Enhancing green open spaces while conserving local genetic resources: Evaluating growth performance of five native tree species

F G Dwiyanti, H H Rachmat, A Susilowati, I Z Siregar and K S Yulita

1Departement of Silviculture, Faculty of Forestry and Environment, Institut Pertanian Bogor (IPB University), Jl. Ulin, IPB Dramaga Campus, Dramaga Bogor, West Java, 16680, Indonesia,
2Forest Research and Development Center, Ministry of Environment and Forestry. Jl. Raya Gunung Batu No.5, Bogor, West Java, 16119, Indonesia
3Faculty of Forestry, Universitas Sumatera Utara. Jl. Tri Dharma Ujung No. 1, Kampus USU, Medan, North Sumatra, 20155, Indonesia.
4Research Centre for Biology, Indonesian Science Institute, Cibinong Science Center, Cibinong, 16911, Indonesia.

E-mail: fifi_dwiyanti@apps.ipb.ac.id

Abstract. Enhancing green open spaces in cities and their buffer areas has gained increasing recognition. While creating a more sustainable, liveable, and comfortable environment, green spaces could also provide an effort for plant domestication and conservation. We consider the potential urban greening and conservation action by planting five tree species consisting of one highly valuable and slow-growing species Eusideroxylon zwageri trees from four different origins and four fast-growing species of Duabanga moluccana, Anthocephalus macrophyllus, Duabanga grandifolia, and kayu papaya at the water reserve in suburban Ciherang-Bogor. Growth performance on mortality rate and the average height of the 4.5-year-old planted seedlings were observed to evaluate the adaptability and suitability of the species in the area. The results of mortality rate revealed that E. zwageri seedlings were ranged from 35% (from South Kalimantan) to 50% (from Jambi), while the four fast-growing species were ranged from 14% (Kayu papaya) to 83% (Duabanga moluccana) indicated that the mortality rate for the five species of seedlings planted varied. Whereas, the results of average height showed that E. zwageri seedlings were ranged from 196.15 cm (South Kalimantan) to 332.50 cm (Natuna), and four fast-growing species was ranged from 582.35 cm (Duabanga grandiflora) to 1411.10 cm (Anthocephalus macrophyllus) indicated that planting fast-growing trees in the suburban area is suitable to increase land coverage in a relatively short time, while slow-growing species are more suitable for species preservation purposes.

1. Introduction

Green Open Space (GOS) is an elongated area or lane or cluster that is used openly and predominantly covered by naturally and intentionally planted vegetation, with an area of at least 30% of the urban area [1]. Generally, green spaces in the urban and suburban areas include natural areas, parks, community
garden, playgrounds, street trees, yards, and rural areas typically include agricultural areas, wetlands, forests, and nature reserves [2]. In Indonesia, the development of green open space itself can be through (i) urban forest development and urban forest greening programs, (ii) development of industrial estates by considering ecological aspects, (iii) development of industrial estates with the existence of a green belt as a buffer between regional functions, (iv) the formation of clusters settlement clusters to avoid the build-up and integration of settlement areas, and between settlement clusters, green open spaces are provided, (v) arrangement of High Voltage Air Ducts (SUTT) and Extra-High-Voltage Air Ducts (SUTET) by maintaining their lines as green lines, (vi) zoning for river borders and areas around lakes or reservoirs for green open space; and (vii) zoning of the watershed for green open spaces and the use of floodplains for green open spaces [3].

The importance of green space in Indonesian cities has been recognized since the increasing awareness of government and community that this green open space provides a strategy to make these cities more sustainable, more liveable, and more equitable, which is indicated by the development of trends in environmentally friendly concepts that apply the principles of green design and construction in property development. Architecture, contractors, and developers try to design, build and develop buildings or housing that meet green regulations in the hope of changing basic lifestyles that care for the environment and save our planet [4]. This is certainly because the vegetation patches in and around the urban, suburban and rural areas play a key role in the provision of ecosystem services such as natural filters, carbon sequestration, nutrient cycling, air, and water purification, noise absorbers, runoff mitigation, food supply, wildlife habitat, and temperature regulation [5, 6, 7, 8] that are of significance in providing the protection and conservation of biodiversity, nature and the natural processes [9]. In addition, green spaces also fulfill the psychological, social, and cultural needs of city residents [10].

