


The Reintroduction of Threatened Plants by Bogor Botanic Gardens: Lessons Learned from Ujung Kulon National Park

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Abstract

To support threatened plant conservation, Bogor Botanic Gardens (BBG) has reintroduced 5 threatened plant species in Ujung Kulon National Park (UKNP) in 2009 and 2014. All reintroduced plants were propagated from seeds of BBG living collections, except *Vatica bantamensis* which came from wildings collected in UKNP. After transplantation in 2009, the survival and growth rate was monitored at six months, one year and eight years period, while those transplanted in 2014 were only monitored in 2017. The average survival rate varied depending on species and reintroduction sites, with the highest and lowest values being observed for *Diospyros macrophylla* at Dungus Balang and *V. bantamensis* at Legon Pakis, respectively. Seedlings transplanted at sites with more open canopy cover grew taller with larger diameters. Based on this study, local communities' involvement through seedling supervision, prevention and reduction of disturbances as well as post-planting management were very important for the reintroduction success.

Keywords: Ex situ conservation, plant conservation, species reinforcement.

1. INTRODUCTION AND OBJECTIVES

Around 21% of global plant species are currently threatened with extinction according to the IUCN Red List (Royal Botanic Gardens Kew, 2016). Reintroduction is one of the essential tools for their conservation (Godefroid et al., 2011) with the main objective being the establishment of new or reinforcement of existing populations to increase the survival prospects of a species. This method can be applied to all plant species, including rare, threatened, and non-threatened species (Dalrymple, 2012). Hundreds of plant reintroduction programs have been performed worldwide (Godefroid et al., 2011; Dalrymple, 2012; Godefroid and Vanderborght, 2011). Disseminating the result of these projects is very important to provide examples and case studies that will promote the development of commonly used methodologies.

Botanic gardens are the main institutions for ex situ plant conservation, playing a vital role in halting and preventing species extinctions through not only preserving the germplasm but also providing the plant material and participating in

reintroduction programs. Furthermore, they are the main driving forces to achieve the past Global Strategy for Plant Conservation (GSPC) Target 8, which aims for at least 75% of threatened plant species in ex situ collections, preferably in the country of origin, and availability of 20% for recovery as well as restoration programs by 2020. Mounce et al. (2017) showed that botanic gardens manage at least 105,634 species, equating to 30% of all plant diversity, and preserve more than 41% of known threatened species in living collections. This large preserved number along with knowledge, skills, and facilities, makes the botanic gardens a necessary part of the reintroduction programs (Guerrant and Raven, 2003; Wendelberger et al., 2008; Noël et al., 2011; Fotinos et al., 2015; Menges et al., 2016; Fenu et al., 2016; Zimmer et al., 2016).

Bogor Botanic Gardens (BBG) is a leading botanic garden in Indonesia and the oldest in the country and South-East Asia. It holds more than 14,585 plant specimens, belonging to 3411 species, 1259 genera, and 215 families (Sari et al., 2010). Among this vast collection, BBG maintains 95 (21.7%) of the Indonesian threatened plant species listed in IUCN 2017 (Bidang PK2TE, 2018).

To create an integrative strategy with in-situ conservation, BBG has actively participated in nine programs of species reintroduction to their natural habitats, with six being carried out in Ujung Kulon National Park (UKNP), West Java. The other three programs were conducted in Gunung Halimun Salak National Park, Bukit Dua Belas National Park and Meru Betiri National Park for the reintroduction of *Pinanga javana* Blume (Arecaceae), *Calamus manan* Miq. (Arecaceae) and *Alstonia scholaris* (L.) R.Br. (Apocynaceae), respectively (Widyatmoko and Risna, 2017). These are all plant reintroduction programs that have been conducted so far in Indonesia. However, none of these has been monitored for their success, except for *C. manan*. Monitoring conducted by Kusuma (2011) showed that seedling survival rate of *C. manan* after 16 months of planting was highest in the plantation (44%), followed by the hill forest site (33%) and riverside site (22%).

