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Effect of Light Intensity and Fertiliser Levels on the Stock Plants of *Chengal* (*Neobalanocarpus heimii)* and Rooting of Its Subsequent Cuttings

(Kesan Keamatan Cahaya dan Tahap Baja ke Atas Pokok Stok Chengal (*Neobalanocarpus heimii)* dan Pengakaran Keratan)

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ABSTRACT

A factorial experiment of three light intensities and three fertiliser levels was carried out on the potted seedlings of Neobalanocarpus heimii *as stock plants for subsequent rooting of cuttings. Light intensities used were 25%, 50% and 100% of the open sunlight and the fertilizer levels were 0 g, 1 g and 2 g plant^{-1} month^{-1}. Results of 11 months after potting showed that the stock plants treated with 1 g and 2 g fertilizer had significantly better height and diameter increments than those without fertilizer in all light intensities tried. On the other hand, no significant effect of light intensity was obtained in height and diameter increments of the stock plants. Survival of stock plants of more than 86% was obtained in all light intensities tried with or without fertilizer application. Test on rooting of subsequent cuttings showed that light intensity of 25% and 0 g fertiliser, to stock plants gave the highest rooting percentage (73%) and the number of roots (2.0). The general trend showed that rooting decreased to below 60% when intensity of light was increased. In terms of size, cuttings with diameter between 1.2 mm and 2.3 mm is recommended as it yielded rooting of 65% to 75%. For practical application, a combination of 25% light intensity and 1 g of fertilizer plant^{-1} month^{-1} can be applied to the stock plants to maintain their healthy growth for continuous production of cutting materials for rooting.*

Keywords: Diameter; dipterocarp; height; rooting percentage

ABSTRAK

Satu uji kaji faktorial tiga keamatan cahaya dan 3 kadar baja telah dilakukan ke atas anak benih Neobalanocarpus heimii *di dalam tabung sebagai pokok stok untuk tujuan pengakaran keratan. Keamatan cahaya yang digunakan ialah 25%, 50% dan 100% pendedahan kepada cahaya matahari, manakala kadar penggunaan baja pula 0 g, 1 g dan 2 g pokok^{-1} bulan^{-1}. Keputusan yang diperoleh selepas 11 bulan di tabung menunjukkan pokok stok yang dibaja dengan 1 g dan 2 g baja mempunyai peningkatan ketinggian dan diameter yang signifikan dan lebih baik berbanding dengan pokok stok yang tidak dibaja pada semua keamatan cahaya yang diuji. Walau bagaimanapun, tidak ada perbezaan yang bererti dalam peningkatan ketinggian dan diameter pokok stok pada tiga keamatan cahaya yang digunakan. Didapati kemandirian pokok stok adalah lebih daripada 86% untuk semua keamatan cahaya yang dicuba sama ada diberi baja ataupun tidak. Daripada segi keupayaan pengakaran, bahan keratan daripada pokok stok yang ditempatkan di bawah 25% keamatan cahaya dan 0 g baja memberi peratus pengakaran (73%) dan jumlah akar yang tertinggi (2.0). Secara amnya pengakaran keratan mula menurun kurang daripada 60% apabila keamatan cahaya ditingkatkan. Walau bagaimanapun, bagi mengekalkan pertumbuhan pokok stok yang sihat dan untuk mendapat bahan keratan yang berterusan bagi tujuan pengakaran, pembajaan 1 g pokok^{-1} bulan^{-1} adalah disyorkan.*

Kata kunci: Diameter; dipterokarpa; peratus pengakaran; tinggi

INTRODUCTION

Neobalanocarpus heimii locally known as *chengal*, is one of the species that belongs to the family Dipterocarpaceae. The tree produces a heavy hardwood timber which is highly valued for its strength, durability and workability. The timber is sought due to its high demand in the world market. However, its timber supply is getting scarce as it has been heavily logged and this species has been listed as vulnerable (Anon. 1985). FAO (1990) noted that the species has been over-exploited and has poor regeneration. There was a measured decrease in volume per hectare and number of hectare for trees over 45 cm in diameter in both virgin and logged over forests. Unless necessary steps are taken to replant them, it is anticipated that this tree species will face serious extinction and severe genetic loss because the demand for its wood is increasing every year.

