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Growth Light Conditions of Stockplants Enhance the Growth and Morphology of Shoots and Rooting Ability of Jackfruit (*Artocarpus heterophyllus*) Cuttings

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ABSTRACT

The study describes the effects of growth light conditions on growth and morphology of stokplants and rooting ability of cuttings for mass clonal propagation of jackfruit (*Artocarpus heterophyllus* Lam.) without application of rooting hormone. Forty five days-old containerized stockplants were placed under three different levels of light: full sun (Red to far red ratio 1.25), partial shade (R: FR 1; 60% of full sun) and deep shade (R: FR 0.4; 3% of full sun) for 45 days. Half of the stockplants growing in partial shade or deep shade were transferred to full sun for another 15 days and growth and morphology of shoots and rooting ability of cuttings were investigated. Growth and morphology of shoots and rooting ability of cuttings was significantly affected by the growth light conditions of stockplants. Internode number was significantly fewer, but internode length, leaf area and specific leaf area was higher in deep shade and deep shade to full sun regime. Leaf weight per unit area was decreased gradually, when sun-grown stockplants were transferred to deep shade or partial shade and regained on returning them from the shade to full sun. The highest rooting percentage (100%), maximum number of root (6.3) and root dry weight (62 mg) per cutting was obtained from the cuttings of deep shade to full sun regime followed by deep shade and the lowest was in full sun regime without application of any rooting hormone.

Key Words: Acclimation; *Artocarpus heterophyllus*; Clonal propagation; Growth light; Rooting ability; Shoot morphology

INTRODUCTION

Jackfruit (*Artocarpus heterophyllus* Lam.) the largest fruit in the world (Sturrock, 1959; Ochse, 1966; Ahmed, 1969), is one of the most popular fruits in Bangladesh (Haque, 1977) and recognized as the national fruit of the country. Jackfruit tree is medium to large in size grown mainly for fruits, timbers and foliages and cultivated throughout country. It is commonly grown from seeds (Hensleigh & Holaway, 1988; Soepadmo, 1991; Craig & Harley, 2006) and sometimes by vegetative means like grafting, budding, layering and stem cuttings. Although the trees produce huge amount of seeds, maximum segregation of desirable characters like fruit size, quality, flavor and yield into progenies due to the open and highly cross pollination, makes it difficult to obtain desirable offspring from the seeds (Kamaluddin, 1988,). Therefore, to produce true-to-type plants or outstanding varieties, the species requires vegetative propagation, which may also enable the plants for early bearing (Acedo, 1992; Craig & Harley, 2006).

Plant propagation by stem cuttings is a popular technique for raising plantations in many countries. However, jackfruit is difficult to propagate vegetatively, without treatment with growth regulators stem cuttings do not produce root (Biswas, 1995; Chaterjee & Mukherjee, 1980; Mukherjee & Chaterjee, 1979). Besides this, formulation and application of expensive growth regulators (rooting hormone) in the cuttings is complex and beyond the farmers' imagination especially in the poor country like Bangladesh. Lack of technical advancement and scientific precautions made it more troublesome for mass propagation and its applicability to the farmers' level in the rural areas (Hoque, 2008). Therefore, propagation of the species requires additional treatments of stockplants for mass production of juvenile shoots and rooting in the cuttings without application of growth regulators. Growth light environment of stockplants is known to affect the growth and morphology of shoots and rooting ability of cuttings (Kamaluddin, 1999). Low light intensity and shade increase the plant height, leaf area, number of node and internode length of the seedlings of many species (Naidu & Swami, 1993; Vyas *et al*., 1996; Vyas & Nein, 1999; Savita *et al.,* 1999; Hossain & Kamaluddin, 2004; 2005), which often accelerate the rooting ability to the cuttings (Leakey, 1985; Kamaluddin, 1999). Cuttings root more readily after the stockplants have been grown under low light intensities. Again, the number of root developed in cuttings is primarily

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dependent on internode length, which in turn is dependent on the irradiance to stockplants and topophysis (Poulsen & Andersen, 1980). However, there have been few studies, which have examined the growth and morphology of shoot developed under various light regimes and their relationship with rooting ability of cutting, as well as with cutting yield of stockplants. Therefore, in the present study, we investigated the effects of growth light environment of stockplants on growth of shoots and rooting ability of cuttings of jackfruit aimed to develop a suitable protocol for mass propagation of the species without applying growth regulators for rooting.

