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Comparison of *Nyamplung* Plant Establishment: Direct Seeding, Bare-root, Blocked Media, and Containerized Seedlings

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Abstract

Nyamplung (Calophyllum inophyllum L.), a native multipurpose tree species, produces good general-purpose timber, biodiesel, and medicine. The most widely used method of establishing the species is transplanting nursery-grown containerized seedlings. The research was aimed to compare the success of plant establishment methods, including direct seeding, direct seeding using seed pellet, bare-root seedling, containerized, and blocked media seedlings. Randomized block design with three blocks was set up for evaluation of field performances including seedling survival, height, collar diameter, root development, and biomass at nine months old. The estimated cost based on 1000 target plants in each method was calculated. Seedling grown up on blocked media and containerized media had the highest field performances (survival, growth, and biomass) followed by bare-root seedlings. Direct seeding using seed pellet tended to have better root formation, especially in tap root length, tap root biomass, and bellow-ground biomass. Based on the cost estimation, direct seeding was twice lower compared to transplanting of containerized and blocked media seedlings. However, planting of blocked media and containerized seedlings was more effective in rapidly growth and establishing canopy, but need higher cost. Whereas direct seeding using seed pellet was more cost efficient. Direct seeding using seed pellet was a promising alternative method for plant establishment of nyamplung.

Keywords: growth, seedling, survival, pellet, transplanting

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Introduction

Nyamplung (*Calophyllum inophyllum* L., family Clusiaceae) is a large tree of shorelines and coastal forests. It usually grows 12−20 m in height, and open-grown trees can develop wide and crowns. *Nyamplung* grows widely in the tropical shores across the Pacific and Indian oceans, from Madagascar to Tahiti and the Marquesas islands. The tree is common in India, Indonesia, Northern Australia, and the Philippines. This species produces timber for carving, boat building, furniture, and food vessels (Prabakaran & Britto 2012) and various parts of the plant have bioactive compounds (alkaloid, tannin, triterpenoid, flavonoid, and saponin) that potential for medicine materials, including antibiotic and analgesic (Misra *et al.* 2010; Susanto *et al.* 2017). Seeds of this species also contain oil that is potential for producing biodiesel (Kumar & Sharma 2011; Dewajani *et al*. 2014) and categorized as a no edible fruit so it is not competed with food necessity.

In Indonesia, *nyamplung* is a promising species for biodiesel industry because it is distributed widely, covering West Sumatra, Riau, Jambi, South Sumatera, Lampung, Java, West Kalimantan, Central Borneo, Celebes, Maluku, up to Nusa Tenggara, and Papua (FORDA 2008). The oil content of *nyamplung* seeds is also very high (40−73% w/w) (Atabani *et al*. 2011). The physico-chemical properties of *nyamplung* oil showed that the esters can be one of the alternatives to substitute of the existing fossil fuel (Vandana *et al*. 2017) with lower hydrocarbon and carbon monoxide emissions compared to conventional fossil fuels (Ashok *et al*. 2017). According to Prihanto *et al.* (2013) biodiesel from *nyamplung* seeds fitted to the Indonesian National Standard Numbered 04-7182-2006 as a biodiesel with the methyl ester content 99.61%.

Effort to increase the seed production for biodiesel feedstock of *nyamplung* should be carried out by establishment of the plantation in a large scale. If it is assumed that all of biodiesel necessity will be supplied by this species, a minimum of 254,000 ha of *nyamplung* plantations would be required (FORDA 2008). Increase of planting areas of *nyamplung* is possible because of the broad areas of critical or degraded lands in Indonesia (estimated) that as many as 24,303,294 ha are consisted of very critical lands about 19,564,911 ha, and critical lands about 4,738,384 ha (MoEF 2017). The critical lands should be reforested, and

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nyamplung is suitable for rehabilitation of critical lands (Nurtjahya *et al.* 2008). In addition, *nyamplung* adapts to different sites distributed along coastal regions, adjacent to lowland areas, and also occasionally grows inland at higher elevations, up to 800 m asl at the equator (Prabakaran & Britto 2012). This species also tolerates salt spray, wind, brief periods of waterlogged soils, and drought (Prabakaran & Britto 2012). In the present, plant establishment of *nyamplung* generally uses containerized (polyethylene bag) media seedlings. However, using polyethylene bag in the large scale can pollute the soil because polyethylene is difficult material to be decomposed (Vaverkova *et al.* 2014).

