Journal of Tropical Forest Science 12(3): 431 – 443

THE INFLUENCE OF MISTING FREQUENCIES ON THE WATER RELATIONS AND ROOTING PHYSIOLOGY OF *SHOREA LEPROSULA* LEAFY STEM CUTTINGS

H. Aminah,

Forest Research Institute Malaysia (FRIM), Kepong 52109, Kuala Lumpur, Malaysia

J. McP. Dick,

Institute of Terrestrial Ecology, Bush Estate, Penicuik, Midlothian, EH26 0QB, Scotland, United Kingdom

J. Grace

Institute of Ecology and Resource Management, University of Edinburgh, Darwin Building, Mayfield Road, Edinburgh EH9 3JU, Scotland, United Kingdom

&

H. Staines

University of Abertay Dundee, Division of Mathematical Sciences, Kydd Building, Bell Street, Dundee DD1 1HG, Scotland, United Kingdom

Received September 1996

AMINAH, H., DICK, J. McP., GRACE, J. & STAINES, H. 2000. The influence of misting frequencies on the water relations and rooting physiology of *Shorea leprosula* leafy stem cuttings. In a misting experiment on *Shorea leprosula* leafy stem cuttings, the rooting percentage obtained ranged from 50 to 63%. There was no significant effect of a one-minute misting applied at intervals of 1, 3 and 6 h on the rooting ability of the cuttings. However, fewer roots were obtained with a 6-h interval compared to either 1- or 3-h misting interval (2.4 versus 3.3 and 3.5 respectively). This may be attributed to the lower photosynthetic rates (P_n) which were also associated with low irradiance received by the treatment. The results presented here demonstrate the interdependence of misting frequency and incident radiation. From the present study, a misting frequency of 1 min duration at hourly intervals is recommended to ensure adequate water content and photosynthetic activity of cuttings. It was also observed that rooting was associated with lower cutting volume while cuttings with high stem volume were more prone to die.

Key words: Dipterocarps - rooting - relative water content - vapour pressure deficit - photosynthesis - stomatal conductance

AMINAH, H., DICK, J. McP., GRACE, J. & STAINES, H. 2000. Pengaruh kekerapan renjisan terhadap kandungan air dan fisiologi pengakaran keratan batang berdaun *Shorea leprosula*. Dalam ujian renjisan terhadap keratan batang berdaun *Shorea leprosula*, peratus pengakaran yang didapati daripada kajian ini ialah antara 50 hingga 63%. Tidak terdapat kesan yang bererti antara kekerapan renjisan air 1, 3 dan 6 jam yang diberi selama satu minit terhadap keupayaan pengakaran keratan batang *Shorea leprosula*. Walau bagaimanapun, jumlah akar yang didapati adalah sedikit dengan kekerapan renjisan 6 jam dibanding dengan 1 atau 3 jam (2.4 berbanding 3.3 dan 3.5 masing-masing). Ini berkemungkinan disebabkan oleh rendahnya kadar fotosintesis (P_n) dan ini selaras dengan rendahnya cahaya yang diterima oleh rawatan ini. Keputusan yang dipaparkan di sini menunjukkan kaitan antara kekerapan renjisan air dengan cahaya yang diterima untuk pengakaran keratan. Daripada kajian ini, kekerapan renjisan air setiap jam selama 1 minit disyorkan untuk memastikan cukup kandungan air dan juga aktiviti fotosintesis keratan. Didapati juga pengakaran mempunyai pertalian dengan isipadu keratan yang rendah manakala keratan yang isipadunya tinggi kebanyakannya akan mati.