MATERIALS AND METHODS

The study was conducted in the nursery of Chittagong University, Bangladesh situated between 22°27′27″ N latitude and 91°48′310″ E longitude. The study area enjoys typically tropical monsoon, characterized by hot humid summer and cool dry winter with mean monthly temperature variation from 21.8°C to 29.2°C maximum and from 15°C to 26°C minimum. Relative humidity is minimum (64%) in February and maximum (95%) in June to September. Mean annual rainfall of the area is about 300 cm, which mostly take place between June and September. The day length varies from 10 h 45 min in December to 13 h 25 min in June.

Growing of stockplants and growth light conditions: Stockplants were the seedlings raised from seeds collected from a phenotypically superior tree and grown under full sun. At the age of 45 days the stockplants (around 25 cm in height with five fully developed leaves) were placed in three different light regimes: full sun (FS), partial shade (PS) and deep shade (DS). The stockplants were grown in polythene pots (15 cm x 10 cm in size) filled with coconut husk mixed with forest soils (usually moderately coarse to fine textured sandy loam soil) with acetic pH (5.5) and decomposed cowdung 2:1:1 by volume.

A bamboo made shed was built for stimulation of two levels of shades, partial and deep shade. The roof and sides of the shed were lined by bamboo sticks of small diameter (2-3 cm). The sides and roof were lined by whole bamboo slats of 20 cm wide leaving 20 cm space in between the slats. This management was made for partial shade. For deep shade, the roof was further lined with bamboo-made mats and the sides with blue polythene sheets. Photosynthetic photon flux was measured on clear days by using a data logger (Datahog2, SDL5360, Sky Instrument Ltd., Powys, UK), quantum sensor (SKP 215 Sky Instrument Ltd., Powys, UK), red to far-red ratio sensor (SKR 110, Sky Instrument Ltd., Powys, UK). In full sun the stockplants experienced around 22 mol photon flux per m^2 per day. Compared to full sun the stockplants in partial and deep shade regime received about 60% and 3% daylight respectively. The partial shade regime allowed direct sun light in the form of sun patch and sun flecks particularly at midday. Red to far-red ratio was around 1.25 in full sun, 1.0 in partial shade and 0.4 in deep shade. During the study, mean maximum and minimum temperature was 31°C and 24°C, respectively with a days length 12 h. After 45 days of growing, half of the stockplants from each of two light regimes, partial shade and deep shade were transferred into the full sun for another 15 days. The transformation of deep shaded stockplants to partial shade and full sun was performed gradually for its acclimatization.

Shoot morphology of stockplants: Fifteen individual shoots from each of the five light regimes, full sun (FS), partial shade to full sun (PS-FS), partial shade (PS), deep shade to full sun (DS-FS) and deep shade (DS) were taken for morphological study. In the morphological study, the number of nodes, length and diameter of internodes and leaf area were assessed. Leaf area was measured by Dot-gird method. Internode with fully developed leaf at the upper part of the shoot was taken as the first cutting and as such the tip of the shoot was not included in the measurement since it usually fails to root (Kamaluddin, 1999). Diameter was measured at the mid-point of the internode. The internode and leaf samples were dried in electrical oven at 70°C for 48 h for dry weight assessment (Kamaluddin, 1999). With these primary data, specific internode length (SIL) and specific leaf area (SLA) were derived. To determine the change in leaf weight due to reduction of light intensity over days 10 discs (0.5 cm^2 each) from each of the ten stockplatns were collected by cork borer from each light regime. The discs were also dried in oven at 70°C for 48 h and leaf dry weight per unit leaf area was calculated and plotted in the graph.

Rooting trials: Single node cuttings of shoots with one leaf trimmed to half were used for rooting trial (Fig. 4) Sixty cuttings from each light regime, a total 300 cuttings were made from five light regimes. Cuttings were immersed briefly in a solution of fungicide, Diathane M45 (Rohm & Co. Ltd., France; 2 g. per litre of water) to avoid fungal infection. Then they were rinsed and kept under shade for 10 min in open air. The cuttings were planted into perforated plastic trays (12 cm depth; filled with coarse sand mixed with fine gravel) and placed into a non-mist propagator (Kamaluddin, 1996) in five completely randomized blocks (Kamaluddin, 1997; Hossain & Kamaluddin, 2004). The cuttings were watered once only just after the setting into the propagator and no watering was done till the transfer of the rooted cuttings from propagator.