Several alternative methods for establishment of tree plantation was applied in several regions in the world, such as direct seeding (Bonilla-Moheno & Holl 2011) and bare root seedlings (Li *et al.* 2011). Direct seeding can be applied in large areas rapidly, lower cost compared with transplanting seedlings, and the seedlings' development had well-structured root systems (Douglas *et al.* 2007). However, direct seeding also has a number of potential disadvantages, including difficulties sourcing large quantities of viable seeds (Douglas *et al.* 2007), lack of information on optimum sowing techniques (Lof & Birkedal 2009), variability in commencement and duration of seed germination, predation of seed and seedlings by insects and rodents (Birkedal *et al.* 2010), and competition from the existing vegetation, particularly grasses and scrubs (Nurhasybi & Sudrajat 2009; Nurhasybi & Sudrajat 2013). On the other hand, bare-root seedlings have been promoted for reforestation projects because it can be easily, hand-carried by planting volunteers or crews and they are typically less expensive to produce than containerized or blocked media seedlings (Annela *et al.* 2008). Nonetheless, the survival rate of outplanting of bare-root seedling is very affected by the planting time or season (Repáč *et al.* 2011; Klavina *et al.* 2013). Blocked media seedlings were able to increase the seedling survival (9%), high (73%), and diameter (49%) on *Caliandra calothyrsus* outplanting study compared with containerized seedling using top soil media (Suita *et al.* 2017). However, production and planting practices especialy in seedlings tansportation of blocked media seedlings is more expensive and complicated.

Plants establishment by containerized seedling transplanting are more uniform, can tolerate or escape early environmental/biological stresses, and can achieve earlier maturity than direct-seeded plants (Liptay *et al.* 1982). The choice of a planting system depends on the cost of plant establishment, plant performance after establishment, and the economic value of the subsequent yield. The objective of this study was to assess how methods of plant establishment, such as containerized seedling, blocked media seedling, bare root seedlings or direct seeding using seed pellet and no treated seeds, influences survival, and early growth of *nyamplung*.

Methods

Plant material *Nyamplung* seed was collected at Carita Coast, Serang District, Banten (6°11'37"−6°20'21" S, 105°50'32"−105°49'34"E, 0−5 m asl altitude) on August 2015. *Nyamplung* seeds were collected in the forest floor by taking the fresh and mature fruits. Seed processing was carried out at the Seed Testing Laboratory, Forest Tree Seed Technology Research and Development Institute, Bogor. The shell of *nyamplung* fruit was removed manually using grinding tool by carefully breaking the seed shell to avoid seed damages. The seeds without shell were used for seed germination (seed sowing) and direct seeding activities.

Seed pelleting production Pelleting is the process of coating seeds with inert materials to make them uniform in size and shape. Process of enclosing the seed carried out by mixing several materials, i.e. soil (10%), compost (40%), rice husk charcoal (30%), lime (10%), and tapioca (10%) (Nurhasybi & Sudrajat 2017). Soil, compost, rice husk charcoal, and lime functioned as filler materials, while tapioca had a role as adhesive material. Tapioca flour was added to hot water (1:5 v/v) and stirred evenly and mixed with the filler materials. Pellet was formed as a cubicle in the size 4 cm × 4 cm × 3 cm. Seed and 2 g of mycorrhizae fungus (*Glomus* sp.) were added at the time that pellet media was formed. One pellet was filled with one seed. *Nyamplung* seed character is categorized as intermediate seed, so the seed pellets were then dried at room condition (27 °C) for 2 days and the seed pellets were applied in direct seeding. Seed pellet in dry condition had average weight 10.8 g.

Blocked seedling media production Blocked media seedling production
Blocked media was made by mixing some materials, i.e. soil 20%, compost 40%, rice husk charcoal 20%, lime 10%, tapioca 10%, mycorrhizae fungus 3 g (Glomus sp.) (Suita et al. 2017). The blocked media was made manually using a tube sized of 10 cm in height and 5.5 cm in diameter with blocked media dry weight 250 g. The top part of blocked media was put a small hole for transplanting the seedling in the nursery. Three grams of mycorrhizae fungal inoculum were added in the hole of the blocked media. The nursery was established at Nagrak Research Station, Forest Tree Seed Technology Research and Development Insitute (FTSTRDI) Bogor. Seeds without shell were sowed directly in the hole of the blocked media. The seedlings were further maintained for 3 months in the nursery, following the nursery conditions of two months in shaded area (light intensity 50%) and one month in open area.