Introduction

Shorea leprosula (Dipterocarpaceae), locally known as meranti tembaga, is one of the most important timber species in Malaysia and is marketed under the trade name of meranti. Due to the scarcity of its seeds, the species has been vegetatively propagated by stem cuttings to provide an alternative source of planting stock supply for reforestation. Mist propagation systems are commonly used for rooting cuttings of tree species in Malaysia including dipterocarps, either with or without enclosures (Momose 1978, Muckadell & Malim 1978, Halle & Kamil 1981, Srivastava & Manggil 1981, Lo 1985, Aminah 1991, Noraini & Ling 1993, Moura & Lundoh 1994). The variability in rooting success of dipterocarps under the mist system, obtained in previous trials by many researchers, cannot be satisfactorily explained since no detailed quantification of the propagation environment or physiological processes has been made. It has been noted in many studies that newly planted cuttings were sensitive to water deficit prior to rooting which in turn affects the physiological processes of cuttings and hence their rooting ability (Loach 1977, Grange & Loach 1983, 1984, Loach 1988a,b, Newton & Jones 1993). The limits of tolerance to water deficits in cuttings have not been well defined (Newton & Jones 1993). The present study was carried out to determine the extent of water deficit affecting the physiology, water relations and rooting ability of *S. leprosula* stem cuttings by regulating misting frequencies on the rooting beds.

Materials and methods

The experiment took place at the nursery of the Forest Research Institute Malaysia (FRIM) in April 1994. A total of 396 single node, leafy stem cuttings were taken from seven-month-old stock plants, raised under 33% full sunlight as potted rooted cuttings. The 28 clones used were: 50, 62, 63, 68, 78, 82, 105, 106, 110, 114, 144, 172, 173, 184, 194, 507, 508, 521, 571, 578, 581, 589, 629, 634, 651, 667, 687, 692. The length of stem and leaf area were the same for all cuttings, 5 cm and 30 cm^2 respectively. The initial diameter and node position of each cutting were recorded. The volume of cuttings was calculated assuming a simple cylindrical shape ($\pi r^2 h$, where r and h are the radius and length of the cutting respectively). The prepared cuttings were planted in a medium consisting of cleaned river sand. These cuttings were then subjected to three different misting frequencies: 1, 3 and 6 h. The duration of each burst of misting was 1 minute. The three treatments were randomly allocated to the node positions so that there was no confounding between treatments and the position on the stock plant from which the cutting was taken. The number of cuttings obtained per stock plant varied from 3 to 7 depending on availability of leaves on the node. Clones with less than 9 cuttings were not used for the experiment. Each treatment consisted of 132 cuttings [60 and 72 cuttings per treatment were used for rooting and relative water content (RWC) assessments respectively]. These cuttings were planted on three rooting beds and misting frequency of each bed corresponded to one treatment. Each bed is a closed polythene mist propagation system. No blocking could be made since misting frequency could only be regulated by beds. This experiment was carried out in natural environment and the temperature, photoperiod and irradiance in the cutting shed were not controlled. Details of the experimental procedure are in Aminah (1995) and Aminah *et al.* (1995).

Temperature, relative humidity and irradiance were recorded by a data logger (21X micrologger, Campbell Scientific, UK) using appropriate sensors. Air and leaf temperatures were measured using thermocouples (Type K chromel-alumel, T.C. Ltd., Uxbridge, UK); relative humidity, using commercial humidity sensors (MP 100 Rotronic probes, Campbell Scientific Ltd., Llandrindod Wells, UK) and irradiance, using quantum sensors (Skye Instrument Ltd., Llandrindod Wells, UK). The sensors were placed in the centre of the rooting bed for each treatment. The data logger was programmed to scan each sensor every 60 seconds, to calculate and store readings every 5 minutes. Data collection extended from day 1 to day 28 of the experiment. Vapour pressure deficit (VPD) was calculated using the formula provided in Aminah (1995).

The relative water content (RWC) of the leaf from different misting frequencies was determined using the method described by Beadle *et al.* (1987). RWC was determined at three different times of the day (09:00, 13:00 and 17:00 hours) on days 1, 8, 14 and 21. At each time of measurement (e.g. 09:00 hours) 24 discs per treatment were sampled from 6 cuttings (2 cuttings were randomly chosen per block and 4 discs were obtained per cutting). Therefore, 18 cuttings were harvested for RWC assessment per treatment per day, giving a total of 72 cuttings per treatment (288 discs) for 4 days.