Propagator environment for rooting: About 85-90% humidity was maintained within the propagator. Every day the propagator was opened briefly in the morning and in the late afternoon to facilitate gas diffusion. The propagator was kept under bamboo made shed to avoid excessive heat accumulation. Further shading was achieved by putting jute mate over the roof of the shed. In this way, photosynthetic photon flux inside the propagator was reduced to about 12% in full sun by the overhead shade. During the rooting trial, the mean maximum temperature was 35°C and the mean minimum temperature 25°C.

Data collection and analysis: The cuttings rooted six weeks after setting into the propagator. The cuttings were subjected to weaning before transferring from the propagator. For weaning the cuttings, the propagator was kept open at night for three days and days and night for another three days. Rooting percentage and the number of root per cutting was recorded seven weeks after setting the cuttings into the propagator. Roots of each cutting were separated and dried in oven at 70°C for 48 h for dry weight assessment (Kamaluddin, 1999). The leaves and internodes were also dried in the oven. Analysis of variance (ANOVA) and Duncan Multiple Range Test (DMRT) were performed to explore the possible difference among the treatments. Rooting percentage values were transferred into arc sign Root Square before putting the data for analysis of variance. Each experiment was repeated at least three times to confirm the reproducibility of the methods.

RESULTS

Effect of growth light conditions on growth and morphology of shoots: Growth light levels significantly affected the growth and morphology of shoots in stockplants. Shoots grown in deep shade or deep shade to full sun produced fewer numbers of nodes than partial shade, partial shade to full sun or full sun regime. Mean internode length was highest in shoots developed in deep shade and lowest in full sun. Maximum internode diameter was observed in shoots grown in partial shade to full sun followed by full sun and lowest in deep shade regime (Table I). The highest leaf area per node (44.8 cm^2) was observed in the deep shade followed by deep shade to full sun and lowest (29.2 cm^2) in full sun regime. However, there was no significant difference in leaf area between deep shade to full sun and the deep shade, as well as partial shade to full sun and partial shade (Table I).

Due to the significant difference in internode length and diameter, mean internode volume was varied with light regimes. The maximum internode volume was observed in partial shade and partial shade to full sun regime with lowest in deep shade and deep shade to full sun regime. There was no significant difference in leaf dry weight in shoots developed under various light regimes. However, leaf weight per unit area was gradually decreased when sun grown stockplants were transferred to the partial or deep shade (Fig. 1). The effect was more pronounced in deep shade regime. Change in leaf weight per unit area after three days was minor. When the stockplants were transferred from the shade to full sun, the leaf weight was regained (Fig. 2).

Again, the highest internode dry weight (184 mg) was observed in partial shade to full sun regime compared to full sun or partial shade, and lowest (88 mg) in deep shade to full sun or deep shade. Specific leaf area (SLA) was highest in deep shade (216 cm^2g^{-1}) and lowest in full sun (126 cm^2g^{-1}) while maximum specific internode length (SIL) was in deep shade to full sun regime (60.6 cmg^{-1}) and lowest was in partial shade to full sun regime (Table I).

Growth light levels of stockplants enhanced the rooting ability of cuttings: Growth light conditions of stockplants significantly affected the percentage of cutting rooted in jackfruit (Table II). Across the cutting types percentage of cutting rooted six weeks after setting ranged from 67 to100 without any rooting hormone. The cuttings from the deep shade to the full sun rooted best (100%) followed by the deep shade (87) and the lowest (67) was in full sun cuttings without IBA.

Number of root and root dry weight per cutting was also significantly affected by different light levels. Mean root number ranged from 3.1 to 6.3 per cutting in different light regimes. The highest number of root (6.3) was obtained in deep shade to full sun followed by deep shade cuttings and the lowest (3.1) was in the cuttings from full sun regime without IBA treatment. Similarly the maximum root dry weight per cutting was obtained from the cuttings of deep shade to full sun regime (62 mg) followed by deep shade regime (43 mg) and the lowest (31 mg) from full sun regime without IBA treatment (Table II & Fig. 3).

