DOI https://doi.org/10.18551/rjoas.2017-11.53

GROWTH OF LUJA PLANTS (PERISTRHOPHE BIVALVIS MERRILL) AT DIFFERENT LIGHT INTENSITIES AND MATERIAL TYPES OF CUTTINGS

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ABSTRACT
Light intensities and planting materials of cuttings are two critical factors affecting plant growth. This research was aimed to find out the effects of light intensities and planting material types of cuttings affecting the growth of *Luja* plants. The light intensity treatments consisted of 100%, 65%, 35%, 15% and the planting material types covered both basal and tip cuttings. The design used was Split Plot Design and continued with Duncan's Test. The results showed that there was no interaction between light intensities and cuttings, but the effect of light intensities and cuttings was singularly found in the SLA, RGR, LAD, LAR, and NAR variables. Moreover, *Luja* plants could grow well at the light intensity of 15% - 65% with the optimum light intensity of 35%. Both basal and tip cuttings could be used as the planting materials. However, the material type of cuttings that could accelerate the vegetative phase-growth of *Luja* plants the most was tip cuttings. *Luja* is categorized as a plant that can grow in full light conditions.

KEY WORDS
Luja, growth rate, light intensity, cuttings.

Before the presence of synthetic dyes, *Luja* plants (*Peristrhophe bivalvis* Merrill) has often been utilized and used by craftsmen as the raw material of fiber dyes in Maluku Province, Indonesia (Melati, 2016). In Vietnam, it is even used for food coloring (Dang *et al.,* 2014). To date, the utilization of *Luja* is only explorative. *Luja* is classified as a wild plant. The results of the research on growing habitats and other cultivation aspects have not been examined further in Indonesia, so there is no clear technical guidance on growth requirements. The purpose of this research was to find out the optimum light intensity and appropriate cutting material type for *Luja* growth. The intensity of light plays an essential role in plant metabolism, affecting the plant growth at the beginning of nursery (Mukhtar, 2016). Previous research has suggested that some of the factors that can influence the plant pigment resulted are light (Sirait, 2008; Ferus and Arkosiova, 2001), as well as the quantity and quality of the plant (Moacyr *et al.,* 2000; Fu *et al.,* 2012).

Different parts of cuttings give effects at the beginning stage of growth to production. Tip cuttings are recommended for growing plants by concerning on the position of the cuttings, the number of nodules, particularly in some plants such as *Stevia Rebaudiana* Bertoni, *Alstonia scholaris* (L.) R., sweet potatoes, *Plectranthus vettiveroides* (Mashudi and Adinugraha, 2015; Mardi *et al.,* 2016). The intensity of light is an environmental factor that must be regulated under low conditions to support the initial growth of cuttings without limiting the process of photosynthesis (Tombosi *et al.,* 2015). This is because light can provide a stimulus to the apical tissue enlargement, biomass formation, leaf area and even the visible plant pigment on the plant growth itself (Rozali *et al.,* 2011 ; Mauro *et al.,* 2011 ; Zervoudakis *et al.,* 2012 ; Gulshan *et al.,* 2012 ; Safeer *et al.,* 2013).

Biomass allocation in each organ of plants varies depending on the species and shade percentages (McAlpine & Jesson, 2007; Devkota & Jha, 2010; Santelices e*t al*., 2015).

METHODS OF RESEARCH

This experiment was conducted using pots in Dadaprejo Subdistrict, Batu City, East Java at an altitude of 450 m asl (above sea level) and the biomass observation was performed in the laboratory of Environmental Resources, Faculty of Agriculture, Brawijaya University, which took place from October 2016 until January 2017. The treatment consisted of two factors namely light intensities (I) and planting materials (S) of cuttings. The light intensities covered 100% (I0), 65% (I1), 35% (I2) and 15% (I3) while the planting materials of cuttings consisted of basal cuttings (S1) and tip cuttings (S2), resulting in a total of 8 treatments. The treatment combinations used in this experiment were I0S1 (100% light intensity + basal cutting), I0S2 (100% light intensity + tip cutting), I1S1 (65% light intensity + basal cutting), I1S2 (65% light intensity + tip cutting), I2S1 (35% light intensity + basal cutting), I2S2 (35% light intensity + tip cutting), I3S1 (15% light intensity + basal cutting), I3S2 (15% light intensity + tip cutting).