As monitoring is a very crucial step in determining if the reintroduction objectives have been met, it should be conducted adequately in term of quality and time span. Long term monitoring is required because reversals over time often follow initially high survival rates (Fahsel, 2007; Hutchings, 2010). Therefore, in the present study we aimed at monitoring the reintroduction programs conducted in UKNP, where most of the reintroduction programs in Indonesia have been carried out. The reintroduction programs in UKNP were conducted during the years 2009 and 2014, which involved propagation, raising, and cultivating the seedlings of 5 tree species i.e. *Diospyros macrophylla* Blume, *Intsia bijuga* (Colebr.) Kuntze, *Stelechocarpus burahol* (Blume) Hook.f. & Thomson, *Heritiera percoriacea* Kosterm. and *Vatica bantamensis* (Hassk.) Benth. & Hook.f. ex Miq. Except for *S. burahol*, all the chosen species are threatened, either regionally or globally (Mogea et al., 2001; WCMC, 1998a; WCMC, 1998b). To measure the reintroduction success, we evaluate the survival and growth rate of all the reintroduced species at 6, 12, 36, and 96 months after planting.

2. MATERIALS AND METHODS

2.1. Study site

Ujung Kulon National Park (UKNP) is located at the westernmost tip of Java Island, within Banten Province of Indonesia (6°45'S, 105°20'E). Due to its natural beauty, geological uniqueness, and high diversity of plant and animal species, UKNP was designated as a world heritage site by UNESCO in 1991 (<http://whc.unesco.org/en/list/608>). Covering an area of 78,525 ha, the park contains the largest remaining

area of lowland rainforests in Java Island, and harbors several endangered organisms. The Critically Endangered Javan rhinoceros (*Rhinoceros sondaicus*) is the most well-known animal to be found only in UKNP, and is seriously threatened by natural catastrophes, habitat loss, diseases, poaching, and potential inbreeding (<https://www.worldwildlife.org/species/javan-rhino>). In addition, DKPP Banten (2011) said more than 50 rare plant species grow in the park, including the endemic *Vatica bantamensis* (Dipterocarpaceae) and *Heritiera percoriacea* (Malvaceae).

The reintroduction programs conducted by BBG were at seven different locations in UKNP, namely Dungus Balang, Cibiuk, Cilimus 1, Cilimus 2, Taman Jaya, Legon Pakis, and Cilintang (Figure 1). Since UKNP is mostly surrounded by seas, the climate conditions are tropical maritime which is categorized in type A (Hommel, 1987), with mean temperatures ranging between 25°C and 30°C and relative humidity of 65% and 100% (Hommel, 1987; Blower and Van Der Zon, 1977). Furthermore, the mean annual rainfall is ca. 3,250 mm, with the respective wettest and drier period occurring from October to April and May to September following annual north-west and south-east monsoon cycles (Rahman et al., 2017).

