *P. pinnata* is suitable for the rehabilitation of post-coal mining land in tropical regions.

1. Introduction

Tropical ecosystem provides high-value natural resources and is important for the human economy [1]. All stakeholders and beneficiaries recognize the value of ecosystem services, benefits that nature provides to the human economy, and reward responsible custodians of Earth's ecosystems and biodiversity. An over exploitation of the tropical forest ecosystem, including open mining, drastically leads to land degradation and damage [2, 3, 4]. Deforestation at a mining concession area in Indonesia during 2009–2013 was 488,374 hectares or >10% of deforestation in the Indonesian forest [5].



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Remediation effort of the degraded land site was highly required to stimulate the growth of vegetation in the tin mining rehabilitation program [6, 7]. The high net primary production of tropical ecosystem is more influenced by the nutrient cycling rate than by the amounts of nutrient availability in soils [1, 2, 3].

Tropical natural resources have high biomass productivity but less economic value [1, 2]. New paradigm from the extraction to the empowerment of natural resource will provide new challenge to shift from red and green economic concept to blue economic concept that should be more smart, global, focus, and futuristic for sustainable development [1]. The Integrated Bio-cycle System is a closed-to-nature ecosystem on landscape ecological management to manage land resources (soil, mineral, water, air, and microclimate), biological resources (flora, fauna, and humans), and their interaction to have a higher added value in environment, economic, socio-culture, and health [1, 8]. The use of soil ameliorant and organic matters could improve the physical, chemical, mineral, and biological properties of the soil to optimize the supporting capability of the environment for a more dignified life [9, 10].

Indonesia has a total coal mine of 90 million tons located in 15 provinces [11], which causes damage to the local and global environment [3, 8]. Open mines result in vegetation destruction, biodiversity loss, land quality degradation, decreased fertility, heavy metal toxicity, and micro-climate change [3, 6, 8]. Other impacts include the declining quality and quantity of water availability, micro-climate change, and public health concerns around the mine [12]. It is necessary to conduct environmental restoration through land reclamation and revegetation [12]. Revegetation is generally performed by planting cover crops, fast-growing species, and climax plant inserts [13].

Pongamia pinnata (kranji) exhibits tolerance to drought [14]; open post-exposed and high temperatures; saline soil, alkaline, sandy, heavy clay, rocky, and flooded [15] soil; very low pH; and poor nutrients. The use of an organic pot ameliorant on dry, heat, and poor nutrient sand can serve as a compact growing medium, thereby saving water, reducing heat, reducing evaporation, providing sustainable nutrients, improving rooting systems, and enhancing plant growth [1, 7].

2. Material and Methods

This study used soil samples taken from an open coal mine in a tropical ecosystem in PT Berau Coal, East Kalimantan, Indonesia. Plants were allowed to grow under greenhouse condition in Faculty of Forestry Universitas Gadjah Mada (UGM). Soil total-N, available-P, Organic-C, and exchangeable-Al concentration were analysed at the Integrated Laboratory UGM Yogyakarta and SEAMEO BIOTROP Bogor Indonesia. Completely randomized factorial design was used with two treatments, i.e., watering intervals [comprising watering every 3 (S3) and 7 (S7) days] and the type of soil media [comprising secondary forest soil media (M1), soil medium disposal (M2), and soil media overburden (M3)]. Each treatment combination was made in three replications, each comprising two tree-plots, making a total of 36 sample seedlings observed.

The intensity of watering and moisture content was regulated using the gravimetric probe method. A soil analysis was made at before and after treatments to know the inter-effect of treatments and plant growth. Total-aluminium aluminum content in plant tissue was measured at the end of the observation. Chlorophyll (a and b) content was calculated using the Arnon method. Data was analysed using analysis of variance with Tukey's HSD advanced tests in SPSS 16.0 software.

3. Results and Discussions

Soil media disposal and overburden soil have an acid pH, a very high aluminium ion solubility, and a low phosphate availability. The use of zeolite-containing organic pots has been proven to increase the soil pH and improve soil chemical properties in the three types of coal media used, as used by Mutakim [16] on a similar land.