The basal cuttings (S1) were taken from the basal parts of the secondary branches (stems) which were cut by four internodes while tip cuttings (S2) were the tip parts of the secondary branches (stems) consisting of four internodes calculated from the bud. The design used in this research was Split Plot Design repeated 3 times and continued with Duncan's Test to determine the difference of each treatment at the confidence level of 0.05 varieties using a Genstat software. The plants were placed in a shaded area for 4 weeks and then transferred to the planting area following the treatments being experimented. A destructive observation was performed at 2 weeks since after that. The subsequent treatments and observation were made at the interval of 2 weeks until the plants reached the age of 12 weeks after the treatments. The destructive observation consisted of Specific Leaf Area (SLA), Relative Growth Rate (RGR), Leaf Area Duration (LAD), Leaf Area Ratio (LAR) and Net Assimilation Rate (NAR). The formulas used to calculate the SLA, RGR, LAD, LAR and NAR variables according to Uzun and Kar, 2004; James and Drenovsky, 2007; Sugito, 2009; Poorter *et al.,* 2012; Sitompul, 2016 are as follows:

Specific Leaf Area (SLA). SLA is the formation of leaf area per assimilate substrate unit shaped or the depiction of leaf thickness. SLA is obtained from the ratio of Leaf Area / LA (cm) to dry Leaf Weight/LW (g). SLA observation was conducted as much as 6 times, covering at the ages of 2, 4, 6, 8, 10 and 12 weeks after the treatments (wat) of transplanting:

$$\text{SLA} = \frac{LA}{LW}$$

Relative Growth Rate (RGR). RGR is the index of plant growth obtained from the total dry weight of the plants / W (g) at a given period/ T (day) to determine the growth rate during the growing period. RGR observation was performed as much as 5 times with the observation intervals of 2-4 weeks, 4-6 weeks, 6-8 weeks, 8-10 weeks and 10-12 weeks after the treatments (wat) of transplanting.

$$\text{RGR} = \frac{\ln W_2 - \ln W_1}{T_2 - T_1}$$

Leaf Area Duration (LAD). LAD is the duration of the ability of leaf unit to do photosynthesis, determined by Leaf Area (LA) and Time (T). LAR observation was carried out as much as 5 times with the observation intervals of 2-4 wat, 4-6 wat, 8-10 wat, and 10-12 wat.

$$\text{LAD} = \frac{LA_2 - LA_1}{\ln LA_2 - \ln LA_1} \times (T_2 - T_1)$$

Leaf Area Ratio (LAR). LAR is the quality of light received by leaves to form the whole plant organs. LAR can be calculated by comparing the Leaf Area (LA) with the total dry Weight (W) of the plants. LAR observation was conducted as much as 5 times with the observation intervals of 2-4 wat, 4-6 wat, 6-8 wat, 8-10 wat, 10-12 wat.

$$LAR = \frac{LA_2 - LA_1}{W_2 - W_1} \times \frac{\ln W_2 - \ln W_1}{\ln LA_2 - \ln LA_1}$$

Net Assimilation Rate (NAR). NAR is the ability of a unit of leaf area to produce biomass. NAR can be calculated by knowing the total dry Weight/ W (g), Leaf Area/ LA (cm), and observation Time/ T (days). NAR observation was performed as much as 5 times with the observation intervals of 2-4 wat, 4-6 wat, 6-8 wat, 8-10 wat, and 10-12 wat.

$$NAR = \frac{W_2 - W_1}{LA_2 - LA_1} \times \frac{\ln LA_2 - \ln LA_1}{T_2 - T_1}$$