Bawa (1998) reported that dipterocarps appear to be strongly cross-pollinated, a feature which could account for poor seed production if flowering trees of the same species occur infrequently and are widely dispersed. This appears to be the case in *N. heimii*, as natural regeneration beneath parent trees is rarely abundant despite annual fruiting

(Elouard & Blanc 2003). Given that seeds are the only feasible method of propagating and regenerating *N. heimii*, future supplies of this timber are likely to be seriously affected. Therefore, propagation using cuttings was tried as an alternative method for obtaining the planting materials. This is because several species of dipterocarps have been successfully rooted through cuttings (Darus & Aminah 1993, 1994). However, there is scanty report available on the success of rooting of this species. Naimah et al. (2007) reported that a rooting of 3% was obtained from *N. heimii* rooted from coppice shoots of 3 years old stock plants. The poor results could probably be due to the use of old stock plants. Another study by Aminah et al. (2012) using younger cutting materials from 15 months old seedlings, have resulted in better rooting of 35%, 12 months after planting. Several literatures have indicated that manipulation on light intensity and nutrients on stock plants could improve the rooting of difficult to root species (Aminah et al. 1999; Leakey & Storeton-West 1992). This experiment was therefore set up to find the optimal condition of light and fertilizer levels for raising the stock plants and their effects on rooting of the subsequent cuttings of *N. heimii*. The stock plants were first grown under various light intensity and fertilizer rates in the nursery. Cutting materials from these stock plants were then harvested and tested for rooting to find the best combination of light intensity and fertilizer rate for raising the stock plants.

Materials and Methods

Experiment 1: Effect of light intensity and fertilizer rates on the growth of stock plants

The stock plants of *Neobalanocarpus heimii* were raised from open pollinated seed. The seeds were collected from Field 12, Forest Research Institute Malaysia (FRIM) on 27 April 2006. The seeds were germinated in 100% cleaned river sand. One month after germination, the seedlings were potted in polythene bag (9 cm diameter × 17 cm height) on 7 July 2006. Potting medium used was a mixture of forest soil and rice hulls in the ratio of 3:1 with no added fertilizer. Soil was obtained from the forest in the campus of FRIM while rice hulls were from the local rice mills. These seedlings were kept in the germination shed for 9 weeks before they were subjected to the treatments of three levels of light intensity and fertilizer rates. Three levels of light intensities used were: 25%, 50% and 100%. Light grown plants remained uncovered and grew under ambient light intensity (0% shade). The two light intensity conditions (50% and 25%) were created by covering a wooden frame box (1 m × 1 m × 1 m) with one and two layers of black plastic netting, respectively. The boxes were placed in open areas avoiding effects of shade from other objects. The three levels of fertilizer used were 0 g, 1 g and 2 g plant^{-1} month^{-1}. The plants were randomly arranged in split plot design with light intensity as the main plot and fertilizer levels as sub plot. Granular compound commercial fertilizer, called NPK Blue ($12N:12P_2O_5:17K_2O:2MgO$ + trace element) was applied to the plants on the day the experiment was executed. Each treatment combination consisted of 30 plants and they were randomly assigned in three blocks with 10 plants per block. A total of 270 plants were used. The initial height and diameter were recorded on the day the plants were subjected to the light and fertilizer treatments. This was followed by monthly height measurements and at termination of the experiment, basal diameter and survival percentage of plants were recorded. The height and diameter increments and survival percentage were subjected to analysis of variance.

For the maintenance of stock plants during the experiment, watering was carried out twice daily, in the morning and late afternoon. Weeding, insecticide and fungicide applications were carried out manually when necessary. The common disease for *N. heimii* was damping-off which was associated with pathogens like *Cylindocladium* sp., *Fusarium* sp. and *Colletotrichum* sp. This can be controlled by using fungicides containing benomyl as active ingredient. On the other hand, the hemipteran insects from family Phyrrocoridae were found sucking the sap from the shoots and tenderly leaves of *N. heimii*. *Hypomeces squamosus* (Fabricus) of Curculionidae, a snout beetles family, was also observed chewing the newly produced leaves of the seedlings. They can be controlled by spraying the stomach or contact type insecticides.

