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Seedling growth of some native trees in Ranu Pani- Ranu Regulo restoration area, Bromo Tengger Semeru National Park

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Key words: plant restoration, biodiversity, conservation and mountain forest.

Abstract

The aim of the research was to classify seedling of native plant species in restoration programs based on species' responses to planting time, species' competitiveness to invasive species, and shading cover. We observed the growth rates and growth characteristics of *Acer laurinum* Hassk., *Acmena acuminatissima* (Blume) Merr. & L. M. Perry, *Aglaia odoratissima* Blume, *Dodonaea viscosa* Jacq., *Engelhardia spicata* Bl., *Ficus* sp., *Homalanthus giganteus* Zoll. & Mor., *Lithocarpus sundaicus* (Blume) Rehd. *Macropanax dispermum* Kuntze., *Pittosporum moluccanum* (Lamk.) Miq. and *Vernonia arborea* Buch.-Ham in two sites—the first site was without exotic species and the second site was with abundant exotic species. The first observation was done six months after planting and the second observation was done twelve months after planting. Species' survival together with plant's height, stem diameter, emerging buds and young leaves was observed and measured. The results of the study showed that eleven seedling species each showed different responses to their planting environment (absence and presence of exotic species), planting time, and covering application. These seedling species fundamentally can be clustered in three clusters, namely plant with less adaptation, plant with moderate to good adaptation, and plant with most adaptation characters. Pioneer species shows its ability to grow in different planting times, survive under exotic plant species invasion, and adapt to frost attack. However, climax species need assistance and protection in order to enhance its survival. This study confirmed that in each restoration program, introducing pioneer species in the beginning of planting program could be significant.

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Introduction

Conservation of mountain forest has been recognized as crucial. Ecologically, mountain forest plays an important role in hydrological process to supply water resources (Brauman *et al.,* 2007). Mountain forest is a habitat of numerous plants (Xu *et al.,* 2005) and animals (Cordeiro and Howe, 2001) which become potential resources to enhance local people's prosperity (Ellefson, 2000). In recent global discussion related to global warming mitigation, mountain forest ecosystems contribute significantly in carbon sequestration system (Hairiyah and Rahayu, 2007).

The impacts of human activities to mountain biodiversity have been documented in many parts of the globe (Lambin *et al.,* 2001; Young *et al.,* 2005; Nogués-Bravo *et al.*, 2008), including Indonesia. Among them, economical background is considered important in increasing deforestation rates (Lambin *et al.,* 2001). Local people live surrounding the forest often lack of infrastructure and basic education. Economic system is limited and many people are poor with inadequate access to public facilities (Kamanga *et al.,* 2009). Electricity is often absent and energy for cooking is generated from wood. These conditions are often reported to contribute to illegal logging and damage many biodiversity forms in mountain forest (Primack, 1991; McNeely, 2003). In mountainous environment, however, the cold temperature leads local people to cut and collect tree to set fire in order to increase the temperature.

Bromo Tengger Semeru National Park is one of the significant areas for mountain biodiversity conservation in East Java, Indonesia. Degradation of mountain forest in Bromo Tengger Semeru has occurred for long time. The anthropogenic factors has been identified contributes significantly to forest disturbance. A strategy to restore degraded mountain forest, however, is complicated due to numerous limitations, including biotic, physical and socio-cultural factors (Hakim *et al.*, 2011). The biotic factor comes from the abundant exotic plant species in the degraded land. In Bromo Tengger Semeru, the most abundant exotic species is *Eupatorium odoratum* (Qomaruddin *et al.*, 2012). In mountainous environment, physical factors are often related to the cold temperature and frost attack, especially in dry season. In a long dry season, however, there is also forest fire which contributes to vegetation disturbance (Macyk *et al.*, 1989; Hakim *et al.*, 2011).