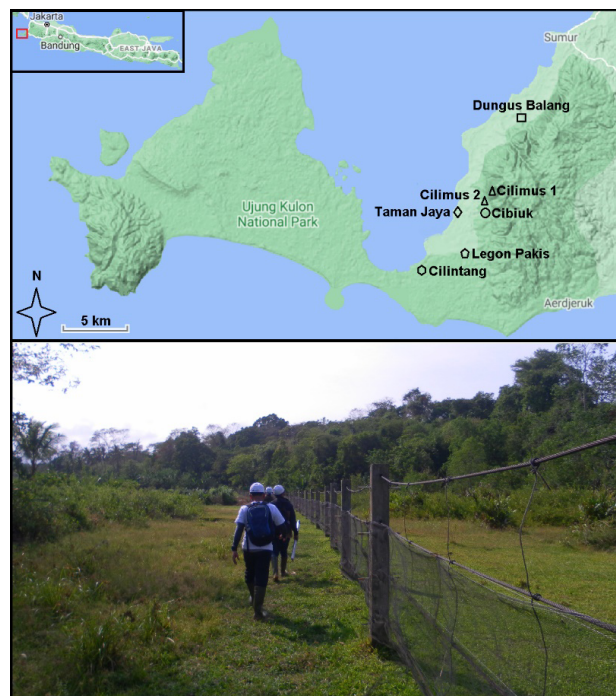


Figure 1. Map showing locations of reintroduction programs conducted by Bogor Botanic Garden in Ujung Kulon National Park (above) (map from www.maps.google.com) and fenced area of the reintroduction site at Legon Pakis (bottom). The reintroduction sites are Dungus Balang (rectangle), Cilimus 1 and 2 (triangle), Cibiuk (circle), Taman Jaya (diamond), Legon Pakis (pentagon) and Cilintang (hexagon).

2.2. Study species

In 2009 and 2014, BBG reintroduced five tree species to UKNP (Table 1) of which *Diospyros macrophylla* & *Intsia bijuga* are nationally vulnerable (Mogea et al., 2001) and *Heritiera percoriacea* & *Vatica bantamensis* are globally endangered according to IUCN Red List (WCMC, 1998a; WCMC, 1998b), while *Stelechocarpus burahol* is at lower risk according to Mogea et al. (2001). The number of transplanted seedlings varied among species as *D. macrophylla* = 100, *I. bijuga* = 450, *H. percoriacea* = 50, *V. bantamensis* = 100, and *S. burahol* = 300. Due to their high conservation status, *H. percoriacea* & *V. bantamensis* were transplanted inside the Javan Rhino Study and Conservation Area (JRSCA) at Legon Pakis. The JRSCA is surrounded by an electrified wire fence (Figure 1), which was expected to protect the seedlings from any possible anthropogenic disturbances.

All transplants were propagated from seeds obtained from the living collections of BBG, except *V. bantamensis* which came from wildings collected at Mount Payung of UKNP. The mother trees at BBG that provided seeds were originally collected from UKNP and had the following living collection numbers: IV.D.128 (*D. macrophylla*), XXIV.A.13a (*H. percoriacea*), XX.D.56 (*S. burahol*), and XI.B.V.53 (*I. bijuga*). These collections were chosen based on the seed availability. To germinate the seeds, we used plastic trays containing sand as the germination media. Seedlings with two true leaves were transplanted into plastic bags containing rice husk, mineral soil, and compost in a 1:1:1 ratio. The seedlings were then watered at least once a day. After reaching 50 cm in height, they were transported to the reintroduction sites while being covered by a shade net and stabilized in the bags using rope to minimize stress and damage.

Table 1. List of reintroduced plant species in Ujung Kulon National Park by Bogor Botanic Garden.

Species reintroduced (local name)	Family	Conservation status	Year	Location (number of transplanted seedlings)
<i>Diospyros macrophylla</i> (Ki calung)	Ebenaceae	Vulnerable A1c ^a	2009	Cibiuk (50), Dungus Balang (50)
<i>Intsia bijuga</i> (Merbau)	Fabaceae	Vulnerable A1cd ^b	2014	Legon Pakis (50)
			2009	Cilintang (250), Dungus Balang (100), Taman Jaya (100)
<i>Stelechocarpus burahol</i> (Kepel)	Annonaceae	Lower Risk ^a	2009	Cilimus 1 (75), Cilimus 2 (25), Dungus Balang (100), Taman Jaya (100)
<i>Heritiera percoriacea</i> (Cerelang laut)	Malvaceae	Endangered B1+2c ^c	2014	Legon Pakis (50)
<i>Vatica bantamensis</i> (Kokoleceran)	Dipterocarpaceae	Critically Endangered B1ab(iii,v)+2ab(iii,v); C2a(ii) ^d	2014	Legon Pakis (100)

^aMogea et al. (2001), ^bWCMC (1998a), ^cWCMC (1998b), ^dRobiansyah (2018)

