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The Effect of Nutrient Availability and Water Deficit on *Acacia decurrens* (J. C. Wendl) Willd. Seedling Growth

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Abstract. The 2010 eruption of Mount Merapi acted as a natural scarification agent for *Acacia decurrens* seeds, enabling vigorous germination and dominance. Consequently, *A. decurrens* is considered to possess invasive potential despite its economic uses. This study aimed to assess *A. decurrens* seedlings' response to nutrient availability and water stress through fertilization and watering treatments. The experiment was conducted at Klebengan Greenhouse and Tree Physiology and Forest Soil Laboratory, Faculty of Forestry UGM, using a split-plot design. Watering treatments (main plot) included daily, every 4 and 7 days, while NPK fertilization doses (sub-plot) comprised 0, 1.5, and 3 g, each with five replications. After transplanting, seedlings received intended treatments and were observed for eight weeks. Measured parameters included seedling height, stem diameter, leaf number & color, root and shoot biomass. Data were analyzed using ANOVA and DMRT for mean comparison. The results showed that watering gave no significant effect on seedling height and diameter. However, it significantly affected shoot and root biomass, with the highest observed under daily watering, while no significant differences were found between seedlings watered every 4 and 7 days. These findings indicate that *A. decurrens* are relatively tolerant to drought. Regarding nutrient requirements, the best growth was achieved with 1.5 g of NPK, suggesting that seedlings do not require high nutrient inputs for optimal growth. The observations also found root nodules in seedlings without fertilization, with the highest number of root nodules observed in those with watering treatments of every 4 and 7 days. Thus, although seedling growth tended to decline under stress conditions, *A. decurrens* exhibited growth characteristics similar to those of invasive species, highlighting the need for proper management.

1 Introduction

The eruption of Mount Merapi in 2010 has led to changes in the ecosystem of the area. Before the eruption, the forest stands in Mount Merapi National Park were composed of species such as *Altingia excelsa* (rasamala), *Schima wallichii* (puspa), *Casuarina junghuhniana* (mountain cemara), and *Pinus merkusii* (pine). After the eruption, the forest stands in Mount Merapi

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National Park became dominated by *Acacia decurrens*. Stands of *A. decurrens* developes in areas that experienced severe damage. Areas that suffered severe damage include RPTN Pakem-Turi, RPTN Cangkringan, RPTN Srumbung, RPTN Dukun, RPTN Sawangan, RPTN Selo, and RPTN Kemalang [1]. This species originates from Australia and has successfully taken over the Mount Merapi National Park area, causing a decline in biodiversity in the region [2]. *A. decurrens* was deliberately planted in the Mount Merapi National Park area in the 1980s to meet fuel needs at that time. And based on its utilization as firewood and charcoal, as well as the material of arabic gum, some of the communities plant *A. decurrens* in their fields [2].

The seeds of *A. decurrens* have a hard and thick coat. These seeds can remain stored in the soil, and when exposed to the hot lava from the 2010 Mount Merapi eruption, they undergo scarification [3]. The seeds then germinated quickly and colonize bare soil left after the eruption of Mount Merapi. *Acacia decurrens* can grow well under extreme conditions. After the 2010 eruption of Mount Merapi, the soil around the Mount Merapi National Park area became sandy in texture and acidic in nature. Under these conditions, *A. decurrens* is able to grow well. In contrast, the eruption has caused many other plants to die, leaving the area without vegetation cover, which further supports the growth of *A. decurrens*, a species that requires full sunlight [4].

According to [3], invasive alien plant species (IAS) are able to survive under extreme conditions following disturbances and subsequently dominate the affected areas. The extreme conditions for plants can be in the form of limited water and nutrient availability that do not meet plant requirements. The resilience of IAS to extreme conditions, such as limited nutrient supply and drought, is due to mechanisms known as Nutrient Use Efficiency (NUE) and Water Use Efficiency (WUE) [5]. As the name suggests, NUE refers to a plant's ability to use nutrients efficiently, allowing it to grow and develop under conditions of limited nutrient availability [6]. [7] explain that WUE is a plant's ability to reduce water demand when water availability is limited.