In the beginning of 2010, a restoration program to save degraded forest in Bromo Tengger Semeru has been initiated and supported by JICA (Miyakawa, 2010). For the experimental site, the area surrounding Lake Ranu Pani and Ranu Regulo has been chosen as an experimental block (Hakim *et al.,* 2011). The restoration programs was expected to create the original ecosystem of Ranu Pani – Ranu Regulo forest for many purposes, including protecting Lake Ranu Pani Ranu Regulo from sedimentation, providing habitat for plants and animals, and enhancing the economic aspects of local people in Ranupani Village. In the implementation, there are many native plants seedling which have been restored in Ranu Pani – Ranu Regulo experimental block (Hakim, 2012). So far, there is no information on the success of the restoration program, particularly in the context of plant survival and their growing characteristic after planting. This information is principally important to provide basic information to ensure restoration success. Research on post planting is important particularly for monitoring growth of increase in height and stem diameter (West *et al.,* 1999; Guerrant and Kaye, 2007; Cole *et al.,* 2010; Coble *et al.*, 2012). Such post planting evaluation was done intensively in North America and Australia, but it was lack survey in tropical ecosystem. A survey on spontaneous and direct seedling of native plant trees has observed in tropical mountain forest (Cole *et al.,* 2010), but there are no assessment in planting success. In the assisted restoration program by planting trees seedling, the plant survival and growing characteristic after planting was considered important. In mountain environment, it is particularly important due to seedling often facing physical and physiological barriers to sustain seedling grows. This information was crucial and become the basic information to improve restoration success in tropical mountain forest. The objective of this research is to classify seedling plant species in restoration programs based on plant survival under different environment, plant responses to frost attack and planting time.

Material and method

Study area

The study was carried out at Ranu Pani – Ranu Regulo experimental block, Bromo Tengger Semeru National Park, East Java, Indonesia. The experimental block lies on the altitude of 2.000-2.200 m asl. The average annual rainfall recorded is about 6.000 mm per year and temperature is about 3°-20°C (Hakim, 2011). Previously this area is covered by tropical mountain forest with abundant epiphytes and lianas in tree trunks. Our previous survey shows that several secondary and climax mountain forest in this area contains many plant tree species which become an ideal referential site to the original model of past forest structure before degradation (Hakim *et al.,* 2011). The experimental block for the restoration program in this area has two fresh water mountains lakes, namely Lake Ranu Pani and Lake Ranu Regulo. Lake Ranu Pani has been heavily disturbed due to rapid development of Ranupani Village and its unsustainable agricultural practices. Ranupani Village is a traditional settlement, which is located inside the national park system (Hakim *et al.,* 2011).

Methods

The experimental block was divided into nineteen 25 x 25 m planting experimental plot (Plot A to S, Fig. 1). Eleven species seedlings which were planted in different planting time were chosen, encompassing *Acer laurinum* Hassk., *Acmena acuminatissima* (Blume) Merr. & L.M. Perry, *Aglaia odoratissima* Blume, *Dodonaea viscosa* Jacq., *Engelhardia spicata* Bl., *Ficus* sp., *Homalanthus giganteus* Zoll. & Mor., *Lithocarpus sundaicus* (Blume) Rehd. *Macropanax dispermum* Kuntze., *Pittosporum moluccanum* (Lamk.) Miq. and *Vernonia arborea* Buch.-Ham. The first planting time was in January 2012, while the second planting time was in May 2012. January was the highest season for rain, while May was the end of the rainy season with low rain.

In order to identify the impact of seedling plant competition with invasive plant species, two plots were observed respectively. The first plot was a site where seedling grew together with invasive species, and the second plot was a site where seedling grew without invasive species. In the second plot, invasive species were cleared regularly to maintain the cleanliness of the site from shrub disturbance. Survival of species and measurement of plant's height, stem diameter, emerging buds and young leaves was done in two times. The first measurement was conducted sixth months after planting, and the second measurement was done twelve months after planting. In order to assess the effectiveness of frost protection, the measurement was done twelve months after seedling planting. The first measurement could not be done since frost come in July to August.

The impact of planting time to the plant survival was observed to the two-seedling population. The seedling planted in January was measured in August, while the seedling planted in May was measured in December 2012. In every plot observation, the survival of seedling was counted and the morphological characteristics were observed including plant's height, stem diameter, emerging buds and young leaves. The bud and leaves abundance were observed based on the abundance parameter (Table 1).

The data generated from the experimental field was recorded, tabulated and analyzed descriptively. The statistical significances were analyzed using Gen Stat 15.0. The classification of native species seedlings based on multivariate cluster with 80% similarity and bi-plot analysis using Paleontological Statistics (PAST) program.

Results and discussion

Seedling survival under the absence and presence of exotic species

In planting area with invasive plant species, the seedling of *E. spicata*, *H. giganteus, P. moluccanum, V. arborea* and *Ficus* sp. had survival rates of about 68.75-100%, indicating that invasive species provided low impact to seedling survival rates. Conversely, there is tendency of invasive shrubs contribution to frost attack countermeasure. D'odorico *et al.* (2010) concludes that shrubs maintaining warmer temperature and humidity of site's environment. The plant height and stem diameter grew very low. There were no increasing buds among *E. spicata*, *H. giganteus, P. moluccanum, V. arborea* and *Ficus* sp. in the first measurement. Buds emerged and increased to 6.26 – 13.31 % in the second measurement. This phenomenon means that in the first month, seedling tended to be dormant, and grew only after the sixth months of planting. Plant dormancy is also supported by the number of leaves. There were no new leaves until six months after first planning, but leaves increased up to 4.17 % in the second measurement (Table 2).