Containerized seedling production in nursery Containerized seedlings of nyamplung were carried out using polyethylene bag (10 in height and 6 in diameter). The volume of media of containerized seedling was slightly higher than blocked media. Media for containerized seedlings was top soil, composted cow manure, and rice husk (3:1:1 by volume). The nursery location and the next proses of the containerized seedling production was similar with the blocked media seedling production.

Bare-root seedling production *Nyamplung* seeds without shell were sown at in the conventional nursery beds with the size of 5 m in lenght, 1 m in widht, and 20 cm in height at

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Nagrak Research Station, Bogor. The media on nursery bed were mixed media of top soil and sand (1:1 by volume). Seeds were spread evenly by sowing spacing of 5 cm × 10 cm (200 seeds m^{-2}) and they were maintained by watering and weed management. The seedlings were continuously grown until 4 months old in the same media in convensional nursery beds with the conditions of three months in shaded area (light intensity 50%) and one month in area without shading net (open area). Seedlings were harvested carefully and brought to planting location using humid materials (humid old newpapers or cocofeat). Planting activities were carried out on one day after bare-root seedlings harvesting.

Field experiment The plant age was set on the same age. The direct seeding aplications were conducted in the same time with the sowing of seed for preparing the bare root, blocked media, and containerized seedlings on October 2015. Transplanting the seedling from nursery to the field test was carried out on February 2016. The planting trial was established at Parung Panjang Forest Research Station, FTSTRDI Bogor, West Java (06°20'42" S, 106°06'15" E, 52 m asl altitute). Mean annual precipitation of the location was 2,440 mm with high precipitation falling between December-February. Soil at the site have low levels of N, P, K, and C-organic, with soil pH 4.8. The planting site is a flat area covered with dense weed, which grow rapidly even after cleaning (Sudrajat *et al*. 2016).

A randomized block design with four blocks and five treatments (plant establishment methods) was used for testing the successful of the methods. The five methods were: direct seeding, direct seeding with seed pelet, planting with bareroot seedlings, planting with containerized seedling, and planting with blocked media seedling. For direct seedling application, within each block, 50 circle plots were established with diameter 40 cm. The circle plots were cleared by removing the scrubs, grasses, and litter layer. In each circle plot, 5 seeds or seed pellets were sown in the small holes (diameter ±5 cm) that made by digging using sharp tipped stick and burying seed or seed pellet in the soil in approximately 3−5 cm deep. The distance among sowing holes was about 20 cm. One sowing hole was contained by one seed or one seed pellet. Laying down seed or seed pellet in the hole was adopted from Bonilla-Moheno and Holl (2011) who reported that seed burial has been shown to increase germination and establishment. Total of sowed seeds and seed pelets was 2,000 (1,000 seeds and 1,000 seed pellets). Bareroot, containerized, and blocked media seedlings were planted in a hole with size of 30 cm × 30 cm × 30 cm and 2 m × 2 m planting spacing. Average of seedling height of blocked media, containerized, and bareroot seedlings were 26 cm, 24 cm, and 18 cm, respectively. In each block, 100 seedlings were planted (total of 400 seedlings per treatment). After seeds were sowed and seedlings were planted, no management was performed around the plots or seedlings to evaluate seed and seedling performance under natural conditions.

Measurement and estimation of plant establishment costs Survival, height, and diameter were measured for 9 months old seedlings (for direct seeding 9 months after sowing and for transplanted seedling 4 months in nursery + 5 months after planting). The survival for direct seeding use the term proportion of live seedlings (number of sowing holes with live seedlings) per number of seeds or seed pellets buried (total number of sowing holes), while for transplanted seedling, seedling survival was calculated as proportion of live seedlings per number of seedlings planted. Height was measured as the distance between the soil surface and the apical meristem, while diameter was measured at the collar diameter.

Three seedlings per treatment were randomly selected to identify the root development. Transplanted and direct-seeded seedlings were manually excavated and the roots were lifted and elutriated with water to remove soil and partitioned into roots, stems, and leaves to identify and measure the taproot length, number and biomass of basal and lateral root (below-ground biomass), and biomass of stem and leaves (above-ground biomass). Roots, stems, and leaves were dried in a drying oven at 70 °C for 48 h and weighed to ±0.0001 g.