The invasive potential of *A. decurrens* in the Mount Merapi National Park area is evident from its increasing presence and the declining biodiversity in the park following the eruption of Mount Merapi. To determine the extent of *A. decurrens* resilience to environmental stress, a study was conducted on *A. decurrens* seedlings subjected to treatments involving nutrient availability and water stress through fertilization and controlled watering.

2 Material and Method

The tools used in this study included polybags (10 × 12 cm), plastic, white markers, syringes and plastic cups, a ruler, a digital caliper, a Munsell leaf color chart, an oven, an analytical balance, envelopes, tally sheets, stationery, a mobile phone, and a laptop. The materials used included *A. decurrens* seedlings, regosol soil from the Cangkringan area as the planting medium, and NPK fertilizer (16:16:16).

The study was conducted from October 2024 to March 2025 at the Klebengan Nursery Greenhouse and the Tree Physiology and Forest Soil Laboratory, Faculty of Forestry, Universitas Gadjah Mada. The research used a split-plot design, with watering treatment as the main plot and fertilization treatment as the subplot.

There were three levels of watering treatment: S1 (daily), S4 (every 4 days), and S7 (every 7 days), and three levels of NPK fertilization dosage per plant: P0 (no fertilizer), P1 (1.5 g), and P2 (3 g). The level of watering treatments used followed the method done by [8] on an invasive species black locust (*Robinia pseudoacacia*), while the levels of fertilizer applied were based on our other study on *Falcataria falcata*, where the dosage more than 3 g resulted on seedling death (data not given).

Each treatment has five replications, resulting in a total of 45 seedlings observed. Seeds collected from around Mount Merapi National Park were germinated for one month and then transplanted into 10 × 12 cm polybags. The fertilization treatment was completed over 6 weeks, followed by 8 weeks of watering treatment [8] and growth observations. At the end of the observation period, the seedlings were harvested.

The parameters observed included seedling height, seedling diameter, total number of leaves per seedling, leaf color, root biomass, and shoot biomass. Data analysis was performed using ANOVA with R, followed by Duncan's Multiple Range Test (DMRT) for treatments that showed significant differences.

3 Result and Discussion

Based on the final observation results, the survival percentage of *A. decurrens* seedlings reached 100% across all treatment combinations. Seedlings subjected to infrequent watering (every 7 days) were also able to grow well. This is consistent with one of the characteristics of invasive alien species (IAS), which, according to [9], have high tolerance to a wide range of environmental conditions. Although *A. decurrens* exhibits traits similar to IAS, it is still possible that its dominance behavior is similar to that of *A. mangium*. According to observations by [10], the dominance of *A. mangium* is temporary and remains tolerant of local species growing alongside it. This assumption may explain why both species share characteristics with IAS but are not listed as invasive alien species in the Regulation of the Minister of Environment and Forestry No. P. 94 of 2016. Growth data were analyzed using ANOVA, and the results are presented in Table 1.

Table 1. Recapitulation of ANOVA result of effect of fertilizer dosage and watering interval on the growth of *A. decurrens* seedlings

Parameter	Fertilizer (P)	Watering (S)	P x S
Height growth	*	-	-
Stem diameter growth	-	-	-
Primary leaf number	*	-	-
Root biomass	*	*	*
Shoot biomass	*	*	-

Note: The notation (*) indicates that the treatment gave a significant effect on the observed parameter.

Table 1 shows that the fertilization treatment gave a significant effect on almost all growth parameters, except for diameter increment. This may be due to the relatively short observation period (diameter measurements began in week 5 because the stems were still too small to measure at the beginning). According to Lewenussa in [11], diameter of seedlings tends to grow slowly because young plants allocate photosynthetic products more to respiration, leaf replacement, root replacement, and height growth. Only after these needs are fulfilled can diameter growth occur. Furthermore, Duncan's Multiple Range Test (DMRT) was conducted for parameters that showed significant differences, and the results are presented in Table 2.

Table 2. DMRT recapitulation on the effect of fertilizer dosage on *A. decurrens* seedlings' growth

Parameter	Fertilization treatment		
	P0 (0 g)	P1 (1.5 g)	P2 (3 g)
Height growth (cm)	6,21^{b}	13,34^{a}	13,65^{a}
Primary leaf no (blade)	103,33^{b}	170,13^{a}	166^{a}
Root biomass (g)	0,61^{b}	1,51^{a}	0,98^{ab}
Shoot biomass (g)	1,09^{c}	3,52^{a}	2,53^{b}

Note: Different superscript notations within a row indicate a significant difference at the 95% confidence level.