2.3. Reintroduction methodology

Based on Regulation of Director General for Forest Protection and Nature Conservation No. SK.100/IV-SET/2011, UKNP has 8 different zones, namely i) core zone used for biodiversity protection and acting as reference points on the natural state of the ecosystems, ii) forest zone used for supporting both core and use zone, iii) marine protection zone, iv) use zone allowing ecotourism & other economic activities compatible with sound ecological practices, v) traditional zone promoting traditional activities of local communities, vi) rehabilitation zone where ecosystem rehabilitation occurs, vii) religious zone

protecting religious activities, cultural heritage and history of local communities, and viii) a special zone which is due to historical reasons, it accommodates human settlements and their supporting facilities. There are also buffer zones located outside the park (UKNP, 2017). Seven locations used for the reintroduction programs were distributed in the buffer, forest, and traditional zone (Table 2). These were the only available sites suggested by the UKNP management to be used for this study. The locations varied in elevation from 13 to 140 m above sea level, but each differed in distance to the nearest human settlement where the closest site was Dungus Balang (50 m) while the farthest was Cilintang (3 km).

Table 2. Reintroduction sites of Bogor Botanic Gardens in Ujung Kulon National Park (UKNP).

Site	UKNP Zonation	Elevation (m asl)	Distance to human settlement (km)	Canopy cover (%)
Cibiuk	Forest	93	1	75-100
Cilimus 1	Forest	140	1.1	25-50
Cilimus 2	Forest	94	0.8	50-75
Cilintang	Forest	14	3	75-100
Dungus Balang	Traditional	52	0.05	0-25
Legon Pakis	Forest	14	0.7	25-50
Taman Jaya	Buffer	13	0.08	0-25

At the reintroduction sites, the seedlings were tagged and then planted randomly at available spaces between existing vegetation in holes of 30x30x30 cm. To ensure they receive sufficient rainfall for an early establishment, these planting activities were conducted at the beginning of the rainy season in November for both 2009 and 2014, while being staked to wooden poles to also prevent damage by high winds. Initial height and stem diameter at 10 cm above ground was measured on each seedling for sake of monitoring. As part of the cooperation agreement between TNUK and BBG, the former was responsible for post-planting seedling management. For this purpose, local communities living inside the areas of the national park were involved in taking care of the seedlings voluntarily. Due to distance constraints, however, the post-planting treatments were only conducted at Dungus Balang and Taman Jaya which were very close to human settlements. At the two sites, local communities watered and fertilized the seedlings approximately two times a week for the first month after planting. They also weeded areas around the seedlings at 1, 6 and 12 months after planting. Post-planting treatments were also applied at Cilimus 1 despite being far from human settlement, the planting points were very close to rice fields managed by local farmers that actively managed the seedlings in the same way as at Legon Pakis and Taman Jaya.

2.4. Monitoring and data analysis

Monitoring was conducted at three periods (six months, one year, and eight years after planting) for seedlings transplanted in 2009, while for those transplanted in 2014, it was performed only in 2017. Furthermore, during this process, the height and trunk diameter of randomly chosen plants representing a minimum of 25% of the total transplants for each species were re-measured due to time constraints. Also, overall survival rate, reproductive maturity, and possible disturbances for seedling establishment at each site were

recorded. The survival rate of each species was measured by comparing the survived seedling with the total number of transplanted seedlings. The cumulative survival rate over species and over sites was then calculated by averaging the observed survival rates across sites and across reintroduced species, respectively. The transplanted plants were considered as mature individuals when they have produced flowers and/or fruits. All observed disturbances at each reintroduction site, including anthropogenic activities, were classified into three levels (low, medium and high) based on their severity.

A log-rank test (Krebs, 1999) was performed to determine whether there were differences in the survival distribution of *D. macrophylla*, *H. percoreacea*, & *V. bantamensis* at Legon Pakis, and between sites where *I. bijuga* and *S. burahol* were planted in 2009. Growth measurements (height and diameter) were analyzed using ANOVA and post hoc Tukey honest significant difference (HSD) tests to evaluate among-species and among-site differences in these variables, hence the height & diameter increments per species measured during each monitoring period were treated as one sample. Statistical analysis was performed using SPSS 18.0 for Windows (SPSS, 2009).