Cutting morphology: Cutting morphology of shoots *i.e.*, cutting length, diameter, leaf area, cutting volume was significantly affected by growth light conditions of stockplants. Cutting length was highest (4.2 cm) in deep shade followed by deep shade to full sun light regime, which was markedly higher than the cuttings from other light regimes. The cutting length was minimum (2.8 cm) and diameter was maximum (3.5 mm) in the full sun regime, while the minimum diameter (2.8 mm) was noticed in deep shade regime (Table III & Fig. 3).

Mean leaf area of cuttings was maximum (17 cm^2) in deep shade to full sun regime, which was much higher than the minimum (12 cm^2) in full sun light regime. Similarly, the highest cutting volume (0.28 cm^3) was in the cuttings from deep shade to full sun with lowest (0.22 cm^3) in full sun regime. However, there was no significant difference in mean leaf dry weight and cutting dry weight due to the different growth light levels of the stockplants (Table III & Fig. 3).

Growth light conditions also significantly affected the specific leaf area (SLA) and specific internode length (SIL) of the cuttings. SLA was highest (132 cm^2g^{-1}) in deep shade and deep shade to full sun regime and lowest (100 cm^2g^{-1}) full sun light regime. Maximum SIL was in the cuttings from deep shade regime and lowest was in full sun. The specific internode volume (SIV) was not significantly affected by the different growth light conditions.

DISCUSSION

Shoots grown in deep shade, became shade acclimated as was evident from morphological characteristics of shoots developed (Table I). Specific leaf area was higher in the deep shade (216.0 cm^2 g^{-1}) and deep shade to full sun regime compared to other light regimes. Generally, thinner leaves in deep shade regime are with higher specific leaf

Table I: Morphology of jackfruit shoots developed under various growth light conditions of stockplants

Variables	FS*	PS-FS	PS	DS-FS	DS	P
Node number per shoot	9.33^{a}	9.67^{a}	9.33^{a}	7.67^{b}	7.33^{b}	*
Internode length (cm)	3.43^{c}	3.75^{bc}	3.85^{bc}	4.01^{ab}	4.45^{a}	**
Internode diameter (mm)	3.3^{a}	3.54^{a}	3.26^{a}	2.44^{b}	2.41^{b}	***
Leaf area per node (cm^2)	29.2^{b}	35.9^{ab}	38.8^{ab}	43.0^{a}	44.8^{a}	*
Internode volume (cm^3)	0.30^{b}	0.38^{a}	0.32^{ab}	0.19^{c}	0.21^{c}	****
Leaf dry weight (mg)	228^{a}	278^{a}	268^{a}	264^{a}	210^{a}	NS
Internode dry weight (mg)	143^{b}	184^{a}	147^{b}	88^{c}	88^{c}	*****
Specific leaf area (cm^{2}g^{-1})	126^{c}	131^{c}	146^{bc}	171^{b}	216^{a}	****
Specific internode length (cmg^{-1})	31.7^{b}	25.4^{b}	32.5^{b}	60.6^{a}	58.1^{a}	*****

Significant: ***** indicates $p < 0.0005$, **** $p < 0.001$, *** $p < 0.005$, ** $p < 0.01$, * $p < 0.05$, NS: Not significant at $p < .05$. The same superscript letters indicate no significant difference at $p <.05$ (ANOVA & DMRT)
*/ FS stands for full sun, PS for partial shade, PS-FS for partial shade to full sun, DS for deep shade and DS-FS for deep shade to full sun.

Table II: Effect of growth light condition of stockplants on rooting ability of cuttings

Variables	FS	PS-FS	PS	DS-FS	DS	P
Rooting percentage	67^{c}	80^{b}	77^{bc}	100^{a}	87^{b}	**
Root number per cutting	3.1^{c}	3.4^{c}	4.2^{b}	6.3^{a}	4.4^{b}	*****
Root dry weight per cutting (mg)	31^{c}	29^{c}	32^{c}	62^{a}	43^{b}	*****

Significant: **** indicates $p < 0.001$, ** $p < 0.01$. The same superscript letters indicate no significant difference at $p < 0.05$ (ANOVA & DMRT)