Based on the results of variance analysis (Table 2), the fertilization treatment gave a significant effect on *A. decurrens* seedlings. Among the three fertilization levels, the 3 g dose was the most optimal NPK fertilizer dosage in producing the greatest seedling height of *A. decurrens*, although its value was not significantly different from the 1.5 g dose. Therefore, the appropriate NPK fertilizer dose to support the growth of *A. decurrens* seedlings while maintaining efficiency is 1.5 g. For other growth parameters, the 1.5 g fertilization treatment (P1) produced the highest results and differed significantly from the control seedlings, increasing by 164%, 147%, and 323% for primary leaf number, root biomass, and shoot biomass, respectively. The increase in leaf number is important for photosynthesis, which ultimately results in better growth, as indicated by higher root and shoot biomass.

The ANOVA results in Table 1 were followed by DMRT, and the results for the watering treatment are presented in Table 3. From Table 3, it can be seen that among the three watering levels, seedlings watered daily (S1) had significantly the highest shoot and root biomass. However, there was no significant difference between seedlings watered every 4 days (S4) and every 7 days (S7). These observations indicate that *A. decurrens* seedlings are relatively tolerant to drought stress.

Table 3. DMRT recapitulation on the effect of watering frequency on *A. decurrens* seedlings' growth

Parameter	**Watering treatment**		
	S1 (everyday)	**S4 (every 4 days)**	**S7 (every 7 days)**
Root biomass (g)	1,47^{a}	0,88^{b}	0,75^{b}
Shoot biomass (g)	3,74^{a}	1,59^{b}	1,81^{b}

Note: Different superscript notations within a row indicate a significant difference at the 95% confidence level.

Under drought conditions (watered once every 7 days), the seedlings were still able to grow well, and their shoot biomass was even higher than that of seedlings watered every 4 days (Table 3). This indicates that *A. decurrens* seedlings do not require large amounts of water for growth. It was stated that watering affects plant biomass but does not directly affect height growth; vertical growth such as height increment tends to be more stable than biomass increase, particularly root biomass, in response to watering treatments [12]. Furthermore, [13] stated that adequate water supply can increase dissolved nutrients, allowing them to be utilized effectively by plants. Sufficient nutrient uptake ultimately increases plant biomass.

The interaction between fertilization treatment and watering interval gave a significant effect on root biomass (Table 1), and the results of the DMRT post-hoc test are presented in Figure 1.