Table 1. Abundance parameter.

Value	Explanation
0	Characters were not found on seedlings
1	Characters found on seedlings ≤ 25%
2	Characters found on seedlings 26% - 50%
3	Characters found on seedlings 51% - 75%
4	Characters found on seedlings 76% - 100%

(Arisoesilaningsih *et al.*, 2001)

In the area without invasive plant species, *A. laurinum, A. acuminatissima, A. odoratissima, L. sundaicus* and *M. dispermum* seedlings had survival rates of about 48.48 to 100%. The lowest survival rates found in such plots seems to be related to the ability of the sites to countermeasure frost attack. It was particularly shown by the lowest value of plant's height, stem diameter, bud and young leave abundance after sixth months of planting. During these periods (June to August), frost is often reported to attack Ranupani area and disturbed many crops. Importantly, *D. viscosa* showed adaptability to grow in both areas. *D. viscosa* is known as one of the most important species for mountain target succession (Van Steenis, 2010).

Table 2. Plants survival rates and growth characteristics under different environments.

Sites environment	Taxa	Survival Rate (%)	Observation Month	Growth (%) Height	Stem diameter	Bud abundance	Young leaves abundance
With Invasive shrubs	*E. spicata*[1,4] *H. giganteus*[2] *P. moluccanum* *V. arborea* *Ficus* sp.	68.75-100	6th	8.02-21.88 (±7.59)	11.09-29.24 (±11.15)	-	4.17 (±2.41)
			12th	2.84-4.83 (±1.41)	2.35-7.02 (±2.64)	6.26-13.31 (±4.99)	
Cleared invasive shrubs	*A. laurinum*[4] *A. acuminatissima* *A. odoratissima*[1] *L. sundaicus* *M. dispermum*[1,4]	48.48-100	6th	2.88-16.76 (±6.79)	39.12-284.33 (±19.79)	0.08-3.59 (±1.77)	2.50 (±1.12)
			12th	1.28-5.54 (±2.40)	0.12-21.35 (±9.30)	5.67-13.39 (±5.46)	1.96-4.24 (±1.61)
With/cleared invasive shrubs	*D. viscosa*[3]	63.27-89.80	27.91-41.62 (±6.97)		18.65-66.56 (±9.93)	12.10-20.13 (±10.90)	8.83-9.59 (±0.54)

[1] *p*-value of height < 0.05, significant, α=5%
[2] *p*-value of stem diameter < 0.05, significant, α=5%
[3] *p*-value of bud abundance < 0.05, significant, α=5%
[4] *F*-test of young leaves abundance > F table, significant, α=5%

The impacts of covering against frost

Cover application on seedlings provided different impacts to *H. giganteus, E. spicata, A. laurinum, A. acuminatissima*, *A. odoratissima, L. sundaicus* and *M. dispermum* seedlings (Table 3). In such species, covering contributed to enhance seedling survival (Snyder and Melo-Abreu, 2005), in this study is up to 26.67-100%. The seedling of *H. giganteus* had the lowest survival rate, while the seedling of *A. laurinum, M. dispermum A. acuminatissima* had a medium survival rate. As a pioneer species in mountain tropical forest succession, *H. giganteus* seems to be able to survive naturally without covers. The covers, however, provides a significant role as to increase survival rates of *E. spicata*, *A. odoratissima* and *L. sundaicus*. Therefore, technically covering is a prerequisite for such seedling. *D. viscosa*, *P. moluccanum, V. arborea* and *Ficus* sp. Showed better adaptability to frost attack.

Table 3. The impacts of covering in plants survival rates and growth characteristics.