Photosynthetic rate (P_n) and stomatal conductance (g_s) of cuttings prior to rooting were measured using an infra-red gas analyser (LCA-3, ADC, Hoddesdon, UK). Four cuttings per treatment per block were randomly chosen for the measurement. These same cuttings were measured on days 1, 8, 14 and 21 at three different times of the day (starting from 09:00, 13:00 and 17:00 hours; each time measurement lasted for *c.* 2 h). At each time of measurement (e.g. 09:00 hours), 12 P_n and g_s values were measured per treatment giving a total of 36 values per day (144 values per treatment for 4 days).

Assessment of cuttings was made weekly starting one week after planting until week 16 for rooted, unrooted and dead cuttings as well as number of roots on each cutting. A cutting was scored as rooted when it produced a root of 1 cm in length or more and it was considered dead when the whole cutting turned brown.

Logistic regression (McCullagh & Nelder 1983) was used to determine if treatments, node position or cutting volume was significantly associated with rooting. Analysis of variance followed by Tukey's pairwise comparison was used to test for significant difference between treatments for number of roots, VPD, RWC, P_n and g_s. Results in all the tests were considered significant when the probability level was less than or equal to 5% ($p \leq 0.05$).

Results

Initial diameter and volume of cuttings between treatments were not significantly different. Mean cutting diameter was 0.36, 0.39, and 0.38 cm whilst mean cutting volume was 0.56, 0.66 and 0.60 cm^3 for 1-, 3- and 6-h misting frequencies respectively.

There was no significant difference obtained in the rooting of cuttings between misting frequencies tested and rate of rooting as shown in Figure 1. It was observed that after a steady rate of rooting from week 4 to 10, all treatments had a delay of 3 weeks before more cuttings rooted. From the data analysed, cuttings that rooted from week 4 to 10 had an average diameter of 3.5 mm while those that rooted after week 13 had a mean diameter of 3.8 mm. Rooting of cutting was found to be significantly affected by initial cutting volume and the relationship was negative.

Mortality at week 16 was not significantly affected by treatments, with mean values of dead cuttings of 12, 8 and 12% for 1-, 3- and 6-h misting frequency treatments respectively. Logistic regression analysis indicated that the mortality of cuttings increased with cutting volume. The average diameter for cuttings that died was 4.6 mm. The percentage of cuttings that remained unrooted at week 16 was not significantly influenced by either treatments or morphological characteristics of cuttings. The mean values of unrooted cuttings at week 16 were 25, 42 and 30% for 1-, 3- and 6-h misting frequencies respectively.

The number of roots was significantly affected by the treatments with significantly fewer roots obtained for 6-h misting interval than the other two misting frequencies (Figure 2).

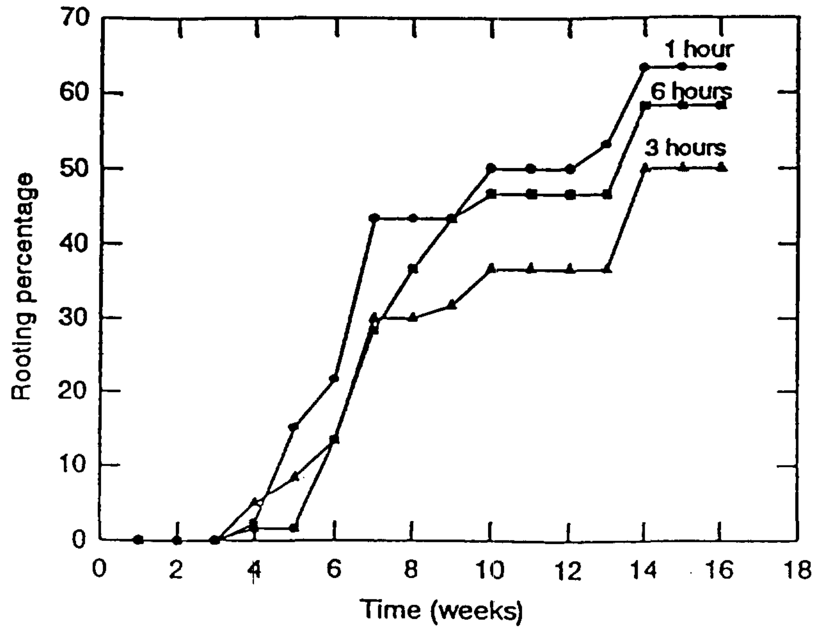


Figure 1. Effect of misting frequencies on the rooting rate of *Shorea leprosula* stem cuttings (n=60 per treatment)