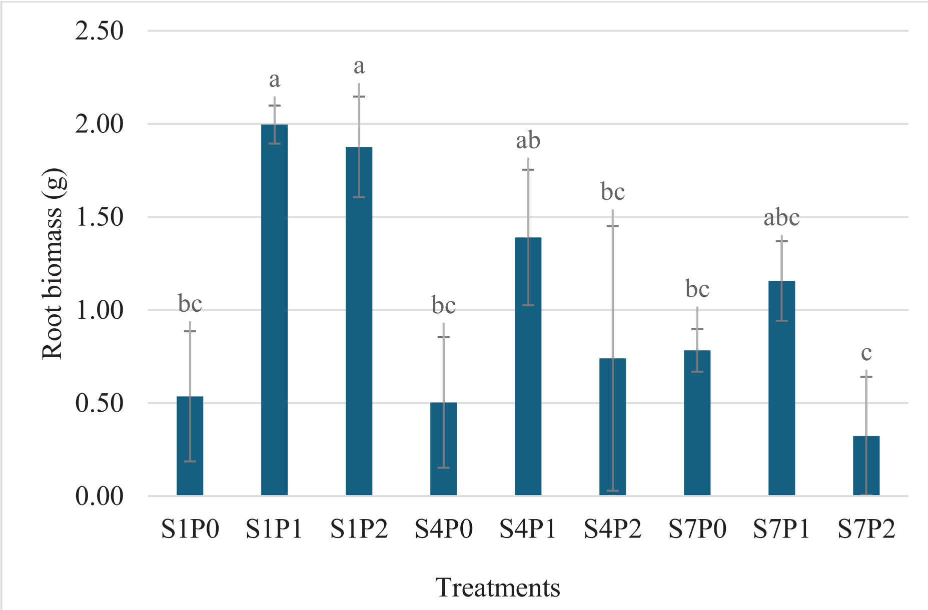


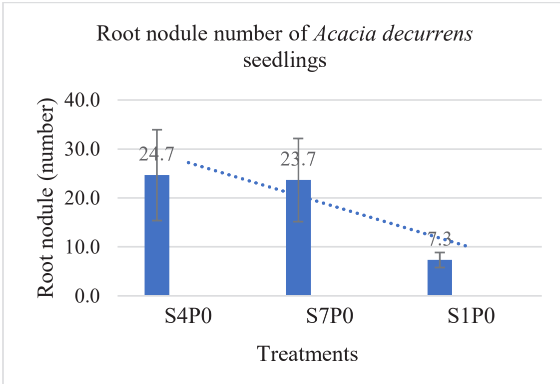
Fig. 1. DMRT results in the interaction effect of fertilizer and watering treatments on root biomass of *Acacia decurrens* seedlings
Note:

- Different letters indicate a significant difference at the 95% confidence level
- Bar = standard of deviation,
- S1, S4, S7 = watering treatments of once in every 1, 4, and 7 days,
- P0, P1, P2 = NPK fertilization dosages of 0, 1,5, and 3 g

From Figure 1, it can be seen that the highest root biomass was obtained under the S1P1 treatment (watered daily with 1.5 g NPK fertilizer), followed by the S1P2, S4P1, and S7P1 treatments, all of which were not significantly different from each other (labeled "a"). This indicates that with appropriate fertilization (P1), *A. decurrens* seedlings become relatively tolerant to water stress (watering every 4 and 7 days).

On the other hand, the lowest root biomass was observed in the S7P2 treatment (watered every 7 days with 3 g NPK fertilizer). According to [13], water acts as a solvent for nutrients that are absorbed by plants. When a high dose of NPK fertilizer is applied without sufficient water availability, the resulting nutrient solution is not adequate to meet plant needs, and the high concentration accumulating around the roots may even have a negative effect on root development.

At the end of the observation period, the seedlings were uprooted to measure root biomass and shoot biomass. Before uprooting for root and shoot biomass measurements, root nodules found on the seedlings were also counted. The results of the root nodule counts in *A. decurrens* seedlings are presented as follows (Figure 2).



(a)

(b)

Fig. 2. (a) Root nodule number of *Acacia decurrens*, (b) Root nodule of *Acacia decurrens* seedling
Note: Bar = standard of deviation, S1, S4, and S7 = watering treatments of once in every 1, 4, and 7 days, P0 = treatment of no fertilizer

The observations found root nodules in seedlings that were not given fertilizer (control seedlings). From Figure 2a, seedlings watered every 4 days (S4) and seedlings watered every 7 days (S7) tended to have a higher number of root nodules. Plant roots (especially legumes) and nitrogen-fixing bacteria *Rhizobium* form a mutualistic symbiosis in the form of root nodules: the plant roots provide compounds needed by the bacteria such as carbohydrates, while the bacteria help supply nitrogen in a form that can be utilized by plant roots. The presence of root nodules in *A. decurrens* seedlings without fertilizer and less water availability indicate the high potential of *A. decurrens* as a species for rehabilitation of marginal lands as it could fix more Nitrogen for its survival. The root nodules found in the sample seedlings are presented in Figure 2b.

The occurrence of root nodules only in control seedlings may be due to fertilizer application inhibiting root hairs from releasing flavonoid compounds that attract rhizobia to infect the root hairs. According to [14], nitrogen fertilizer application, especially at high doses, inhibits the release of flavonoid compounds by plant roots. The study by [14] also shows that plants under nitrogen-deficient conditions stimulate the production of flavonoid compounds. Flavonoids are natural compounds in plants and are widely found in nature.

4 Conclusions

The results of the study show that, in general, the best growth of *A. decurrens* seedlings was obtained from the treatment with 1.5 g NPK fertilization and daily watering. The best treatment combination was S1P1 (daily watering and 1.5 g fertilization), although it was not significantly different from the S4P1 treatment (watering every 4 days and 1.5 g fertilization) and the S7P1 treatment (watering every 7 days and 1.5 g fertilization).