Experiment 2: Effect of the light and fertilizer treatments on the rooting ability of the subsequent cuttings

The experiment was carried in the green house, nursery of FRIM on 14 June 2007. The cutting materials were taken from the stock plants of Experiment 1. The age of the stock plants was about 11 months when cuttings were taken for the experiment. Cuttings were taken both from the terminal and lateral shoots. The length of each cutting was 5 cm and the leaf area was 30 cm^2. Diameter of each cutting was measured using digital verneer calliper. The base of cuttings were cut at right angle and was treated with commercial hormone powder Plantone-R 2000 (0.2% indole butyric acid – IBA + 0.1% naphthalene acetic acid - NAA). This hormone was chosen because it has resulted in rooting of *N. heimii* in previous experiment carried out by Naimah et al. (2007).

In this experiment, nine treatment combinations given to stock plants as in Experiment 1 were used. Each treatment combination consisted of 30 cuttings. The cuttings were randomly planted in three blocks with 10 cuttings in each block. A total of 270 cuttings were used. The cuttings were planted in an enclosed mist propagation system. The enclosure was made of transparent plastic supported by steel frames. The plastic enclosure was then shaded with black plastic netting (20% light intensity). The cuttings were kept moist by an automatic mist sprinkler system set for one min of misting every 1 h. The relative humidity inside the propagation system is more than 80%

and temperature ranged from 23° to 39°C. Media used was cleaned river sand. The cuttings were assessed every month after planting and the following variables were recorded: the number of roots per rooted cutting, rooted cuttings, unrooted and dead cuttings. The unrooted cuttings were replanted into the rooting bed and reassessed until the twenty four months. In the assessment, a cutting was scored as rooted when it produced at least one root of about 1 cm long. The cuttings were considered dead when the whole stem turned brown. The mean accumulated number of roots was calculated by dividing the total number of roots produced by the total number of rooted cuttings at each assessment week.

The analysis of variance was used to test for significant differences in the treatments for percentage of rooted, unrooted and dead cuttings and number of roots. The percentage data were arcsine transformed before analysis of variance was carried out (Snedecor & Cochran 1980). Duncan multiple range test was used to test the significant difference between treatments. The results were considered significant when $p \leq 0.05$. For this work, the data used were until 12 month since most of the cuttings have rooted (Figure 1).

RESULTS AND DISCUSSION

EXPERIMENT 1: STOCK PLANTS

The results of 11 months after planting showed that there was no significant relationship between light intensity and fertilizer on both height and diameter increments of the plants. The plants fertilized with 1 g and 2 g fertilizer had significantly better in height and diameter increments than those without fertilizer in all light intensity tried (19.5 cm vs 4.3 cm for height and 2.0 mm vs 0.9 mm for diameter) (Table 1). The results confirmed previous studies by Aminah et al. (1999), Leakey (1983) and Moe and Andersen (1988) who demonstrated that application of nutrients is important for healthy growth of stock plants. However, the required optimal amount of fertilizer of stock plants should be determined for producing cutting materials suitable for rooting. Application of too much fertilizer will affect the survival of stock plants as indicated in experiments with *Dyera costulata* where their survival percentage was significantly reduced when 5 and 10 g plant^{-1} month^{-1} were used (Aminah & Lokmal 2002).

On the other hand, no significant effect of light intensity was obtained in both height and diameter increments of the stock plants. The height and diameter increments were between 13.0 and 15.3 cm and 1.3 and 1.8 mm, respectively (Table 1). Similar results were obtained by Farah Shahanim and Raja Barizan (2008), Siti Rubiah (1990) with seedlings grown in the nursery and those planted in the field (Raja Barizan & Farah Shahanim 2009). The survival percentage of plants was not significantly affected by both light intensity and fertilizer. High survival of 86.7 to 97.8% was obtained in the respective treatments (Table 1).

EXPERIMENT 2: ROOTING OF SUBSEQUENT CUTTINGS

The results presented were on data analyzed twelve months after planting. This was because rooting started to stabilize and not much increment was observed in rooting after the twelfth month (Figure 1). The results indicated that treatment 0 g fertiliser, 25% light intensity was significantly different from 1 g fertiliser, 50% light; 2 g, 50% light and 1 g, 100% light. The highest rooting (73%) was obtained using cuttings from stock plants with 0 g fertiliser, 25% light followed by cuttings with 1 and 2 g fertilizer grown under 25% light intensity (60%) (Table 2). General trend showed that rooting decreased to below 60% when the level of light was increased, across the levels of fertilizer tested. No significant difference was obtained with the dead and unrooted cuttings (Table 2). For the number of roots, cuttings from treatment 0 g fertiliser, 25% light intensity also resulted in the most number of roots produced and it was significantly different compared with cuttings from treatment 1 g fertiliser, 50% light (2.0 vs 1.1). There was an indication that the number of roots started to decrease with cuttings from stock plants