To estimate costs, the calculation followed the regulation of plant establishment standard of industrial plantation and community forest (Regulation of Ministry of Forestry, Republic of Indonesia No. P.64/Menhut-II/2009) with some modifications and field experience of worker performance per day in Parung Panjang Forest Research Station. The calculation based on establishment costs for 1,000 target plants (±1 ha in 3 m × 3 m spacing) at first year activity, including seed procurement, nursery, and planting activities.

Data analysis Plant establishment method effects on seedling survival and growth were assessed by using SPSS (v21) for analysis of variance (ANOVA) according to a randomized complete block design. Percentage variables were arcsine square root transformed in order to meet assumptions of normality and homogeneity of variances. Duncan's multiple range test was used to determine the seedling survival, growth, and biomass differences among plant establishment methods.

Results and Discussion

Seedling growth and survival Plant establishment methods significantly affected survival, height, and diameter of *nyamplung* seedlings at age 9 months old. Comparison study for seedling survival revealed that the transplanting of blocked media seedlings and containerized seedlings statistiscally recorded the same values and they were significantly different with survival of bare-root seedlings and direct seeding. Blocked media and containerized seedlings had on average higher survival than bareroot seedling and direct seeding (Table 1). Similar results were reported by Leskovar and Cantliffe (1993) on *Capsium annum* and van Sambeek *et al*. (2016) on *Quercus bicolor*. In this study, blocked media and containerized seedling had the highest values of seedling height and blocked media seedlings also had the highest diameter. Direct seeding using the seed showed the lowest survival and growth, followed by direct seeding and by seed pellet. Herbaceous vegetation

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Table 1 Comparison of *nyamplung* (*Calophyllum inophyllum*) seedling growth on the several plant establishment methods

Plant establishment methods	Survival (%)	Seedling height (cm)	Seedling diameter (mm)
Direct seeding	20 ± 5 d	25.86 ± 9.06 c	4.38 ± 1.54 c
Direct seeding using seed pellet	62 ± 5 c	32.77 ± 0.69 b	6.14 ± 2.10 bc
Bareroot seedling	84 ± 4 b	37.38 ± 9.63 b	6.34 ± 1.43 b
Containerized seedling	98 ± 2 a	46.15 ± 5.40 a	7.79 ± 2.62 ab
Blocked media seedling	98 ± 1 a	48.12 ± 7.85 a	9.26 ± 1.11 a
F-test			
Planting method	230.314**	21.823**	7.512**
Block		0.858^{ns}	0.335^{ns}

The data shown are mean ± standard error of six replicates; Different letters a, b, c, d and ab denote significant difference ($P \le 0.05$) between different treatments; ** = Significant at $P < 0.01$, * = Significant at $P < 0.05$, ns = no significant.

(weeds) seriously affected the survival and growth of direct seeding through interspecific competition for light, water, and nutrient, meanwhile the blocked media, containerized and bareroot seedlings can overcome competing vegetation because of the greater seedling size.

Plants established by transplanting seedlings were more uniform, they could tolerate or escape early environmental/biological stresses and can achieve earlier maturity than direct-seeded plants (Liptay *et al.* 1982). In this study, blocked media and containerized seedlings were the best growth and based on the standard deviation, they were more uniform. According to Repáč *et al.* (2011), containerized seedlings were very suitable material for afforestation and reforestation of critical or eroded sites. Nonetheless, in this study of *nyamplung*, blocked media and containerized seedlings provided the superior seedlings in height and diameter growth. Several researches reported that blocked media could increase seedling growth and it was lighter in weight than containerized seedlings that use soil media as a prominent media (Nursyamsi 2015; Suita *et al.* 2017) because the materials of blocked media were completed by nutrient (compost), mycorrhizae, and media conditioning (charcoal and lime).

The growth of bareroot seedlings were lower than in blocked media and containerized seedlings. The risk of lower physiological quality is substantially higher in bareroot than in containerized planting stock. The disadvantage of bare-root seedlings is that having lost the protective soil cover, roots are exposed and prone to desiccation (Anella *et al.* 2008), so they take longer to establish good contact between roots and soil after planting. A decisive parameter is the condition of the root system, first of all the growth of new roots that facilitate the uptake of nutrients, and water for rooting and bud-breaking of plants (Repac *et al.* 2011). However, in this study, bareroot seedling had better survival and growth than direct seeding.