The water reserve in suburb Ciherang-Bogor is an important buffer suburb area for nearby highly populated cities such as Jakarta, Bogor, and Sukabumi. The role of green space in this area is significant in maintaining the sustainability of the ecosystem services and conserving biodiversity. However, the existence of green open space in this area is decreasing every year as a result of rapid development and population growth. Thus, the increase in vegetation cover must be maximized through intensive planting with the optimization of an office or factory landscape or public place where green open spaces are made as "forest enclaves" to neutralize the quality of the environment. Efforts to increase vegetation cover have been carried out along the water reserve in suburb Ciherang-Bogor since 2016 by planting five tree species consisting of the highly valuable ironwood trees (Eusideroxylon zwageri) from four different localities and four fast-growing species of Duabanga moluccana, Anthocephalus macrophyllus, Duabanga grandifolia and Kayu Papaya from various locations, but the success of this planting has not yet been measured. Therefore, the present study aims to assess the growth performance, such as survival rate and tree height of the 4.5-year-old planted trees, to evaluate the adaptability and suitability of the species in the area.

2. Materials and method

2.1. Materials

The planting area was located behind a private company area designated as a water catchment area in the suburb of Ciherang-Bogor in West Java province, Indonesia (figure 1). Geographically, the plantation area was located at 6°41'49.6"S - 106°50'26.2" E. Planting has been carried out since 2016 using five species of Indonesian tree seedlings include one highly valuable and slow-growing species, Eusideroxylon zwageri or locally known as ironwood (ulin) (figure 2), which was collected from Natuna Island, Jambi, South Kalimantan, and West Kalimantan and four fast-growing species from various locations such as Duabanga moluccana (binuang laki), Anthocephalus macrophyllus (red jabon), Duabanga grandifolia (binuang laki), and Kayu Papaya (figure 2).
2.2. Method

Seedlings of *Eusideroxylon zwageri* were planted with five replications, which each replica consisting of 4 seedlings, while seedlings of each of 4 fast-growing species were planted with four replications, which each replica consisting of 9 seedlings (table 1). In total, 216 seedlings were planted, with the planting distance applied between individual seedlings for all species was uniform (4 m x 4 m). The growth parameters were measured for each species in 2016, 2017, and 2019, including (i) mortality rate, which is calculated by the number of dead seedlings divided by the total number of seedlings when planted, and (ii) seedling total height. The growth performance analysis, including the Duncan multiple range test at a significance level of *P*-value < 0.05, was then performed using SPSS software [11].

![Figure 1](image)

**Figure 1.** Map of plantation area in the suburb of Ciherang-Bogor. (a) Suburb Ciherang-Bogor location on the map of Java Island indicated by a red pin. (b) Plantation plot position on suburb Ciherang-Bogor area indicated by a red pin, and (c) Planting plot (inside the white line) with the coordinates of each plot angles indicated by blue pins.

| Species Growth Rate | Species          | Origin                    | No. of Individual | No. of Replication | Total No. of Individual |
|---------------------|------------------|----------------------------|-------------------|---------------------|------------------------|
| Slow-growing        | *Eusideroxylon zwageri* | South Kalimantan           | 4                 | 5                   | 20                     |
|                     |                   | Natuna                    | 4                 | 5                   | 20                     |
|                     |                   | West Kalimantan           | 4                 | 5                   | 20                     |
|                     |                   | Jambi                     | 4                 | 3                   | 12                     |
| Fast-growing        | *Duabanga moluccana* | Cileungsi-Bogor           | 9                 | 4                   | 36                     |
| Fast-growing        | Kayu Papaya      | Buru Island-Maluku Archipelago | 9     | 4                   | 36                     |
| Fast-growing        | *Duabanga grandiflora* | Cileungsi-Bogor           | 9                 | 4                   | 36                     |
| Fast-growing        | *Anthocephalus macrophytus* | Dramaga-Bogor            | 9                 | 4                   | 36                     |
| TOTAL               |                  |                            |                   |                     | 216                    |
Figure 2. The condition of the seedlings of the species studied in 2019. (a) Eusideroxylon zwageri, (b) Anthocephalus macrophyllus, (c) Duabanga moluccana and Duabanga grandiflora, and (d) Kayu Papaya.

3. Result and discussion

3.1. Growth performance of Eusideroxylon zwageri seedling

In the present study, the mortality rate of 4.5-year-old Eusideroxylon zwageri based on four origins were ranged from 35 % to 50 % (figure 3), with the highest showed by seedlings from Jambi (50%) and the lowest showed by seedlings from South Kalimantan (35%) indicated that seedlings from Jambi have low survivability and seedlings from South Kalimantan have high survivability. This result suggested that the E. zwageri seedlings from South Kalimantan were more adaptable when planted in the surrounding water reserve in the suburb Ciherang-Bogor compare to other origins.