Table III: Morphology of cuttings of Jackfruit

Variables	FS	PS-FS	PS	DS-FS	DS	P
Cutting Length (cm)	2. 8^{c}	2.9^{c}	3.3^{b}	3.8^{ab}	4.2^{a}	*****
Cutting diameter (mm)	3.1^{a}	3.0^{ab}	3.1^{a}	2.9^{b}	2.8^{b}	**
Leaf area per cutting (cm^2)	12^{c}	14^{b}	17^{a}	17^{a}	16^{a}	***
Cutting Volume (cm^3)	0.22^{b}	0.22^{b}	0.25^{ab}	0.28^{a}	0.24^{ab}	**
Leaf dry weight (mg)	117^{a}	136^{a}	146^{a}	126^{a}	128^{a}	NS
Cutting dry weight (mg)	98^{a}	103^{a}	125^{a}	126^{a}	98^{a}	NS
Specific leaf area (cm^{2}g^{-1})	100^{c}	104^{c}	115^{b}	132^{a}	128^{ab}	*****
Specific internode length (cmg^{-1})	31^{b}	32^{ab}	30^{b}	30^{b}	35^{a}	**
Specific internode volume (cm^{3}g^{-1})	2.4^{a}	2.5^{a}	2.4^{a}	2.3^{a}	2.3^{a}	NS

Significant: ***** indicates $p < 0.0005$, *** $p < 0.005$, ** $p < 0.01$, NS: Not significant at $p < 0.05$. The same superscript letters indicate no significant difference at $p < 0.05$ (ANOVA & DMRT)

area (SLA) (Smith, 1991; Kamaluddin & Grace, 1995; Hossain & Kamaluddin, 2004) due to the low photosynthetic capacity. Photosynthetic acclimation of tropical forest tree seedlings to sun and shade has been studied by several workers (Oberbouer & Stain, 1985; Kwesiga *et al.,* 1986; Thomson *et al.,* 1988; Kamaluddin & Grace, 1993, Wiebel *et al.,* 1994; Kamaluddin, 1999). In most of the studies, increased amount of light led to increase the rate of photosynthesis and ultimately to higher growth rates. Reduction of leaf thickness was observed under low light intensity and increased leaf thickness under full sun accompanied with cell enlargement and increased layers of palisade cells (Naidu *et al.,* 1999). The SLA was higher in low light grown seedlings but when the seedling transferred to high light, SLA reduced and leaves became significantly thicker (Kamaluddin & Grace, 1993). This was due to the

Fig. 1: Change of leaf weight per unit area of jackfruit under Full sun (o), Partial shade (Δ) and deep shade (•) over period of time. Forty five day-old seedlings were placed in partial shade or deep shade and leaf samples were examined for leaf weight per unit area at three days interval

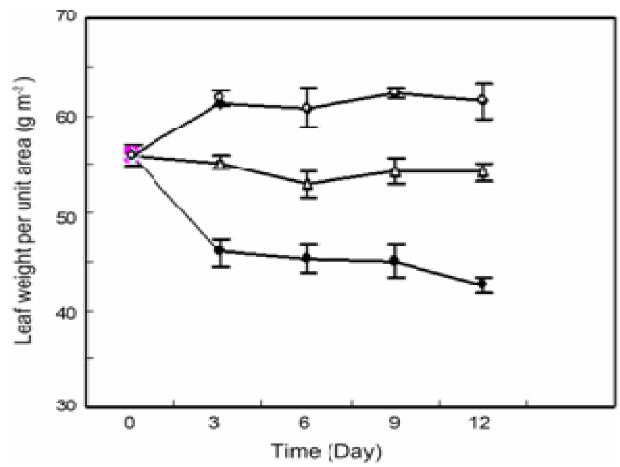
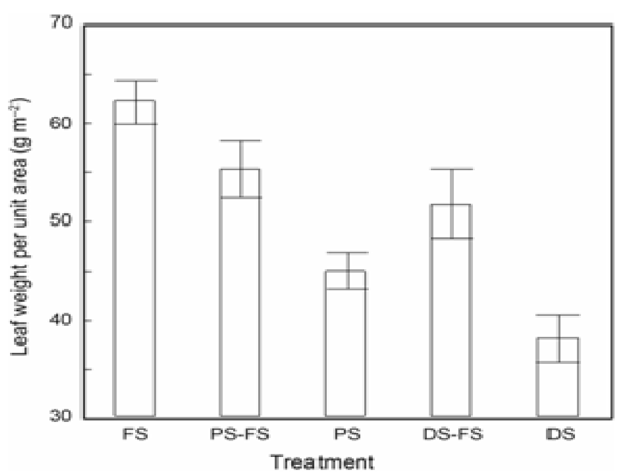