RESULTS AND DISCUSSION

Specific Leaf Area (SLA). In this research, the interaction between light intensities and planting material types of cuttings did not influence the growth of *Luja* plants. The effect of light intensities on the SLA was seen at all observation times, except 8 wat (Table 1). *Luja* plants exposed to the light intensity of 15% had a higher SLA value and were different from other treatments at the ages of 2 and 4 wat. In the other hand, *Luja* plants exposed to the light intensity of 35% obtained the highest SLA value at the age of 6 wat. However, they showed insignificant differences from those exposed to the light intensities of 65% and 15% but indicated significant differences from those exposed to the light intensity of 100%. *Luja* plants exposed to the light intensity of 15% had a higher SLA value and were different from the other treatments at the ages of 2 and 4 wat. At the age of 6 wat, the SLA of the plants exposed to the light intensity of 35% got the highest value and was the same with those exposed to the light intensity of 65% and 15% but different from those exposed to the 100% light intensity. The SLA values of all treatments began to decline at the age of 10 wat, but the SLA of the plants with the exposure of 35% light intensity obtained the highest and consistent value. This research is similar to the previous research on *Taxus baccata* L. plants that are tolerant to low light intensities and positively influence the SLA, leaf area, total chlorophyll, and, in contrast, give an adverse effect on the plant height and stem diameter (Perrin & Mitchell, 2013). Besides, this research is also in line with research on low SLA values at high intensities for *Ocimum basilicum* L. plants (Caliskan *et al.,* 2009). The genetic ability of *Luja* plants exposed to the low light intensities tended to widen the leaves to receive light. The plants located in the environments with limited light would use the light as efficiently as possible to form carbohydrates, which are characterized by higher SLA values that also can be used as the characteristics of shade-tolerant plants such as *Nothofagus leonii* (Santelices e*t al*., 2015). Furthermore, according to Ma *et al.* (2015), plant performance will be different in shaded conditions, but the biomass and production under low light conditions will affect the carbohydrate production. Similarly, the coffee plants cultivated on a shaded land will have a higher SLA value than those cultivated on a full light-exposed land (Bote & Struik, 2011). The part of the cuttings that affected the specific leaf area was only found at the age of 4 wat, and there was no significant effect on the subsequent observations. The cuttings derived from the base (basal cuttings) obtained higher SLA values than the tip cuttings. The growth rate of the basal cuttings could be seen towards the generative phase in which the formation of leaves and biomass was produced quite a lot, thus affecting the SLA values. The success of stem cuttings is also influenced by the ability and morphology of the stem of the plant itself. For example, the cultivation of fig tree (*Ficus carica* L) using a tip, middle, and basal

cutting has the same statistical number of leaves at the ages of 2-10 weeks after planting (Yulistyani *et al.,* 2014).

One of the growth indicators that were used as a measure in identifying the determinants of the growth and biomass of *Luja* plants was the specific leaf area. The quality and quantity of biomass produced were influenced by the number and size of the leaves. The habitats supporting the growth of *Luja* plants had low-light intensity conditions (shade plant), indicating that *Peristrhophe bivalvis* Merrill is tolerant to low light intensity although it also can grow in full light conditions. However, the increase in the leaf area was hampered by photo inhibition, resulting in smaller and fading leaves (Figure 1). The lower level of light intensity occurred in a more extensive leaf area. The same research result is also found on three varieties of *Dracaena sanderiana* with a larger leaf area at 50% - 70% shade. Higher shade levels will result in a larger leaf area on the three species of grass (Sirait, 2008; Srikrishnah and Sutharsan, 2012). Besides, the genetic factors of the plants also determine the limits of light absorption (Sevik *et al*., 2012). Furthermore, stem-tip and basal cuttings planted in full and shaded light intensities show different growths, in which the tip cuttings of *Plectranthus vettiveroides* plants also successfully grow if they are in shaded conditions. (Safeer *et al.,* 2013). The more excellent SLA value was, the thinner the *Luja* leaves would become. It is affected by the ability of leaves to enlarge the leaf tissue and allow light that enters the plant canopy as efficient as possible. This research is in line with the previous research on *Taxus baccata* L. plants, which are tolerant to low light intensities and positively influence the SLA, leaf area, total chlorophyll, and, in contrast, give an adverse effect on the plant height and stem diameter (Perrin & Mitchell, 2013). Besides, this research is also similar to the previous research on low SLA values at high intensities for *Ocimum basilicum* L.plants (Caliskan *et al.,* 2009).

Table 1 – Effect of Light Intensity and Planting Material on Specific Leaf Area (SLA) at the age of 2, 4, 6, 10 and 12 Weeks after Treatments (wat)

Light Intensity	Average Specific Leaf Area (cm/g/t)				
	2 wat	4 wat	6 wat	10 wat	12 wat
100%	224.75 a	166.49 a	150.69 a	131.69 a	119.12 a
65%	233.26 a	166.01 a	196.50 b	138.53 a	150.60 a
35%	290.52 a	207.18 b	232.20 b	214.27 b	213.01 b
15%	303.80 b	242.71 c	213.00 b	210.69 b	207.64 b
Planting Material					
Basal Cutting	ns	208.14 b	ns	ns	ns
Tip Cutting	ns	183.06 `a	ns	ns	ns

Description: The numbers followed by the same letters are not significantly different based on Duncan's Test at the 0.05 level; wat = weeks after treatment; ns = not significant.