Direct seeding can result in slow, variable, and reduced plant stands when extreme high or low temperatures, water stress, heavy rains, or the presence of soil-borne pests and diseases occur at the time of seeding. Application of seed pelleting in direct seeding improved the survival and growth of target seedlings. In previous studies, pelleted seeds were found to improve biological control capacity and increase the percentage and speed of germination (Choong *et al.* 2006). Other research also stated that seed pelleting was able to improve the germination on *Lycopersicon esculentum* and the effect was similar with priming treatment (Govinden-Soulange & Levantard 2008). According to Jyoti and Bhandari (2016), the benefits of seed pelleting were improving of seed germination, protection from abiotic or biotic stress, attraction of moisture, supply of growth regulation nutrients and influence of micro-environment. The addition of mycorrhizal on direct seeding practice using seed pellets was also able to improve the seedling survival such as on *C. inophyllum* and *Enterolobium cyclocarpum* (Nurhasybi & Sudrajat 2017). Mycorrhizae can increase plant growth (Bayozen *et al.* 2009), alter cell biochemical composition, and reduce plant diseases (Neeraj & Singh 2011). Mycorrhizae is also able to increase plant resistance to drought stress (Manoharan *et al.* 2010). Nurhasybi and Sudrajat (2017) also reported suitability of *nyamplung* for direct seeding application. The species could be competed with grasses, shrubs, and relatively also tolerant to drought, waterlogging, and shade or low lighting.

Root development and biomass No statistically significant effect of plant establishment methods was observed on some root development parameters, except for tap root biomass, basal root biomass, bellow-ground biomass, above-ground biomass, and top-root ratio. Direct seeding using seed pellet tended to better root formation, especially in tap root length (50 cm), tap root biomass (24.9 g), and bellow-ground biomass (29.9 g). The highest above-ground biomass (108.3 g) was resulted by blocked media seedlings (Table 2). Seedlings had greater total biomass were suggested higher nutrient availability in that treatment (Cole *et al.* 2011) that revealed by blocked media seedlings.

Blocked media and containerized seedlings had more number of basal roots with higher biomass (Table 2). Blocked and containerized media may provide a more

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Table 2 Root development and biomass of *nyamplung* (*Calophyllum inophyllum)* seedling of various plant establishment methods

Plant establishment methods	TRL	NBR	NLR	TRB	BRB	LRB	BGB	AGB	TRR
Direct seeding	43.3±13.9	18±3	173±46	19.1±0.8 b	3.8±0.4 c	2.3±0.8	22.3±1.9 c	79.2±16.5 bc	4.6±2.9 ab
Direct seeding using seed pellet	50.0±23.3	16±1	166±72	24.9±5.9 a	3.5±0.1 c	1.4±0.1	29.9±6.0 a	83.4±16.2 bc	3.8±0.3 ab
Bare root seedling	48.6±1.6	15±4	133±39	16.1±1.5 b	5.7±0.7 b	1.7±0.5	25.4±3.8 ab	71.5±6.2 c	3.8±0.3 b
Polyethylene bag seedling	33.0±2.6	18±1	155±7.8	16.1±0.7 b	7.0±0.3a	1.6±0.2	24.7±0.9 ab	96.2±17.0 ab	4.5±0.5 ab
Blocked seedling media	39.0±2.8	18±1	157±23	17.8±5.9 b	6.3±0.7 ab	1.4±0.5	26.9±1.0 ab	108.3±9.1 a	5.3±0.4 a
F-test	1.302^{ns}	1.493^{ns}	0.483^{ns}	4.091*	36.895**	2.994^{ns}	24.517**	898,464**	4.522*

TRL = taproot length, NBR = number of basal root, NLR = number of lateral root, TRB = tap root biomass, BRB=basal root biomass, LRB = laterat root biomass, BGB = bellow ground biomass, AGB = above-ground biomass, TRR = top root ratio. The data shown are mean ± standard error of six replicates; Different letters a, b, c, d, and ab denote significant difference ($P \leq 0.05$) between different treatments; ** = significant at P <0.01, * = significant at P <0.05, ns = no significant.

uniform moisture level around the hypocotyl and promoting early basal root growth than direct seeding. Conversely, the lateral roots were more developed in direct seeding. Similar result also was reported on *C. annum* (Leskovar & Cantliffe 1993).