In the natural distribution, E. zwageri trees are mostly distributed on areas along rivers and adjacent hills where the soil consists of loamy sand or pure sand [12]. Therefore, the planting location of E. zwageri seedlings in the suburb of Ciherang-Bogor was appropriate considering the location is a water catchment area. In addition, E. zwageri is a shade-tolerant species when immature, whereby gradual sun exposure does not harm the seedlings and may instead support seedling growth [13]. While direct full sunlight exposure will cause the seedling to die [13]. However, E. zwageri seedlings were first planted in open areas in the suburb of Ciherang-Bogor, which may cause high seedling mortality.

Figure 3. Eusideroxylon zwageri seedling mortality rate (%) from four origins.
Besides the mortality rate, the growth performance of 4.5-year-old *E. zwageri* seedlings planted in the suburb of Cihang-Bogor was also indicated by the average seedling height. The present study results showed that the average of *E. zwageri* seedling height in 2019 measurement data was ranged from 196.15 cm to 332.50 cm (table 2), with the highest showed by the seedling from Natuna and the lowest from South Kalimantan. The pattern of this study is slightly similar to the results of the 5.5-year-old *E. zwageri* growth study in the progeny test in Bondowoso (East Java). The pattern of this study was slightly similar to the results of the 5.5-year-old *E. zwageri* growth study in the progeny test in Bondowoso (East Java), which also showed that *E. zwageri* families from the North Kalimantan and East Kalimantan have a poor height growth [14].

| Table 2. The average height of *Eusideroxylon zwageri* seedling. |
|---------------------------------------------------------------|
| **Origin** | **Average Height (cm) in Each Measurement Year** |
| South Kalimantan | 76.55 | 101.55 | 196.15 |
| Natuna | 127.10 | 168.95 | 332.50 |
| West Kalimantan | 70.90 | 94.05 | 259.23 |
| Jambi | 41.17 | 70.27 | 233.33 |

However, the analysis of the effect of seedlings origin on the growth of seedling height in *E. zwageri* showed no significance from zero with a *P*-value of 0.870 (table 3), indicated that no relationship between *E. zwageri* seedling height with origin using current data. This is possible because the age of the seedlings is still young, so that the height growth of the seedlings from the four origins was still not stable [14]. In addition, considering that *E. zwageri* has a long-life cycle and slow growth [14,15,16,17], the quantitative value of the current seedling growth rate may change along with the growth and development of seedlings [14].

| Table 3. Effect of seedling origin on the growth of *Eusideroxylon zwageri* seedling height. |
|---------------------------------------------------------------|
| **Parameter** | **Average** | **P-value** |
| Seedling origin | 1248.214 | 0.870 > 0.05 |

3.2. Growth performance of seedling of four fast-growing species

In this study, the growth rate of 4.5-year-old of four fast-growing species planted in suburb Cihang-Bogor was indicated by the mortality rate and average seedling height. The mortality rate of four fast-growing species was ranged from 14 % to 83 % (figure 4), with the highest showed by *Duabanga moluccana* seedlings (83%), follows by *Anthocepalus macrophylus* (50%) and *Duabanga grandiflora* (47%), while the lowest showed by Kayu Papaya seedling (14%) indicated that *Duabanga moluccana* seedlings have low survivability and Kayu Papaya seedlings have high survivability. The high seedling mortality of *D. moluccana* might be due to the influence of competition with grass or other plants for nutrients [18]. Besides that, as a fast-growing species, the crown of this *D. moluccana* seedlings are dense at the age of three years, so thinning is necessary with an ideal spacing of 6 cm x 6 cm [18]. Therefore, this thinning program is recommended to be applied in the future, and evaluation of seedling growth after thinning is also expected to be carried out in order to obtain data on the effect of this thinning on the survival rate of *D. moluccana*. However, with the current data, the study revealed that the Kayu Papaya seedlings were more adaptable when planted in the surrounding water reserve in the suburb Cihang-Bogor compared to other species, making this Kayu Papaya a recommended plant to be planted in this area for the future expanding planting area.

Although the mortality rate of seedlings in these four species varied from low to high, the surviving seedlings showed normal height growth, as shown in the result of the average seedling height analysis (table 4). The analysis of average seedling height showed that the average of four fast-growing seedlings
highest in 2019 measurement data was ranged from 544.74 cm to 1411.11 cm (table 4), with the highest showed by *Anthocephalus macrophyllus* seedling and the lowest showed by *Duabanga grandiflora* indicated that *A. macrophyllus* has a faster growth rate in terms of height than other species. This results pattern was possible given that *A. macrophyllus* is a fast-growing species with a wide range of growth environments and adaptability, meaning that the tree can grow well in different land conditions such as marginal land or waterlogging land [19, 20, 21]. The average height of 4.5-year-old *A. macrophyllus* in the present study is also in line with the results of other studies, which reported that *A. macrophyllus* could reach 5.9 m to 7.3 m at the age of 2 years [20] and could reach a height of 18 m at the age of 6 years with good cultivation conditions [22].