Relative Growth Rate (RGR). In addition to SLA, the other indicator used to examine the growth of *Luja* plants in this research was the relative growth rate. The results of the variances found that the growth rate of *Luja* plants to the relative growth rate did not show an interaction between light intensities and planting materials of cuttings. The light intensities influenced the relative growth rate at the ages of 2-4 wat and 4-6 wat. In another side, the sections of cuttings showed its effects at the age of 4-6 wat (Table 2) while, at the other observation intervals, there was not found any significant difference. The plants exposed to the light intensities of 65%, 35%, and 15% differed significantly with those exposed to the light intensity of 100% (no shade) with the observation interval between 2-4 wat. In this phase, the highest RGR value was obtained at the light intensity of 15%. In contrast, entering the generative phase (aged 4-6 wat), the plants exposed to the light intensity of 100% got the highest RGR value compared to other treatments. The growth rate of *Luja* plants in shaded conditions at the beginning of growth was faster than that in unshaded conditions. However, the plants exposed to 100% light intensity began to adapt in the second month because of the influence of the biomass produced. Each herbaceous species has a different response to the growth rate of plants (Fini *et al.,* 2010). In shrubs, the highest relative growth rate was obtained in shaded conditions compared to the condition of full light intensity at the nursery

phase (Hastwell and Facelli, 2003). *Hevea brasiliensis* without shades at the age of 0-7 months after planting has a higher RGR value than those with shades of 33%, 55%, and 77%. However, the RGR values among the treatments are not different when the plants are at the age of 7-14 months after planting (Senevirathna *et al.,* 2003). As for *Adansonia digitata* plants, the highest RGR value is at 25% light intensity compared to 50-100% light intensities but among the treatments are not significantly different (Mukhtar, 2016). According to Wersal and Madsen (2013), aquatic plants of *Myriophyllum aquaticum* also have a high total RGR value in shaded conditions of 30% - 70%, affecting the physiological process that gives impacts on the difference in biomass among the plants exposed to full light intensity. Moreover, there is also a tendency to RGR increase of *P.notatum* and *S.secundatum* if placed in shaded conditions (Sirait, 2008). Each plant species has a different RGR value during the growing period in the forest area (Lamers *et al.,* 2006) and there is a positive relationship between the shaded plants and the values of RGR and LAR (Portsmuth and Niinemets, 2007).

Leaf Area Duration (LAD). The results of the variances found that there was no interaction between light intensities and material types of cuttings on the LAD variable but what made effects was a single factor. The light intensities did not affect at the age of 2 wat while the material types of cuttings showed significant differences between the basal cuttings and tip cuttings in which the tip cuttings obtained a higher value of LAD than basal cuttings. The light intensity of 35% got a high and consistent LAD value at each observation interval although it was not different from the results of 100% light intensity at the observation intervals of 4-6 wat and 6-8 wat. The plants exposed to 15% light intensity had the lowest LAD value and were not significantly different from those exposed to 65% light intensity at each observation interval. This indicated that the duration of *Luja* leaf area at the light intensity of 35% was more active or longer to photosynthesis than that of other treatments (Table 2). The value of LAD depends on the growth rate and the adaptability of the plant itself. The results of this research are supported by the previous research stating that LAD has a positive correlation with the plant growth and yield, and depends on the genotype of the plant itself (Hunkova *et al*., 2011). Moreover, this research found that the plant age also determined the LAD for each treatment and it seemed that the highest LAD achievement was at the observation interval of 8-10 wat. However, the LAD value experienced a decline after entering the aging phase. The similar case is also found in some cereal plants that have different LAD values depending on the types and ages of the plants (Verma *et al.,* 2016).

Net Assimilation Rate (NAR). Light plays an important role in improving plant biomass. In another side, Net Assimilation Rate (NAR) becomes an indicator in examining the effect of light on plant growth rates. Plant propagation by cutting techniques should take into account the optimum growing conditions supporting the growth of the nursery phase, vegetative growth to production. The results of this experiment showed that there was no interaction between light intensities and material types of cuttings affecting the net assimilation rate of *Luja* plants. However, it was found a separated effect of light intensities. The different light intensities affected the value of NAR at the ages of 4-6 wat and 8-10 wat, while the effect of the cuttings was seen at the age of 8-10 wat (Table 2).