Seedlings produced after direct seeding develop a natural root system and may therefore be better prepared to withstand the conditions prevailing at the regeneration site. For example, in containerized holm oak (*Quercus ilex*) seedlings, tap root development has been found to be restricted to the length of the container (Tsakaldimi *et al.* 2009), which may lead to increased sensitivity to drought. In this study, the tap root of blocked media and container (polyethylene bag) seedlings had shorter that the tap roots of direct seeding (Table 2). According to Leskovar and Cantliffe (1993), taproots accounted for only 4% of total root mass from *C. annum* grown from transplants and 18% of seeded plants. The root systems of bare rooted seedlings, on the other hand, are usually trimmed before transplantated to the forest; in some tree species, such loss of root biomass increases mortality and decreases growth under field conditions. However, the choice of a planting system depends on the economics of plant establishment, plant performance after establishment, and the value of the subsequent yield.

Comparison of estimeted costs A comparison among plant establishment using direct seeding, bareroot seedlings, and blocked media seedlings is presented in Table 3. There was large variation in total cost, depending mainly on plant size and material. However, the comparison showed that to attain 1,000 plant ha^{-1}, direct seeding using seed pellet was generally the cheaper option. One of the largest uncertainties in the calculation of direct seeding cost is the assumption that the seedling survival, because the condition will depend on the effectiveness of sowing time, microclimate, and seed viability.

Based on the calculation (Table 3), the estimated cost of container and blocked media seedling was in range of standard of Ministry of Forestry-Republic of Indonesia. Plant establishment costs (seedling preparation in nursery until outplanting) using the containerized seedlings range from IDR5,320,400−IDR7,315,551 (MoF 2009). However, the cost of 1,000 plant establishment (9 months of plant age) using direct seeding was lower almost half of transplanting costs of containerized and blocked media seedlings. The result was similar with Atondo-Bueno *et al*. (2018) report on *Oreomunnea mexicana* in a secondary tropical montane cloud forest in central Veracruz, Mexico, stated planting by containerized seedlings was almost two times more expensive than direct seeding. According to Cole *et al.* (2011), cost of transplanting with seedling is 2–4 times higher compared to direct seeding depending on the level of maintenance given. The estimated costs for planting nursery-raised tree seedlings at the tropical pastures (Zahawi & Holl 2009) were 10 times higher per 100 seedlings before maintenance costs were taken into account and 10–30 times higher after maintenance costs, which vary depending on the objectives of the planting effort and the initial vegetation type.

Implication for *nyamplung* plantation establishment
Establishment of *nyamplung* plantation can be conducted by planting of blocked media seedling, containerized seedling, and direct seeding using seed pellets. Blocked media and containerized seedlings are more effective to rapidly develop canopy but more expensive than direct seeding so that the methods are recommended for intensive silviculture practices of *nyamplung* to establish seed sources mainly in accelerating seed production. Direct seeding using seed pelleting technology can be applied on the critical lands rehabilitation to cover or restore large areas. The method is an alternative method for accelerating of critical lands covering and it can also be used for establishing *nyamplung* stands for seed production in large areas.

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Table 3 Comparison of estimated costs for direct seeding, bareroot seedling, containerized seedling and blocked media seedling to establish 1000 *nyamplung* (*Calophyllum inophyllum)* plants

Item	Direct seeding		Direct seeding using seed pellet		Bareroot seedling		Containerized seedling		Blocked media seedling	
	Unit	Cost (IDR)	Unit	Cost (IDR)	Unit	Cost (IDR)	Unit	Cost (IDR)	Unit	Cost (IDR)
Seed cost[1]	5,000	50,000	1,613	16,130	1,429	14,290	1,224	12,240	1,224	12,240
Seed pellet production[2]			1,613	233,885						
Seedling production[3]					1,190	466,480	1,020	624,240	1,020	770,100
Transportation[4]	5,000	50,000	1,613	50,000	1,190	100,000	1,020	400,000	1,020	400,000
Land preparation[5]	1 ha	2,706,500	1 ha	2,706,500	1 ha	2,706,500	1 ha	3,721,400	1 ha	3,721,400
Sowing cost[6]	5,000	500,000	1,613	161,300						
Planting preparation[7]					1,000	500,000	1,000	500,000	1,000	500,000
Planting hole digging cost[8]					1,000	300,000	1,000	500,000	1,000	500,000
Planting cost[9]					1,000	100,000	1,000	200,000	1,000	200,000
Total (IDR)		3,306,500		3,167,815		4,172,980		5,946,864		6,091,500