TABLE 1. Effect of fertiliser and light intensity on the growth and survival of *N. heimii* stock plants eleven months after potting

Fertiliser levels (g)	Height increment (cm)	Diameter increment (mm)	Survival (%)
0.0	4.3 b	0.9 b	96.7 a
1.0	19.5 a	2.0 a	97.8 a
2.0	19.2 a	1.9 a	92.2 a
Levels of light intensity (%)	Height increment (cm)	Diameter increment (mm)	Survival (%)
0	14.3 a	1.7 a	86.7 a
50	15.3 a	1.8 a	97.8 a
25	13.0 a	1.3 a	97.8 a

Means followed by the same letters of each column are not significantly different at $p \leq 0.05$, based on three blocks of 10 plants for each treatment combination

TABLE 2. Rooting of subsequent cuttings of *N. heimii* taken from stock plants treated with fertilizer and light intensity twelve months after planting

Fertiliser (g)	Light intensity (%)	Rooting (%)	Dead cuttings (%)	Unrooted cuttings (%)	Mean number of roots per rooted cutting
	25	73.3 a	23.3 a	3.4 a	2.0a
1	25	60.0 ab	36.7 a	3.3 a	1.7a
2	25	60.0 ab	30.0 a	10.0 a	1.4ab
0	50	50.0 ab	43.3 a	6.7 a	1.7a
1	50	36.7 b	46.7 a	16.6 a	1.1b
2	50	36.7 b	50.0 a	13.3 a	1.4ab
0	100	56.7 ab	26.7 a	16.6 a	1.9a
1	100	33.3 b	60.0 a	6.7 a	1.4ab
2	100	50.0 ab	40.0 a	10.0 a	1.4ab

Means followed with the same letters of each column are not significantly different at $p \leq 0.05$, based on three blocks of 10 cuttings per treatment combination

treated with 1 and 2 g fertilizer under various light levels tested (Table 2).

As indicated in the above results, rooting percentage seemed to decrease with increase in light intensity. High light levels to stock plants has been shown to result in high levels of carbohydrates of cuttings which was unfavourable for rooting (Hansen et al. 1978; Loach & Whalley 1978; Lovell et al. 1972). This high initial carbohydrates has been shown to inhibit post severance photosynthesis in cuttings of *Triplochiton scleroxylon* and *Eucalyptus grandis* (Hoad & Leakey 1993; Leaky & Storeton-West 1992), respectively. The low rooting of cuttings due to high initial carbohydrates content in the present experiment is reflected in cuttings with larger diameter/volume since cuttings were cut to the same length and cuttings with high volume may contain higher carbohydrates reserves than thinner cuttings. High light intensity to stock plants may cause photo destruction of auxin, changes in water relations and production of rooting inhibitors/promoters (Moe & Andersen 1988). On the other hand cuttings taken from stock plants grown under low light intensity may have a beneficial change in internal structure of the stem where width of secondary xylem and phloem decreases with decrease in light intensity which correlated well with increase in percentage of rooting as shown in *Caprinus betulus* (Maynard & Bassuk 1996).

Other reports had indicated that application of NPK fertilizer to pruned stock plants of *Triplochiton scleroxylon* enhanced their growth, improved rooting of cuttings from lower lateral shoots, but had no effect on cutting from apical lateral shoots which is more exposed to light than the lower lateral shoots (Leakey 1983). Cuttings of *Albizia guachepele* rooted better when stock plants were grown under low irradiance (200 µmoL m^{-2} s^{-1}) and low dose (0.25% $plant^{-1}$) of fertilizer (20:20:20 N:P:K). On the other hand, rooting was reduced when stock plants were treated with high irradiance (500 µmoL m^{-2} s^{-1}) and high dose (1.25% $plant^{-1}$) of similar fertiliser (Mesen 1993). An addition of 0.2% solution of 1:1:1 NPK fertilizer improved rooting of *Triplochiton screloxylon* cuttings from stock plants grown at high irradiance (650 µmoL m^{-2} s^{-1}), but not when the plants grown at low irradiance (250 µmoL m^{-2} s^{-1}) (Leakey & Storeton-West 1992). Mesen (1993) found that application of 7.5 g per plant per two weeks of NPK fertilizer (10:30:10) to stock plants grown under shade or full sunlight was detrimental to rooting of subsequent cuttings compared with those without the fertiliser. High levels of fertilizer application to stock plants were unfavourable for the production of cutting materials suitable for rooting, perhaps due to undesirable morphological and physiological characteristics of stock plants. For example, high fertilizer given to stock plants can produce leaves with low specific area, which may increase mutual shading of chloroplast and thus reducing the efficiency of gas exchange and photosynthesis in cuttings (Hoad & Leakey 1993) and consequently reduce their rooting ability.