Fig. 2: Leaf weight per unit leaf area of jackfruit under full sun (FS), partial shade to full sun (PS-FS), Partial shade (PS) and deep shade to full sun (DS-FS) and deep shade (DS) with standard error of means (I). Forty five day-old seedlings were placed in partial shade or deep shade for 45 days and then half of the seedlings were returned to full sun for another 15 days and leaf discs were examined for the leaf weight per unit area from the full sun (FS), partial shade (PS), partial shade to full sun (PS-FS), deep shade (DS) and deep shade to full sun (DS-FS) regime

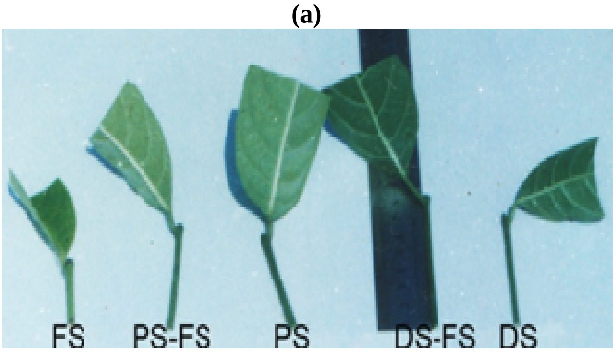


increased leaf weight per unit area and decreased chlorophyll content as reported by Kamaluddin and Grace (1995).

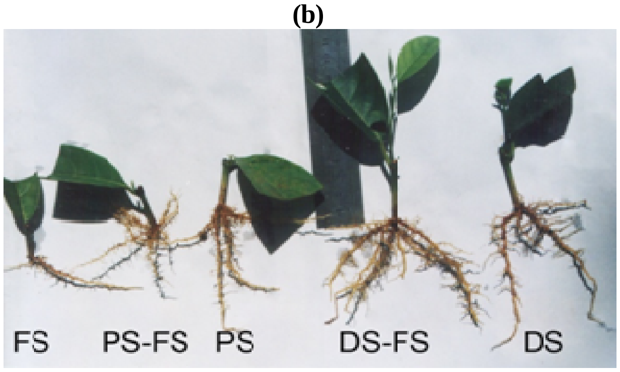
Deep shade led to an increased internode length and specific internode length (SIL) (Table I). The high SIL means the shade grown internodes produced the same length with lower amount of materials. The high SIL in

Fig. 3: Cutting morphology and rooting ability of cuttings of jackfruit shoot developed under various growth light conditions of stockplants. Sun grown seedling of jackfruit (45-day old) were transferred to partial shade or deep shade for 45 days and then returned to full sun for another 15 days. Shown are the representative cuttings (a) or rooting in cuttings (b) seven weeks after planting into the non-mist propagator

(a)



(b)



deep shade might be attributed to the lower supply of photosynthates in light-limiting deep shade regime. Formation of fewer nodes in deep shade (Table I) might also be due to the limited supply of photosynthates. The fewer nodes in deep shade mean high internode length and few numbers of cuttings per shoots (Table I). There was no report found to compare the specific internode length in deep shade, but the higher internode length in low light regime (deep shade) was supported by Kamaluddin (1999) and Hossain and Kamaluddin (2004). While, Vyas and Nein (1999) observed that the internode length was higher in partial shade (25% shade).

The expansion of leaf area in shoots of jackfruit in full sun was significantly restricted. The individual leaf area was much larger in deep shaded stockplants than the full sun (Table I). Naidu and Swamy (1993) supported the larger leaf area in shade and mentioned that shade increases the leaf area of *Pongamia pinnata*. There was no significant difference in leaf dry weight in different light regime, since the smaller leaf area from full sun was thicker compared to large thin leaves from partial shade and deep shade regime.