3. RESULTS

3.1. Seedling survival and growth

The seedlings planted in 2009 generally had high survival rates at 6 and 12 months after planting. Table 3 shows that during the two monitoring periods, the survival rates of the entire species at all sites were above 80% except for *I. bijuga* at Cilintang (52.4%). This rate then dropped for almost all species 96 months after planting, with *I. bijuga* at Cilintang being the lowest (10.8%), while by ignoring site differences, the highest was *D. macrophylla* (58±18 %), followed by *S. burahol* (43.9±11 %) and *I. bijuga* (18.6±4.7 %).

For seedlings planted at Legon Pakis in 2014, the survival rates after 36 months were very low (Table 3). Based on the

log-rank test, the three reintroduced species at this location exhibited significant differences in survival trends ($\chi^2 = 15.2$, $df = 4$, $p = 0.001$), where the highest rate was found in *H. percoriacea* (14 %) while the lowest was in *V. bantamensis* with none of the transplanted seedlings being observed during the monitoring.

For among-site comparison, there was a significant different in the survival trend of the *I. bijuga* ($\chi^2 = 14.3$, $df = 2$, $p = 0.001$) and *S. burahol* ($\chi^2 = 20.4$, $df = 3$, $p = 0.0005$) planted in 2009. The highest survival rate of *I. bijuga* was detected in Taman Jaya (27%), followed by Dungus Balang (18%), and Cilintang (10.8%). In contrast, a higher rate was gained by *S. burahol* at all sites except Cilimus 2 (12 %) as can be seen in Table 3.

Figure 2 and Figure 3 showed that the entire species at all sites had one similar feature i.e. the growth was considerably slow during the first several months after planting. ANOVA

Test showed that the height differed significantly among species ($F = 19.1$, $df = 3$, $p = 0.001$). Post hoc comparisons using the Tukey HSD test indicated that the height of *I. bijuga* (54.9 ± 3.8 cm/year) was significantly higher than of *D. macrophylla* (33 ± 5.5 cm/year), *S. burahol* (23.3 ± 1.6 cm/year) and *H. percoriacea* (9 ± 3.2 cm/year). For diameter, the highest was observed in *I. bijuga* (0.7 ± 0.04 cm/year) and *D. macrophylla* (0.7 ± 0.09 cm/year), followed by *S. burahol* (0.5 ± 0.02 cm/year), and *H. percoriacea* (0.5 ± 0.13 cm/year). The result of ANOVA test, however, showed that this recorded difference was not significant ($F = 2.1$, $df = 3$, $p = 0.105$).

The species of *D. macrophylla*, *S. burahol* & *I. bijuga* reached higher height and trunk diameter 96 months after planting at sites with lower canopy cover. As can be seen in Figure 2 & Figure 3, the above two growth parameters were higher at Dungus Balang and Taman Jaya sites (canopy cover: 0-25%) than at sites with higher canopy cover.

Table 3. The survival rate of transplanted seedlings at the reintroductions sites in Ujung Kulon National Park.

Species	The survival rate after 6, 12, and 96 months after planting (%) in trial 2009							Cumulative over sites
	Cibiuk	Cilimus1	Cilimus2	Cilintang	Dungus Balang	Legon Pakis	Taman Jaya	
<i>Diospyros macrophylla</i>	83.3, 66.7, 40	-	-	-	92.3, 84.6, 76	-	-	58±18
<i>Intsia bijuga</i>	-	-	-	80.9, 52.4, 10.8	96, 96, 18	-	100, 92, 27	18.6±4.7
<i>Stelechocarpus burahol</i>	-	100, 100, 46.7	89.5, 89.5, 12	-	100, 100, 60	-	100, 100, 57	43.9±11
Cumulative over species	40	46.7	12	10.8	51.3±17.3	-	42±15	
Survival rate 36 months after planting (%) in trial 2014								
<i>Diospyros macrophylla</i>	-	-	-	-	-	4	-	4
<i>Heritiera percoriacea</i>	-	-	-	-	-	14	-	14
<i>Vatica bantamensis</i>	-	-	-	-	-	0	-	0
Cumulative over species	-	-	-	-	-	9±5	-	