Very little work has been reported on the effect of light and fertilizer on stock plants and rooting of their subsequent cuttings of dipterocarps. In general, cuttings taken from stock plants grown under low light intensity was reported to be more favourable for rooting. For example, cuttings from stock plants of *Shorea leprosula* grown under low irradiance (10% full sunlight) produced higher rooting percentage than those from high irradiance level (30% full sunlight) (Aminah et al. 1999). Kantarli (1993) grew stock plants of *Hopea odorata* under 50% black shade nets and obtained 59 to 81% rooting depending on stump height of stock plants from the ground. Moura-Costa and Lundoh (1994) grew the stock plants of *Dryobalanops lanceolata* under 30% light intensity and 83% rooting of cuttings was obtained. Leppe and Smits (1988) noted that shading of stock plants is required to achieve good rooting percentage in cuttings of several dipterocarp species but the actual amount of light was not quantified. In terms of fertilizer, Yasman and Smits (1988) reported that routine fertilizer application is necessary to maintain the production of cutting materials for dipterocarps. Lo (1985) applied a slow release fertilizer to *Shorea macrophylla* stock plants and 80% rooting of subsequent cuttings was achieved but no experimental data was presented. Lower dose applied to stock plants of dipterocarps was found to be more conducive for producing cutting materials suitable for rooting. For example, cuttings of *S. leprosula* taken from stock plants with high level of NPK fertiliser (1.5 g per two weeks) produced lower rooting than those treated with low fertilizer (0.5 g per two weeks) (Aminah et al. 1999).

In terms of rooting rates, cuttings started to root two months after planting in most of the treatments except for cuttings taken from stock plants treated with 1 g fertilizer under 50% light and 2 g fertilizer under 100% light. These cuttings started to root in the third and fourth month and still had rooting increment of 10 and 13% rooting, respectively, at 24 months compared with other treatments which showed little (3 to 6%) or no further increment (Figure 1). It was also observed that the unrooted cuttings would eventually drop their leaves and die when the carbohydrate reserves had depleted. The rate of rooting indicated that rooting of *N. heimii* cuttings was slower compared with most of other dipterocarp species tried earlier where rooting took place within 12 weeks (Aminah 1991).

The relationship between rooting and diameter of cuttings indicated that cuttings with diameter less than 2.3 mm gave better rooting percentages than bigger diameter which produced higher mortality rates compared with cuttings from smaller diameter groups (Table 3). The increase in diameter could be associated with increase in cutting volume since cuttings were cut to the same length and may contain higher initial carbohydrates reserves than thinner cuttings. Negative relationship between rooting and diameter/volume of cuttings may indicate that reserved starch in the cuttings was not converted to sugar and so not available for cuttings. Also the relationship suggests that cuttings depended to a greater extent on current assimilates rather than carbohydrates reserves (Leakey & Coutts 1989; Veierskov 1988). High starch concentration in cuttings appeared to inhibit rooting, while active photosynthesis was associated with good rooting. Previous experiments with several dipterocarp species showed similar trends where thinner diameter cuttings rooted better than those thicker ones: *Shorea leprosula* (Aminah et al. 1997, 1999) and *S. parvifolia, S. macroptera* (Aminah et al. 2006). However, the relationship between rooting and diameter of cuttings was inconsistent and was observed to depend on species, age and condition of the stock plants (Aminah 1995, 1996; Leakey 1983; Mesen et al. 1997).