Growth light levels of stockplants significantly affected the percentage of cutting rooted. Rooting percentage of cuttings was highest (100%) in deep shade to full sun without any rooting hormone. Low light intensity increased the rooting percentage was supported by the several authors (Poulsen & Andersen, 1980; Stromquist & Hansen, 1980; Leakey, 1985; Maynard & Bassuk, 1992). This might be due to the low carbohydrate/starch content in stockplants grown under low irradiance (Migita & Nakala, 1978). The higher carbohydrate content in high light grown leaves reduces rooting ability reported by Hansen *et al.* (1978). He proposed that the carbohydrate level exceeds a certain limit could result in reduction of root formation. It is probable that the higher and steady increasing carbohydrate content in cuttings from stockplants grown in high irradiance is super-optimal for root formation. Highest rooting percentage in cuttings from deep shade to full sun might also be due to the longer cutting length (Table II & III). Similar result was observed by Poulsen and Andersen (1980) and mentioned that the root formation and root number was related to the length of internode, while internode length in turn was dependent on irradiance to stockplants. The longer internode of low irradiance rooted best.

The number of root developed per cutting was also highly affected by the growth light levels. The maximum number of root per cutting was observed in deep shade to full sun regimes (Table II & Fig. 3). Root number was increased due to the longer internodes in low irradiance (Poulsen & Andersen, 1980) and at optimum level of carbohydrate for root formation (Stromquist & Hansen, 1980). Similarly, root dry weight per cutting was found higher in cuttings from the deep shade to full sun regime without rooting hormone. This result was due to the maximum number of root produced per cutting in the low light regime (Table II & Fig 3). The maximum number of root and higher root dry weight per cutting in deep shade to full sun regime might also be due to the larger leaf area per cutting (Table III & Fig. 3) as in a separate experiment Kamaluddin and Ali (1996) reported that neem cuttings with larger leaf area produced more roots and higher root dry matter in rooted cuttings. It was concluded that the cuttings with larger leaf area might have obtained more assimilates from current photosynthesis than the cuttings with lower leaf area.

Rooting percentage, root number and root dry weight per cutting was highest in deep shade to full sun followed by deep shade with lowest in full sun cuttings. Usually cuttings obtained from deep shade contain less amount of starch. The cuttings from very low especially 10% irradiance in a short photoperiod may tend to reduce the root formation. However, when the deep shaded stockplants were treated by full sun (7 days partial shade & another 7 days of full sun), it gained some carbohydrates (Kamaluddin & Grace, 1995) and increased leaf weight, which might be utilized during the rooting in propagator.

Rooting ability in leafy cuttings is sometimes related to the production of reflux carbohydrates, apparently derived from the current photosynthesis, while cuttings are in a propagation unit (Leakey & Storeton-West, 1992). Photosynthesis contributes sugar that is translocated to the base of the cuttings. This increase in sugar availability at the base of the cuttings enhanced the development of rooting primodium (John, 1979). It seems that both pre and post severance carbohydrates input might have contributed to the formation and growth of roots in cuttings of jackfruit leading to increase the root number and root biomass in cuttings of deep shade to full sun regime. Rooting ability of cuttings also related to cutting volume. Larger volume means larger amount of assimilates, which are utilized to produce more roots and higher root biomass. For jackfruit mean cutting volume of one node cutting in deep shade to full sun cutting (0.28 cm^3) was larger than full sun or partial shade (Table III). The significant difference in mean root number and mean root biomass might be attributed to the higher amount of assimilates per unit volume of cuttings developed in the low light regime.

CONCLUSION

Growth light conditions of stockplants significantly enhanced the growth and morphology of shoots and rooting ability of cuttings. Partial shade regime produced higher growth with maximum number of internode per shoot compared to full sun or deep shade regime. Deep shade produced longer internodes allowing the use of mostly one-node cuttings. The highest rooting percentage, maximum number of root and root dry weight per cutting was found in deep shade to full sun regime without IBA treatment. Therefore, considering the internode length, rooting ability, stockplants preconditioning by deep shade to full sun was the best for rooting ability in the cuttings. This might be one of the important alternatives for achieving adequate rooting of cuttings without applying the complex procedure of costly IBA solution in treatments. However, the internal biochemical change in shoots of stockplants that enhanced the rooting ability of cuttings due to different light conditions was not explored in this study, which might be one of the important areas of future study.

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