![Figure 4. Mortality rates (%) of four fast-growing species in the suburb of Ciherang-Bogor.](image)

**Table 4.** The average height of four fast-growing seedlings.

| Species Name              | Average Height (cm) in Each Measurement Year |
|---------------------------|----------------------------------------------|
|                           | 2016  | 2017  | 2019       |
| *Anthocephalus macrophyllus* | 44.96 | 261.82 | 1411.11   |
| Kayu Papaya               | 106.67| 183.74| 857.10     |
| *Duabanga grandiflora*   | 59.69 | 128.85| 544.74     |
| *Duabanga molucana*      | 30.95 | 208.78| 900.00     |

In addition, the analysis of the effect of four fast-growing species on seedling height growth showed significance from zero with a *P*-value of 0.017 (table 5), indicated that there was a relationship between species and seedling height using current data. This is also supported by the result of Duncan’s test analysis, which showed that the seedling species had a significant effect on the average seedling height (table 6).

**Table 5.** The effect of various fast-growing species on seedling height growth.

| Parameter              | Average     | *P*-Value |
|------------------------|-------------|-----------|
| Fast-growing species   | 296036.96   | 0.017 < 0.05 |
Table 6. Duncan’s test analysis on fast-growing species on the seedling height growth.

| Species Name                  | Seedling Height Growth* |
|-------------------------------|-------------------------|
| Anthocephalus macrophyllus    | 682.862a                |
| Kayu Papaya                  | 643.055a                |
| Duabanga grandiflora         | 254.472b                |
| Duabanga moluccana           | 143.835b                |

*Values followed by the same letter are not significantly different (p < 0.05) by Duncan's multiple range test.

4. Conclusion

In this study, evaluation of the 4.5-year-old seedling growth performance of one slow-growing species (*Eusideroxylon zwageri*) and four fast-growing species (*Duabanga moluccana, Anthocephalus macrophyllus, Duabanga grandiflora,* and *Kayu Papaya*) planted in the suburban of Cihang-Bogor in terms of the mortality rate was revealed that *E. zwageri* seedling mortality rate was ranged from 35% (from South Kalimantan) to 50% (from Jambi), while the seedling mortality rate of the four fast-growing species was ranged from 14% (Kayu papaya) to 83% (*Duabanga moluccana*). These results indicated that the mortality rate for the five species of seedlings planted varied. In addition, the slow-growing species did not always have a higher mortality rate than the fast-growing species because the success of a seedling to live and grow depends on the preference of biotic and abiotic factors of each species. In terms of average height, the range of *E. zwageri* seedlings was from 196.15 cm (South Kalimantan) to 332.50 cm (Natuna) and the range for four fast-growing species was from 582.35 cm (*Duabanga grandiflora*) to 1411.10 cm (*Anthocephalus macrophyllus*) indicated that planting fast-growing trees in the suburban area is suitable to increase land coverage in a relatively short time, while for slow-growing, it is more suitable for species preservation purposes.

5. References

[1] Minister of Forestry of the Republic of Indonesia 2009 Regulation of the Minister of Forestry of the Republic of Indonesia No: P.71/Menhut-II/2009 concerning Guidelines for Managing City Forests (Jakarta, Indonesia: Minister of Law and Human Right of the Republic of Indonesia) [in Indonesian]

[2] Morisson K 2017 Leveraging the Benefits of Green Space for Environmental and Public Health Benefits A casebook of Ontario Initiatives

[3] Gunawan H and Sugiarti 2015 The role of Lido Biodiversity Park, Sukabumi as a green space and conservation area of flora-fauna in urban environment Pros Sem Nas Masy Biodiv Indon 1 (8) 1828–1835 [in Indonesian]

[4] Anastasia N 2013 The Way to Encourage Green Building in Indonesia sRES International Conference (Kyoto-Japan) 1-14

[5] Gómez-Baggethun E, Gren Å, Barton DN, Langemeyer J, McPhearson T, O’Farrell P, Andersson E, Hamstead Z and Kremer P 2013 Urban Ecosystem Services, in Elmqvist T, Fragkias M, Goodness J, Güneralp B and Marcotullio, P J (eds), Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities: A Global Assessment, (Netherlands: Springer) 175–251