The pH of secondary forest soil media and disposal watered every 3 days drastically increased to near neutral, which is the optimal condition for plant growth. In contrast, the pH in soil disposal and overburden soil with interval watering of every 7 days also increased but remained acidic. This

increase in pH affects the decrease in aluminium content in the three soil types until it reaches zero in secondary and disposal forest media, whereas for the overburden soil media type, although it sharply decreased, its aluminium content remained high. In addition, the increase in pH affects the increased phosphate content available in all three soil types in a very low range. Phosphate content is available on disposal soil (46.3 ppm) and overburden (41.25 ppm) and exceeded the phosphate content available in soil prior to coal mining (31.4 ppm) in [3, 7].

The organic C content decreased in the secondary forest soil media, but increased in the soil media disposal and overburden. The total N content did not significantly change in all three types of soil media, although a tendency to decrease was observed. The decrease of the total N content in the soil media also occurs in *C. pubescens* planting [17].

Table 1. Soil chemical properties at before and after treatments.

No	Parameter	Unit	Before treatment			After treatment					
			M1	M2	M3	M1S3	M2S3	M3S3	M3S7	M2S7	M1S7
1	pH		5.1	3.8	2.5	6.9	6.4	4.2	3.4	5.5	6.9
2	C Org	%	1.88	0.42	1.62	1.84	0.83	2.09	2.03	1.1	1.58
3	N Total	%	0.22	0.11	0.12	0.19	0.1	0.13	0.14	0.11	0.17
5	P ₂ O ₅	ppm	10.4	1.9	9.9	102.9	31.4	47	35.5	61.2	54.8
6	Al-dd	me/100g	0.1	4.5	29.28	0	0	1.66	5.21	0	0

The watering interval has a marked influence on the height, diameter, and dry weight of the crown seedlings. More frequent watering increased the height, diameter, and dry weight of the canopy (Figure 1), as the dissolution and decomposition of organic pots became more intensive to improving soil properties and plant growth. However, the kranji plant under water shortage synthesized chlorophyll by the same amount. The condition of water shortage resulted in a decrease in the dry weight of the canopy / roots, because the kranji plant is tolerant to drought [18].

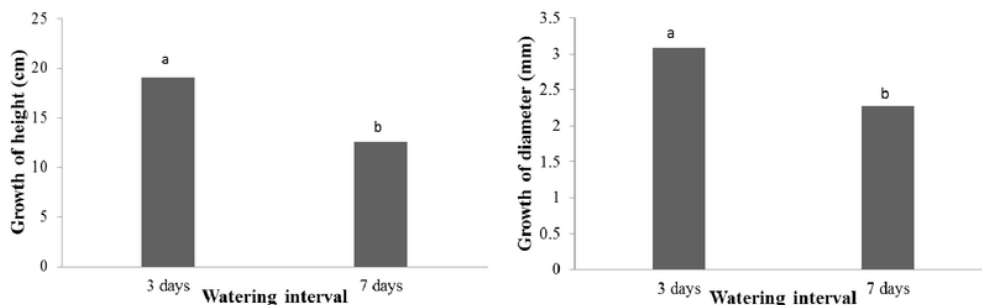


Figure 1. Effect of watering interval on the average height and diameter growth of seedlings. Different letters indicate significant differences between levels.

Although different types of coal mining media have a marked influence on high parameters, dry weight of canopy, and dry weight ratio of canopy / root of kranji seedlings, these media did not significantly affect the total chlorophyll content, diameter, and dry weight of kranji seedling roots. Watering every 7 days resulted in a height increase of 12.55 cm and a diameter of 2.27 mm after three

MST; thus, with more intensive watering, the growth rate increased to approximately 50% at 19.07 cm and 3.09 mm, respectively. The lack of water inhibits high growth, due to turgor pressure drop (19), water flow disturbance from xylem (20), inhibition of mitosis, and enlargement of cells [21]. Prasad et al. [22] and Kirnak et al. [23] have reported that water shortages can inhibit growth. Watering more often allows the decomposition of organic matter and faster dissolution of zeolite derived from organic pots so that nutrients can be exploited by plants.