The observations also found root nodules in the control seedlings, with the highest number of root nodules observed in seedlings subjected to watering every 4 days and every 7 days. In general, it can be concluded that *A. decurrens* is relatively tolerant to drought stress and potentially resembles an invasive species. The presence of root nodules in *A. decurrens* seedlings without fertilizer and with limited water availability indicates its potential for use in rehabilitation planting, however due to its potential as an invasive species, its management should be carried out carefully.

References

1. H. Marhaento, Refleksi 5 tahun paska erupsi gunung merapi 2010: menaksir kerugian ekologis di kawasan Taman Nasional Gunung Merapi. Geoplanning: Journal of Geomatics and Planning. **2**(2), 69-81 (2015). https://doi.org/10.14710/geoplanning.3.1.15-22
2. Sutomo, *Acacia decurrens* di sebagian kawasan Taman Nasional Gunung Merapi Yogyakarta. Jurnal Al-Azhar Indonesia Seri Sains dan Teknologi. **5**(1), 38-42 (2019). https://doi.org/10.36722/sst.v5i1.321
3. Sunardi, Sulistijorini, T. Setyawati, Invasion of *Acacia decurrens* Willd. after eruption of Mount Merapi, Indonesia. Biotropia, **24**(1): 35-46 (2017). https://doi.org/10.11598/btb.2017.24.1.524
4. H Gunawan, N.M. Heriyanto, E. Subiandono E, A.F. Mas'ud, H. Krisnawati, Invasi jenis eksotis pada areal terdegradasi pasca erupsi di Taman Nasional Gunung Merapi. In Pros Sem Nas Masy Biodiv Indon. **1**(5), 1027-1033 (2015).
5. J.L Funk,The physiology of invasive plants in low resource environments. Conservation Physiology. **1**(1) (2013). https://doi.org/10.1093/conphys/cot026
6. C.A. Rosolem, S. Husted, Nutrient use efficiency: science to field practice. Plant Soil. **496**, 1–6 (2024). https://doi.org/10.1007/s11104-024-06533-w
7. W Zhao, L Liu, Q Shen, J. Yang, X. Han, F. Tian, J. Wu, Effects of water stress on photosynthesis, yield, and water use efficiency in winter wheat. Water. **12**(8)-2127: 1-19 (2020). https://doi.org/10.3390/w12082127
8. N. Anggraini, E. Faridah, S. Indrioko, Pengaruh cekaman kekeringan terhadap perilaku *fisiologis* dan pertumbuhan bibit *black locust* (*Robinia pseudoacacia*). Jurnal Ilmu Kehutanan. **9**(1): 40-56 (2015). https://doi.org/10.22146/jik.10183
9. S. Yunita, K. Lekitoo, Tumbuhan asing invasif di areal Kesatuan Pengelolaan Hutan Lindung (KPHL) Kota Sorong, Papua Barat. In Pros Sem Nas Masy Biodiv Indon. **4**(1): 92-96 (2018).
10. Sutedjo, Warsudi, Menakar sifat invasif spesies akasia mangium (*Acacia mangium* Willd.) di Hutan Penelitian dan Pendidikan Bukit Soeharto. Ulin: Jurnal Hutan Tropis. **1**(1): 82-89 (2017). http://dx.doi.org/10.32522/ujht.v1i1.795
11. M.V. Bima, W. Seran, A.E. Mau, Pengaruh berbagai konsentrasi pupuk organik cair (POC) urin sapi terhadap pertumbuhan semai kayu putih (*Melaleuca leucadendra*). Jurnal Wana Lestari. **2**(2): 201-211 (2020).
12. A. Fahn, Plant Anatomy. 3rd edition. ISBN 0–08–0280293, (Pergamon, Oxford. 545p. 1982).
13. S.G. Pallardy, Physiology of Woody Plants. (Academic Press, San Diego, 454p, 2008).
14. S. Bag, A. Mondal, A. Majumder, S.K. Mondal, A. Banik, Flavonoid mediated selective cross-talk between plants and beneficial soil microbiome. Phytochem Rev. **21**(5): 1739-1760, (2022). https://doi.org/10.1007/s11101-022-09806-3