[6] Pincetl S, Prabhu S S, Gillespie T W, Jenerette G D and Pataki D E 2013 The evolution of tree nursery offerings in Los Angeles County over the last 110 years Landscape and Urban Planning 118 10–17

[7] Ahern J, Cilliers S S and Niemelä J 2014 The concept of ecosystem services in adaptive urban planning and design: A framework for supporting innovation Landscape and Urban Planning 125 254–259
[8] Aronson M F J, Piana M R, MacIvor J S and Pregitzer C C 2017 *Management of Plant Diversity in Urban Green Spaces* In Ossola A and Niemelä J (eds), Urban Biodiversity from Research to Practice (Routledge, London) 101-120

[9] Bolund R and Hunhammar S 1999 Ecosystem services in urban areas *Ecological Economics* 29 293–301

[10] Patarkalashvili T K 2017 Urban forests and green spaces of Tbilisi and ecological problems of the city *Annals of Agrarian Science* 15 187–191

[11] IBM Corp. 2020 IBM SPSS Statistics for Windows, Version 27.0. (Armonk, NY: IBM Corp.)

[12] Gresser E 1919 Bijdragen resumeerend repport over het voorkomen van ijzerhout op de olieterreinen Djambi I *Tectona* 12 283–304

[13] Soedibja R S 1952 Penyelidikan tentang tumbuh dan ekologi kaju besi (*Eusideroxylon zwageri* T. et B.) di lingkungan hutan Semandai (Palembang) *Rimba Indonesia* 1(5) 215–223 [in Indonesia]

[14] Prastyono and Susanto M 2015 Variation in growth traits of ironwood (*Eusideroxylon zwageri* T. ET B.) progeny trial in Bondowoso *Journal Wisiarn* 2 (2) 79–86 [in Indonesian]

[15] Soerianegara I and Lemmens R H M 1994 *Timber Trees: Major Commercial Timbers* PROSEA, Bogor

[16] Efendi R 2006 *Teknik Silvikultur Ulin* Pusat Penelitian dan Pengembangan Hutan Tanaman dan Tropenbos Internasional Indonesia [in Indonesian]

[17] Junaidah A W, Nugroho H, Siahaan and Sofyan A 2006 Status Penelitian dan Pengembangan Ulin (*Eusideroxylon zwageri* T et B.) di Sumatera Bagian Selatan dalam Peran Lihatbang Dalam Pelestarian Ulin Pusat Penelitian dan Pengembangan Hutan Tanaman dan Tropenbos Internasional Indonesia [in Indonesian]

[18] Surata I K 2007 Plantation trial of duabanga (*Duabanga moluccana* Blume) on intercropping system at Rarung, West Nusa Tenggara Province *Jurnal Penelitian Hutan dan Konservasi Alam* 4 (4) 365–376

[19] Surip, Indrioko S, Nirsatmanto A and Setyaji T 2017 Effect of selection on genetic gain of first-generation seedling seed orchards of jabon merah (*Anthocephalus macrophyllus* (Roxb.) Havil) established in Wonogiri *Jurnal Pemuliaan Tanaman* 11 (1) 33–44 [in Indonesian]

[20] A’ida N, Muhlis, Larekeng S H, Arsyad M A, Putra R P, Musriati and Restu M 2019 Progeny test on plant growth of 2-year-old jabon merah (*Anthocephalus macrophyllus* Roxb. Havil.) in Gowa, South Sulawesi, Indonesia: Preliminary study *IOP Conf. Series: Earth and Environmental Science* 270 012020

[21] Yulianti and Sudrajat D J 2016 Morphological responses, sensitivity and tolerance indices of four tropical trees species to drought and waterlogging *Biodiversitas* 17 (1) 110–115

[22] Halawane J E, Hidayah H N and Kinjo H J 2011 *Prospek Pengembangan Jabon Merah* (*Anthocephalus macrophyllus* Roxb. Havil), *Solusi Kebutuhan Kayu Masa Depan* Balai Penelitian dan Pengembangan Kehutanan, Balai Penelitian Kehutanan Manado [in Indonesian]

**Acknowledgement**

The author would like to thank Komatsu-Forest and Environment Research, Development and Innovation Agency (FORDA), Ministry of Environment and Forestry of Republic Indonesia for assistance in procuring seedlings and planting. This study was supported by the Ministry of Research and Technology/National Agency for Research and Innovation (RISTEK/BRIN) of the Republic of Indonesia through the Basic Research scheme (Penelitian Dasar) with the contract No. 1/E1/KP.PTNBH/2021 (between IPB University and RISTEK/BRIN) and contract No. 2029/IT3.L1/PN/2021 (between researchers and IPB University).