The growth rate of seedlings planted on soil media disposal was slow because of the low C organic content. C- organic in the former coal mine is a source of N, P, and S, micro elements, and other essential nutrients [24]. Nitrogen triggers plant growth during the vegetative phase, particularly the stems and leaves [25]. Phosphor can increase the plant height because it functions in respiration and plant metabolism [25].

Kranji seedlings grow faster during the 2nd 10th weeks under drought conditions, indicating that these adapt to drought conditions during their early growth. In the 12th week, kranji seedlings that are watered every 3 days begin to grow faster than those that are watered every 7 days. In black seeds, the diameter growth decreases as the drought level increases [26]. The kranji plant adapts to acid soil conditions, and its high aluminium content is poisonous [27]. The kranji seeds in both overburden and disposal soil media showed no symptoms of aluminium poisoning (Figure 2); Orcutt and Nilsen [28] categorized Kranji as an excluder plant that is capable of absorbing metals but limiting concentrations in shoots to critical levels.

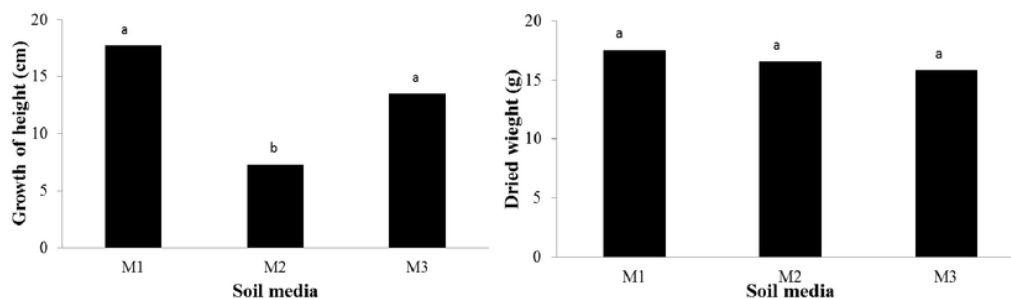


Figure 2. Effects of different types of media on the average height and growth of seedlings. Different letters indicate significant differences between height levels.

The watering interval and type of mining medium had no significant effect on total chlorophyll content (1,175– 1,181 mg / g), which showed the efficiency of photosynthesis and environmental stress [29] as relatively similar. Mensah [30] showed that sesame plant chlorophyll content increased under low water conditions, indicating its tolerance to drought. The study was not in line with Gardner et al.'s study [25] who reported that chlorophyll formation would be hampered by small water potential. The ability of kranji seedlings to form chlorophyll under very acidic conditions and high aluminium content is demonstrated in the mean total chlorophyll content of kranji seedlings in the three media types, which did not significantly differ. Shirbhate and dan Malode [31] also reported that kranji seedlings produce larger amounts of chlorophyll on soil media contaminated by heavy metals.

4. Conclusions

Acidic soil conditions and high aluminium content have no significant effect on chlorophyll synthesis, high growth rate, and dry weight of the kranji seedling root. Factors inhibiting the growth of kranji seedlings are low C organic content, available phosphate, and total N content as shown by a low mean of high increment, dry crown weight, and the amount of root/canopy dry weight ratio in response to

1 poor nutrient soil. More frequent watering intervals increase the average growth rate, dry diameter, and dry weight of canopy crowns significantly through the acceleration of organic matter decomposition and zeolite dissolution in organic pots so that they can be immediately utilized by plants. Longer watering intervals do not inhibit chlorophyll synthesis, and root growth, and minimize the dryness of the crown / root weights, illustrating the adaptation of seedlings to low water conditions. Kranji plants are suitable used as post-industrial revegetation species based on their ability to survive under water stress and on marginal soils with a low pH, high aluminium content, and low nutrients.

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