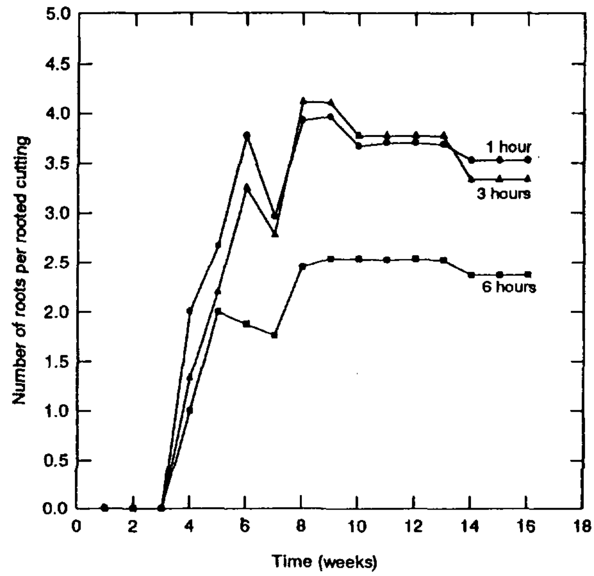


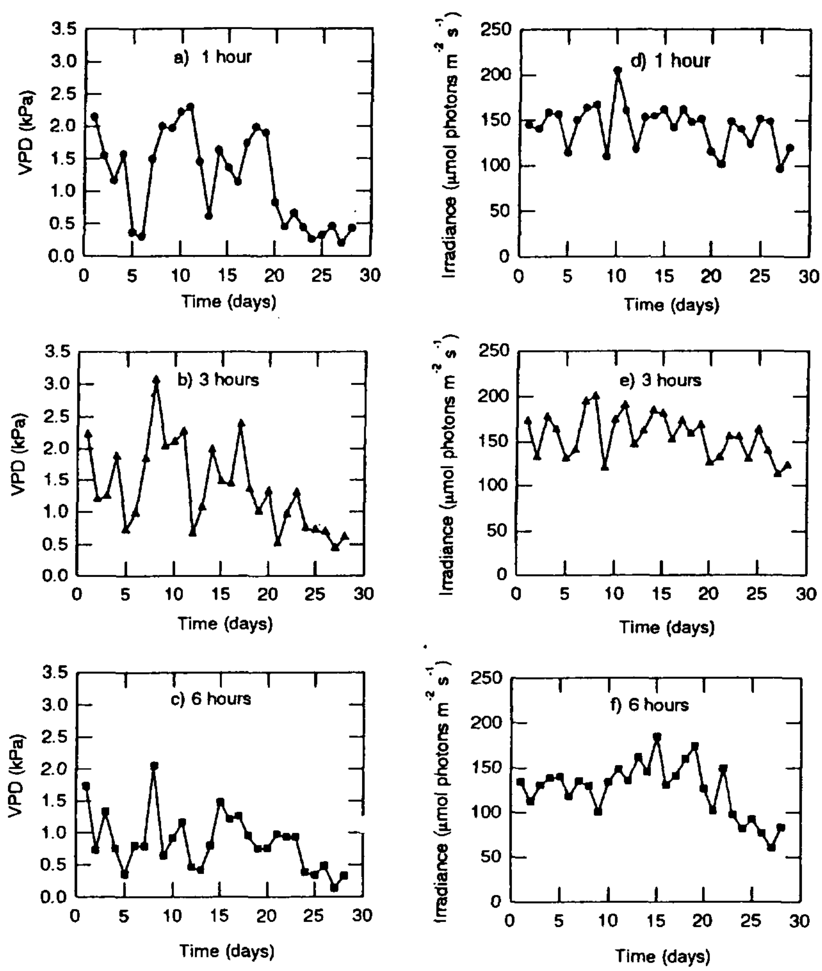
Figure 2. Effect of misting frequencies on rate of mean accumulated number of roots per rooted stem cutting of *S. leprosula* (n=60 per treatment)

Environmental data collected in propagators over a period of 28 days are shown in Table 1. There was a significant difference in daily maximum VPD irradiance between treatments. Daily maximum VPD was significantly higher in 3-h misting compared to that of 1-h and 6-h misting (Figures 3a, b, c). Despite less frequent misting, VPD in 6-h did not differ significantly from that in 1-h misting, possibly due to significantly lower irradiance received in the treatment compared with the other two treatments (Figures 3d, e, f).