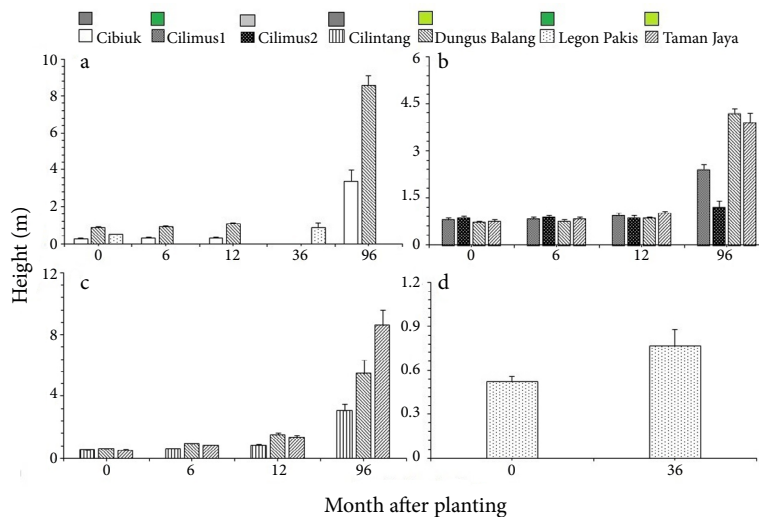


Figure 2. Mean height growth of reintroduced seedlings of *Diospyros macrophylla* (a), *Stelechocarpus burahol* (b), *Intsia bijuga* (c), and *Heritiera percoriacea* (d) at different sites in Ujung Kulon National Park. The line above each bar is the standard error of means, while the canopy cover of each site was indicated by colored boxes above it (light green =0-25%, green =25-50%, grey =50-75%, and dark grey =75-100%).

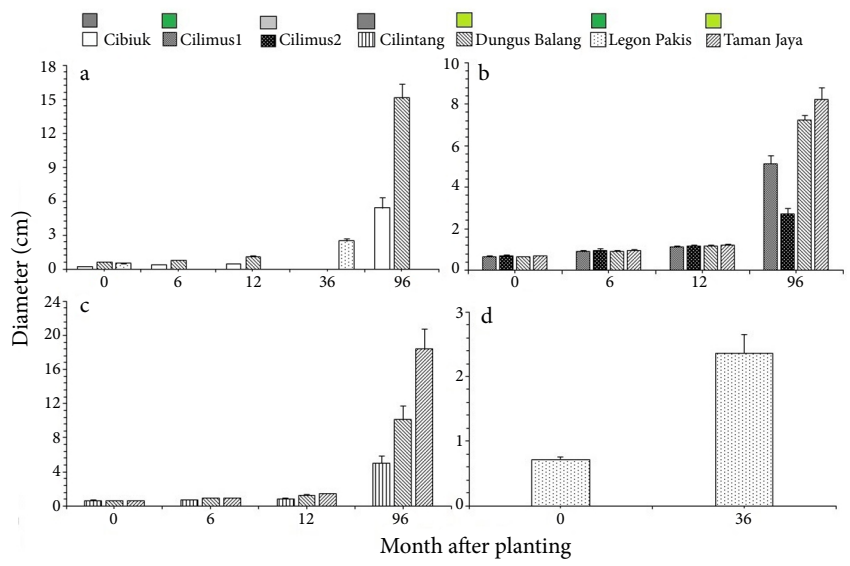


Figure 3. Diameter growth of reintroduced seedlings of *Diospyros macrophylla* (a), *Stelechocarpus burahol* (b), *Intsia bijuga* (c), and *Heritiera percoriacea* (d) at different sites in Ujung Kulon National Park. The line above each bar is the standard error of means, while the canopy cover of each site was indicated by colored boxes above it (yellow =0-25%, green =25-50%, grey =50-75%, and black =75-100%).