Better Cover Applications	Taxa	Observ. Month	Survival Rate (%)	Growth (%)			
				Height	Stem diameter	Bud abundance	Young leaves abundance
With cover	*E. spicata*[2] *H. giganteus*[1,2] *A. laurinum* *A. acuminatissima*[1] *A. odoratissima*[1] *L. sundaicus* *M. dispermum*[1,3]	12th	26.67-100	2.12-4.24 (±1.14)	2.06-26.75 (±8.74)	22.32-617.39 (±33.34)	5.55-6.00 (±0.50)
With/ without cover	*D. viscosa* *P. moluccanum*[1,3] *V. arborea* *Ficus* sp.	12th	60-100	1.89-35.74 (±14.54)	5.34-40.63 (±15.48)	32.20-92.20 (±42.43)	5-13.06 (±2.70)

[1]*p*-value of height < 0.05, significant, α=5%
[2] *p*-value of stem diameter < 0.05, significant, α=5%
[3]*F*-test of young leaves abundance > F table, significant, α=5%

Seedling survival under different planting times

Seedling survival of plants species under different planting times varied. Seedling of *A. acuminatissima, A. odoratissima* and *L. sundaicus* planted in January had survival rates ranging from 68.75 – 96.75%, while the other plants had low survival rates. The survival rates of the seedling of *E. spicata, H. giganteus, P. moluccanum, A. laurinum, Ficus* sp. and *M. dispermum* planted in May showed different responses as an impact of climates. As mentioned above, frost occurring threats seedling growth (Ball *et al.,* 2002; Groeneveld, 2002). During those periods, the survival rates of *E. spicata, H. giganteus, P. moluccanum, A. laurinum, Ficus* sp. and *M. dispermum* were 50 to 100%. The seedling of *Ficus* sp. had the lowest survival rates (50%), while *E. spicata, H. giganteus, P. moluccanum, A. laurinum,* and *M. dispermum* were more adaptive. The planting time in May faced frost attack in June to August. Frost was able to decrease seedling survival rates of *A. laurinum* until 32%. The consistent trend of best survival rates were shown by *D. viscosa* and *V. arborea*, representing their species characteristic as a pioneer species in degraded land in mountain areas.

The growth percentage of height, stem diameter, buds and young leaves abundance of seedling varied among species (Table 4). Six seedling species of *Acer* *laurinum*, *Engelhardia spicata*, *Ficus* sp., *Homalanthus giganteus*, *Macropanax dispermum*, and *Pittosporum moluccanum* planted in January showed less growth. Three seedling species of *Acmena acuminatissima*, *Aglaia odoratissima* and *Lithocarpus sundaicus* planted in May showed less growth. Frost attack in June to August seems to contribute to the plant growth.

Table 4. The percentage of height, stem diameter, bud and young leaves abundance of the seedling.

Planting Time	Taxa	Growth (%)			
		Height	Stem diameter	Bud abundance	Young leaves abundance
January	A. acuminatissima[1,2]	0.19-12.28	21.93-70.36	0.32-4.68	0.21
	A. odoratissima	(±6.11)	(±12.25)	(±1.79)	(±0.06)
	L. sundaicus"				
May	E. spicata"	1.12-46.15	1.71-9.77	4.06-13.25	2.50
	H. giganteus[3,4]	(±2.30)	(±3.16)	(±1.37)	(±1.77)
	P. moluccanum				
	A. laurinum[4]				
	Ficus sp.				
	M. dispermum				
January	D. viscosa	4.96-34.15	6.50-46.25	1.27-10.34	7.50-8.57
May	V. arborea	(±16.40)	(±15.34)	(±3.60)	(±0.76)
		13.28-20.54	6.32-9.35	0.08-9.25	15.61-26.25
		(±5.13)	(±2.14)	(±0.06)	(±7.52)

[1] p-value of height < 0.05, significant, $\alpha=5\%$
[2] p-value of stem diameter < 0.05, significant, $\alpha=5\%$
[3] p-value of bud abundance < 0.05, significant, $\alpha=5\%$
[4] F-test of young leaves abundance $>$ F table, significant, $\alpha=5\%$

Seedling classification

Based on the cluster (80% similarity) and bi-plot analysis, the seedling of plants in the restoration experimental block can be classified into six groups with similarity of more than 80% (Fig. 2). Group I and II are more closely related in term of growth characteristics. Abundant old and fallen leaves characterized plant seedling species in group I and II. There are two reasons for such phenomena. Firstly, the abundant old and fallen leaves may represent the physiological process of the seedling to avoid water deficit due to dry season (Yulistyarini and Ariyanti, 2004). Secondly, there was also an impact of frost stress in June to August. Frost is able to damage the plant and lead to dark leave color changing to brown (Richter, 2009). Species in such group has least adaptive growth.

Species in groups III and VI had middle adaptation rate. *D. viscosa* seedling showed middle to most adaptive rate of adaptation. In both planting seasons, this species was able to grow and was competitive to invasive shrubs. This species was also flexible to plant cover treatment. *D. viscosa* is considered as a pioneer species with fast growing characteristics (Van Steenis, 2010). Another species that has similar characteristics with *D. viscosa* is *V. arborea* seedling. Overall, such species showed positive signs of growth in stem diameter, height, mature leaves and degree of competitiveness to invasive shrubs on the first six-month observation.