Table 2 – Effect of Light Intensity and Planting Material on Leaf Area Duration and Net Assimilation Rate at the age of 2-12 wat

Light Intensity	Average Relative Growth Rate (g/t)		Average Leaf Range Duration (cm.week)					Average Net Assimilation Rate (g/cm/t)	
	2-4 wat	4-6 wat	2-4 wat	4-6 wat	6-8 wat	8-10 wat	10-12 wat	4-6 wat	8-10 wat
100%	0.03 ^{a}	0.12 b	ns	20983.00^{b}	37722.00^{bc}	44336.00^{b}	43749.00^{b}	8.28E-04 ^{b}	7.20E-05 ^{a}
65%	0.08 ^{b}	0.07 a		17837.00^{ab}	31602.00^{ab}	36551.00^{ab}	32802.00^{a}	6.31E-04 ^{a}	6.30E-05 ^{a}
35%	0.07 ^{b}	0.08 a		21226.00^{b}	38326.00^{c}	53266.00^{c}	43498.00^{b}	1.53E-03 ^{c}	1.33E-04 ^{b}
15%	0.09 ^{b}	0.07 a		13131.00^{a}	30552.00^{a}	32282.00^{a}	31620.00^{a}	6.66E-04 ^{ab}	7.50E-05 ^{a}
Planting Material									
Basal Cutting	ns	0.10 ^{b}	4844.00^{a}	ns				ns	3.10E-05 ^{a}
Tip Cutting		0.07 ^{a}	6908.70^{b}						1.41E-04 ^{b}

Description: The numbers followed by the same letter are not significantly different based on Duncan's Test at the level of 0.05; wat = weeks after treatment; ns = not significant.

Luja plants exposed to 35% light intensity obtained the highest NAR value and were significantly different from other treatments at the ages of 4-6 wat and 8-10 wat. Meanwhile, there was a similarity between the plants received full light intensity (100%) and those exposed to 15% light intensity but significantly different from those exposed to 65% light intensity at the observation interval of 4-6 wat. The plant growth in generative phase was different from the previous phase in which the highest NAR value was only found at the light intensity of 35% and significantly different from other treatments whereas the NAR values at the light intensities of 100%, 65%, 15% showed no difference. Adequate adaptability was shown by the high NAR values although the incoming light was blocked.

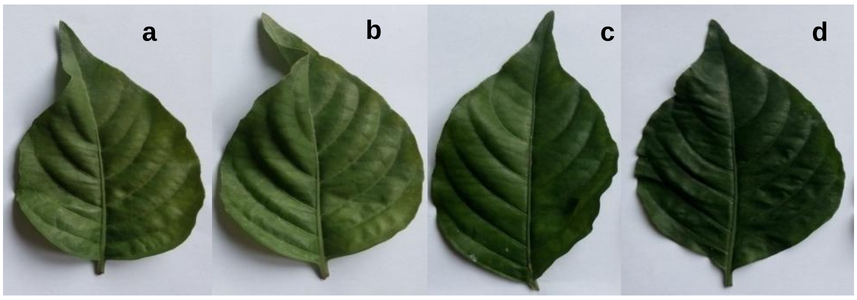

Figure 1 – Color Differences of *Luja* Leaves Based on Light Intensities:
a = 100%, b = 65%, c = 35%, d = 15%

The response of *Luja* plants to the limited light conditions was to enlarge the leaf area and increase the number of leaves. In other words, the low light intensity formed the plant character by absorbing the received light as much as possible, showing the darker leaf color or dark green (Figure 1). The similar thing is also found in *Adansonia digitata* (L.) plants that have the same NAR value when exposed to the light intensities of 25%-100%, particularly at the time of nursery (Mukhtar, 2016). Differently, herbal plants of *Epimedium pseudowushanense* B.L.Guo exposed to a high light intensity (90.9 ± 2.5 μmol.m-^{2}.s-^{1}) have a higher NAR value than those exposed to a low light intensity (Pan and Guo, 2016) and *Trema micrantha* (L.) Blume plants (Valio, 2001). Physiologically, there is a positive correlation between NAR, RGR and the area of leaves which actively carry out the process of photosynthesis in brushes during the initial growth originating from a tropical forest (Li *et al.,* 2016). Low light intensities vary for each type of plant to a certain limit (Sevik *et al*., 2012).

CONCLUSION

Light intensities and planting materials of cuttings are the growth requirement that must be considered in cultivating and propagating *Luja* plants. *Luja* plants can grow generally at the light intensity range of 15%-65% with the optimum light intensity of 35%. However, the planting material that is able to encourage and accelerate the vegetative growth of *Luja* plants the most is tip cuttings.

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