3.2. Regeneration

Natural regeneration of established population was observed only in *I. bijuga* transplanted at Dungus Balang and Taman Jaya (Figure 4). Ninety-six months after planting, a total of 50 new seedlings

were discovered at Dungus Balang with an average height of 70 cm, while there were 14 at Taman Jaya with an average height of 30 cm. Subsequently, one fruiting individual of *I. bjiuga* (DBH 14 cm) transplanted in 2009 was also observed after 96 months during the monitoring at Dungus Balang.



Figure 4. Regeneration of *Intsia bijuga* populations at reintroduction site of Dungus Balang (a: recruited seedling; b: seeds) and Taman Jaya (c: mature individual; d: recruited seedling).

3.3. Site disturbances

Disturbances due to anthropogenic or natural factors were observed at almost all reintroduction sites (Figure 5). Furthermore, they include cattle ranching, fuelwood chopping, wood cutting for constructions, and farmland expansion (Table 4). Despite the presence of an electrified wire fence, the intensity of the first two disturbances at Legon Pakis was very high which tends to explain the reason none of the *V. bantamensis* seedlings survived there. While the voluntary work of post-planting treatments involved local communities living near the reintroduction sites, wood chopping and cutting were carried out by non-locals living far off (as explained by local guides). For natural-caused disturbance, it was only observed at Cilintang where wild pigs dig the soil searching

for earthworms, hence this activity disturbed the growth and survival rate of the seedlings.

Table 4. Type of anthropogenic disturbance found at the reintroduction sites in Ujung Kulon National Park. The number of plus (+) indicates level of the disturbances: +: low, ++: medium, and +++: high.

Site	Grazing	Fuelwood chopping	Wood cutting	Farmland
Cibiuk		++	+	
Cilimus 1				++
Cilimus 2		++	+	
Cilintang		+	++	
Dungus Balang			+	
Legon Pakis	+++	+++	+	
Taman Jaya		+	++	



Figure 5. Several types of disturbances observed at the reintroduction sites were wood cutting for fuel and construction at Dungus Balang (a), Cilimus 2 (b), Cilintang (c), and Taman Jaya (d), farmland expansion at Cilimus 1 (e), cattle grazing at Legon Pakis (f), and wood cutting for fuel at Legon Pakis (g).

4. DISCUSSION

Monitoring is essential in plant reintroduction to evaluate the program's success. For long-lived plant species, long-term monitoring is necessary to judge whether the reintroduced population becomes self-sustaining. Most reintroductions have been monitored for less than 5 years (Maschinski and Albrecht, 2017), and this study accounts for only a handful of these programs in which the introduced populations are monitored for a longer period.

The average survival rate of the reintroduced species obtained in the present study was rather low compared to those reported in the meta-analysis of reintroduction studies on 128 plant taxa which the value was 65% for the introduced juveniles 41 months after planting (Dalrymple, 2012). The population of *D. macrophylla* in Dungus Balang, however, was exceptional with its seedling survival rate 96 months after planting being 76%. As this site was very close to human settlement, local communities at Dungus Balang tended to voluntarily nurture the seedlings and protect them from disturbance. Therefore, site selection and volunteer involvement were suggested to be very crucial for reintroduction success since both influences the management & protection required for seedling survival. Far away reintroduction sites caused access difficulty for local volunteers and the inability to nurture the seedlings. This was the case for Legon Pakis, where none of the 100 planted seedlings of *V. bantamensis* was located during monitoring. Due to the absence of volunteer assistance, the seedlings were cut and trampled by grazing buffalo despite the electrified fence surrounding the site. The animals were helped to pass through by their owner, which lives outside the area of the national park. Volunteer assistance had previously been shown to perform a critical function in the reintroduction trials of five endangered species in Miami, USA (Wendelberger et al., 2008; Maschinski and Wright, 2006; Possley et al., 2009; Maschinski et al., 2010). Because of the care provided by 466 volunteers from various organizations & local communities, the entire species doubled in population size over a relatively short time and all but one of the species had documented next-generation recruitment.