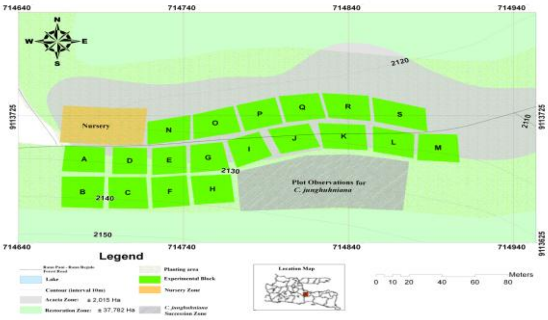

Fig. 1. The plot of planting experimental in the restoration block in study area.

The species in the last two groups, IV and V, were the most adaptive ones. The seedling in these groups are characterized by positive stem diameter and height, bud abundance, young and mature leaves on month twelfth of observation, and high survival rates. The most adaptive tree seedlings were the pioneer species, i.e. *D. viscosa*, *E. spicata*, *P. moluccanum* and *V. arborea,* while on climax tree seedlings of *A. odoratissima*. Except for *H. giganteus* showed less adaptation rate. The problems with the latter species seem to be related to technical planting. Coll (2008) suggested on the use of native tree species having high adaptation to local environment, which finally will contribute to success of reintroduction programs.

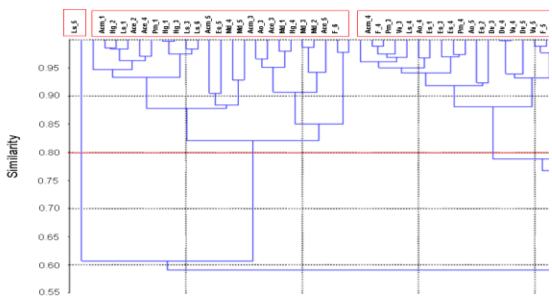

Fig. 2. Cluster of native species seedling growth by PAST program (80% Similarity).

Explanations Dv*: *Dodonaea viscosa*, Es*: *Engelhardia spicata*, Hg*: *Homalanthus giganteus*, Pm*: *Pittosporum moluccanum*, Va*: *Vernonia arborea*, Ace: *Acer laurinum*, Acm: *Acmenna acuminatissima*, Ao: *Aglaia odoratissima*, Ls: *Lithocarpus sundaicus,* Md: *Macropanax dispermum*. 1: planted in January, clear invasive shrubs, without cover; 2: planted in January, clear invasive shrubs, with cover, 3: planted in January, with invasive shrubs, without cover; 4: planted in January, with invasive shrubs, with cover; 5: planted in May, with invsive shrubs, without cover; 6: planted in May, with invasive shrubs, with cover

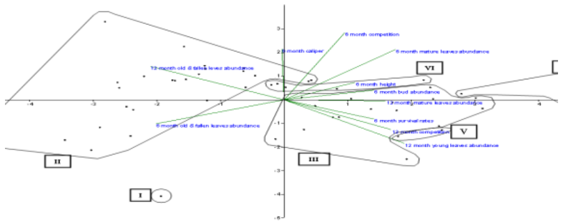

Fig. 3. Bi-plot of native species seedling growth by PAST program Explanation: Group I and II were not adaptive, Group III and VI were less adaptive, Group IV and V were very adaptive.

Conclusion

Selecting native seedlings for plant restoration programs in tropical mountain forest is important. In Ranupani area, the prospective native plant species are *Acer laurinum* Hassk., *Acmena acuminatissima* (Blume) Merr. & L.M. Perry, *Aglaia odoratissima* Blume, *Dodonaea viscosa* Jacq., *Engelhardia spicata* Bl., *Ficus* sp., *Homalanthus giganteus* Zoll. & Mor., *Lithocarpus sundaicus* (Blume) Rehd. *Macropanax dispermum* Kuntze., *Pittosporum moluccanum* (Lamk.) Miq. and *Vernonia arborea* Buch.-Ham. These species have different responses to the planting environment (the absence and presence of exotic species), planting time, and covering application. Based on plant's evaluation, those species can be classified into six groups. These groups fundamentally can be clustered in three clusters, namely plant with less adaptation, plant with moderate to good adaptation, and plant with most adaptation characteristics. Pioneer species show good growth performance in the initial restoration program, and therefore such species should be promoted in the first step of forest restoration.

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