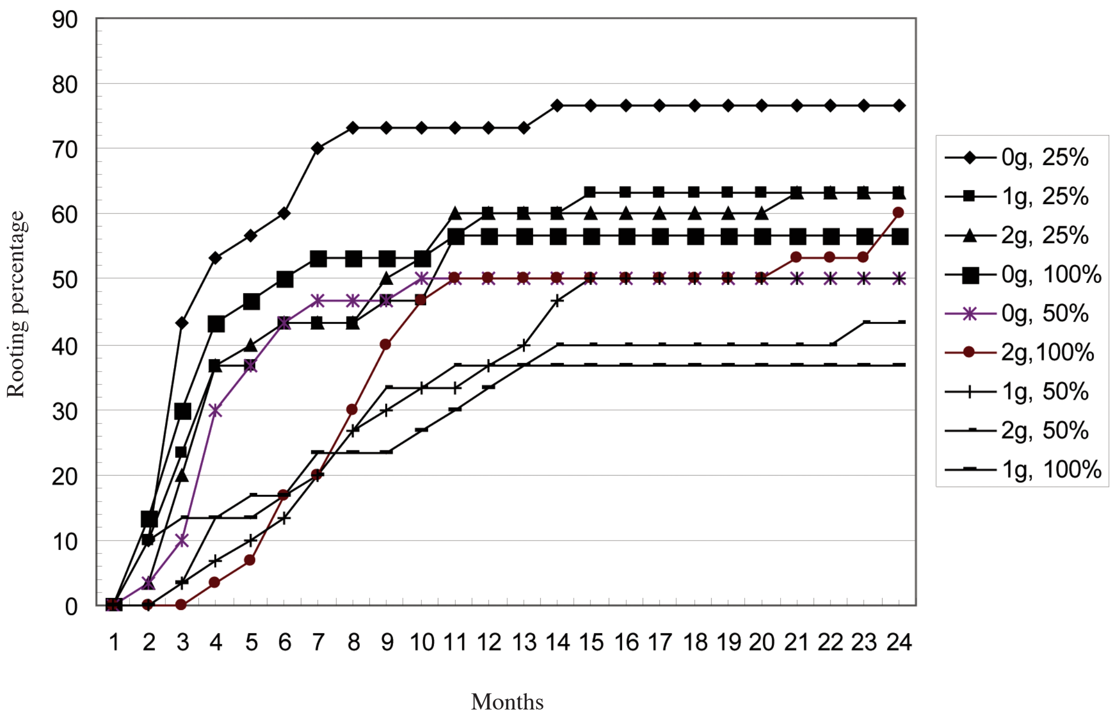

FIGURE 1. Rooting rates of *Neobalanocarpus heimii* cuttings taken from stock plants treated with three levels of light intensity and fertilizer. Mean of each treatment was based on three blocks of 10 cuttings per treatment combination

TABLE 3. Effect of diameter on the rooting of *N. heimii* cuttings twelve months after planting (pooled data of all treatments)

Diameter (mm)	Number of cuttings	Rooted ± S.E. (%)	Dead ± S.E. (%)	Unrooted ± S.E. (%)
1.18–1.79	44	75.00±4.88	22.73±1.45	2.27±0.04
1.80–1.97	34	73.53±5.55	17.65±1.19	8.82±0.49
2.00–2.29	49	65.31±4.42	26.53±1.70	8.16±0.31
2.30–2.58	35	37.14±3.02	48.57±4.12	14.29±0.83
2.60–2.99	35	45.72±3.86	48.57±4.12	5.71±0.24
3.00–3.48	43	34.88±2.56	53.49±4.03	11.63±0.59
3.51–4.78	30	10.00±0.55	76.67±5.93	13.33±0.79

S.E.: Standard error of means

CONCLUSION

The results of this experiment showed that juvenile leafy cuttings of *N. heimii* could be rooted with prior treatments given to stock plants. The results of this experiment also showed that stock plants raised under 0 g fertiliser and light intensity of 25% gave the best result. However, without fertilizer, the stock plants grew very slowly and assumed a stunted appearance as indicated in Experiment 1 and a limited number of cutting materials can be obtained compared with those with fertilizer treatment. Therefore, for practical application, a combination of 25% light intensity and 1 g of fertilizer plant^{-1} month^{-1} can be applied to the potted stock plants to maintain their healthy growth for production of cutting materials for rooting. Lower dose of fertiliser could be tried in the future experiment.

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