The present study showed that the seedlings' height and diameter growth varied depending on the species and site. The average diameter growth rate of all transplanted species except *H. percoriacea* was considered reasonable. Meanwhile, the value recorded for *I. bijuga* (0.7 ± 0.04 cm/year), for example, was almost close to that of the transplanted populations in Bondowoso, East Java (0.8 ± 0.05 cm/year) and Gunung Kidul, Yogyakarta (1.03 ± 0.09 cm/year) (Yudohartono and Ismail, 2013). Furthermore, Steup (1935), Beversluis (1947), and Alrasyid (2002) reported that the diameter growth rate of

D. macrophylla was 0.5 cm/year, which was slightly lower compared with the 0.7 ± 0.09 cm/year obtained in the present study. For *S. burahol*, Ramadhan (2012) stated a similar diameter growth rate (0.47 ± 0.04 cm/year) compared to the recently obtained 0.5 ± 0.02 cm/year. The present study also showed a reasonable height growth rate for *I. bijuga*, while Yudohartono & Ismail (2013) observed 43.4 ± 2.3 cm/year and 54.8 ± 2.5 cm/year for this same species transplanted in Bondowoso and Gunung Kidul, respectively. These values were similar to the height growth rate of 54.9 ± 3.8 cm/year detected in the present study.

Several qualitative measures can be used as indications of successful reintroduction, such as survival rate, flowering & fruiting rate, and new seedling recruitment (Godefroid et al., 2011). The last measure is considered to be the best success indicator (Pavlik, 1996; Sutter, 1996) due to indicating a self-sustaining population (Primack, 1996). Using this criterion, the reintroduction of *I. bijuga* at Dungus Balang and Taman Jaya was considered successful as newly recruited seedlings were observed in both locations. Further monitoring of other introduced species shows whether their populations are sustainable.

It should be noted that all the reintroduced transplants propagated from seeds were come from a single mother tree. This could lead to a low genetic diversity in the reintroduced populations and could be another reason why survival and next generation recruitment were low for some of the species. Previous studies (e.g. Godefroid et al., 2011; Prati et al., 2016; Ren et al. 2014) have shown that survival rate of the reintroduced species were much higher when genetic diversity was incorporated in to the project designs.

Anthropogenic disturbances were discovered to be apparent, with seedlings at Legon Pakis being the most severely affected. From three species transplanted at this location, only two were found during the monitoring 36 months after planting with a very low survival rate (4% and 14%). Even though Fenu et al. (2016) successfully used fencing to enhance long-term survival, reproductive success, and seedling recruitment of reintroduced *Dianthus morisianus*, the presence of an electrified wire fence at Logon Pakis did not promote the achievement of a similar result. The absence of local community involvement, due to the distant location of this site, caused the proper protection of the planted seedlings from detrimental anthropogenic disturbances to become difficult.

The survived transplants hopefully can become self-sustaining populations in the future and therefore can reduce the extinction risk of the species in the wild. Based on IUCN Red List Category and Criteria (IUCN Standards and Petitions Committee, 2019), the reintroduced populations can be included in an extinction risk assessment if the individuals

within those populations have produced viable offspring (i.e., offspring that have reached maturity). Therefore, monitoring programs are still required in the future in order to record the further survival and growth rate of the transplant and their offspring as well as to document the ability of the offspring to reach maturity.

5. CONCLUSION

The present study showed that the success of reintroduction is enhanced by the involvement of local communities and post-planting management. These two activities require the reintroduction site not to be too far from human settlement. Usually, reintroductions in protected areas are more successful than in unprotected areas. However, protection status and the electrified fence surrounding the site cannot prevent anthropogenic disturbances. In contrast, local communities' participation and post-planting management even in unprotected sites lead to a high seedling survival rate and next-generation recruitment at transplant sites. The results of our study can be used to inform further reintroduction programs of these plants and other plant species in the future.

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