[1]*Nyamplung* seed price IDR3,000 kg^{-1}, germination capacity 80%, seedling survival for each method based on Table 1; [2]Production cost per pellet (appendix 1); [3]Production cost bareroot, containerized and blocked media seedling (appendix 1); [4] pick up charge for blocked media and containerized seedlings and courier charge for seed/seed pellet;[5] based on standar of Ministry of Forestry, Republic of Indonesia No. P.64/Menhut-II/2009 (Standard biaya pembuatan hutan tanaman industri dan hutan tanaman rakyat), range of land preparation cost IDR 2,706,500-3,721,438; [6]Sowing cost IDR 100 per seed/seed pellet; [7]Planting preparation (making and seting up planting marker/stake in the field) for 1000 seedlings andIDR 500 per stake, seedling stock was prepared for replanting; [8, 9]Planting hole digging and planting cost based on experience of work performance per worker in Parung Panjang, Bogor, IDR500 per a planting hole, IDR200 per planting of a seedling.

Appendix 1 Estimated cost for production of seed pellet, bareroot, containerized, and blocked media seedlings

Materials and labor cost	Seed pellet			Bareroot seedling			Containerized seedling			Blocked media seedling		
	Composition (%)	Kg	IDR	Composition (%)	Kg	IDR	Composition (%)	Kg	IDR	Composition (%)	Kg	IDR
Media:												
- Top soil[1]	10	1	200	50	5	1,000	50	5	1,000	30	2	400
- Compost[2]	40	4	4,000	-	-	-	30	3	3,000	30	4	4,000
- Rice husk[3]	-	-	-	-	-	-	20	2	1,000	-	-	-
- Sand[4]	-	-	-	50	5	1,500	-	-	-	-	-	-
- Rice husk charcoal[5]	30	3	4,500	-	-	-	-	-	-	20	2	3,000
- Lime[6]	10	1	1,000	-	-	-	-	-	-	10	1	1,000
- Tapioka[7]	10	1	3,800	-	-	-	-	-	-	10	1	3,800
- Total cost for media		10	13,500		10	2,500		10	5000		10	12,200
Materials (media) cost per a product[8]			45			41.67			152			305
Polyethylene bag[9]			-			-			60			-
Mycorrhizae application[9]			50			-			-			50
Seedling production[10]			50			50			100			100
Seedling maintenance[11]			-			300			300			300
Total cost per a product			145			391.7			612			755

The media estimated cost based on 10 kg mixed material; [1]top soil IDR 200 kg^{-1}; [2]compost IDR 1,000 kg^{-1}, [3]rice husk IDR 500 kg^{-1}; [4]sand IDR 300 kg^{-1}; [5]rice husk charcoal IDR 1,500 kg^{-1}; [6]lime IDR 1000 kg^{-1}; [7]tapioka IDR 3,800 kg^{-1}; [8]material cost per a product based on number of product from 10 kg mixed material (300 seed pellets, 60 bareroot seedlings, 33 container seedlings, 40 blocked media seedlings); 8One kg polyethylene bag IDR 30,000 containing ±500 bags; Mycorrhizae fungus IDR 25,000 kg^{-1}(2 g = IDR 50); [10]seedling production cost including seed sowing, filling the container or making blocked media; [11]seeling maintenance including watering, weeding etc.

Conclusions

Plant establishment methods influenced the survival and growth of nyamplung at age of 9 months old, planted in Parung Panjang, Bogor. The blocked media and containerized seedlings had the highest survival (98%), height (48.12 cm and 46.15 cm, respectively), collar diameter (9,26 mm and 7.79 mm, respectively) and more number of basal roots with higher biomass followed by bareroot seedlings. Direct seeding using seed pellet tended to better root formation, especially in tap root length (50 cm), tap root biomass (24.9 g) and bellow-ground biomass (29.9 g). Based on the estimated cost for establishing 1000 target plants, direct seeding was cheaper almost half of transplanting of containerized and blocked media seedlings. When the planting objective is to rapidly establish canopy, then planting fast-growing blocked media and containerized seedlings are more effective method but higher in cost approach. Direct seeding using seed pellet can be recommended as a complimentary method to more intensive restoration efforts or alternative method for plant establishment of nyamplung on the degraded lands, especially in remote areas.

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