There was a significant interaction between treatments applied with times of day and days of measurement on RWC of *S. leprosula* stem cuttings. The RWC was significantly higher with 1- and 6-h than with 3-h misting frequency (Figure 4a). The RWC recorded was highest in the morning, implying that cuttings recovered from the previous day's water deficit as indicated by lower RWC at 13:00 and 17:00 hours (Figure 4b). Stomatal conductance was also significantly affected by treatments, times and days of measurement. Significant interaction was also obtained on g_s between times and days of measurement. Stomatal conductance exhibited a similar trend as RWC in response to treatments and times of measurement (Figures 5a, b). Significantly higher values of RWC and g_s were obtained 21 days after insertion (Figures 6 a, b). Mean RWC measured ranged from 79 to 92% while mean g_s varied from 80 to 216 mmol H_2O m^{-2} s^{-1} depending on treatments, times and days of measurement. P_n was significantly influenced by interactions of treatments and times, times and days of measurement. P_n was significantly lower in 6-h misting and was associated with significantly low photosynthetically active radiation (PAR) (Figures 7a, b). An influence of the diurnal cycle of PAR on P_n was obvious with the rate being significantly lower in the morning than in the afternoon and towards evening where cuttings were mainly respiring (Figures 8a, b).

Table 1. Environmental data in the enclosed mist propagators subjected to different misting levels measured from day 1 to day 24 of the experiment. The value of each variable was calculated as a 5-min average. Mean value for each variable was calculated over a 12-h period for each session of measurement.

	a) Day time (07:05 to 18:55)						b) Night time (19:00 to 07:00)					
Misting frequency	1 hour		3 hours		6 hours		1 hour		3 hours		6 hours	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Irradiance (μmol photons $m^{-2} s^{-1}$)	0–204.3	44.2	0–194.1	50.5	0–185.0	38.0	0–4.3	0.1	0–4.3	0.1	0–3.0	0.1
Relative humidity (%)	61.0–100	95.7	54.9–100	96.7	73.5–100	97.2	63.9–100	99.0	57.7–100	98.6	53.3–100	97.9
Air temperature (°C)	21.9–39.0	30.2	23.4–38.0	30.5	21.5–36.2	29.4	20.2–32.2	26.3	20.2–32.6	27.0	21.1–31.8	26.4
Leaf temperature (°C)	21.7–39.5	30.1	22.4–39.2	31.0	23.4–36.7	29.7	20.9–32.2	26.2	21.6–32.6	26.9	20.7–36.7	26.3
VPD (kPa)	0-2.3	0.2	0–3.1	0.3	0–2.1	0.2	0–1.4	0.00	0–1.4	0.00	0–1.5	0.1



Figures 3a, b, c, d, e, f. Daily maximum VPD and irradiance in propagators with different misting frequencies measured from day 1 to day 28 of the experiment. Daily maximum VPD and irradiance were calculated as a 5-min average.

Discussion and conclusion

Rooting of *S. leprosula* stem cuttings was not significantly affected by frequencies of misting despite differences in water status of cuttings. This may suggest that differences in water status found in this study were too slight to have an effect on rooting ability. This study would suggest that maintaining RWC above 80% was sufficient to ensure adequate water for rooting of *S. leprosula*. Similar results were found by Newton and Jones (1993) on cuttings of several tropical species.

In terms of microclimates around the cuttings, mean VPD in the different misting frequencies was kept low, but periods of water deficit did occur as indicated by the maximum VPD in all treatments which in many cases was more than the threshold level (0.5 kPa) suggested by Grange and Loach (1983) for many broad-leaved species.

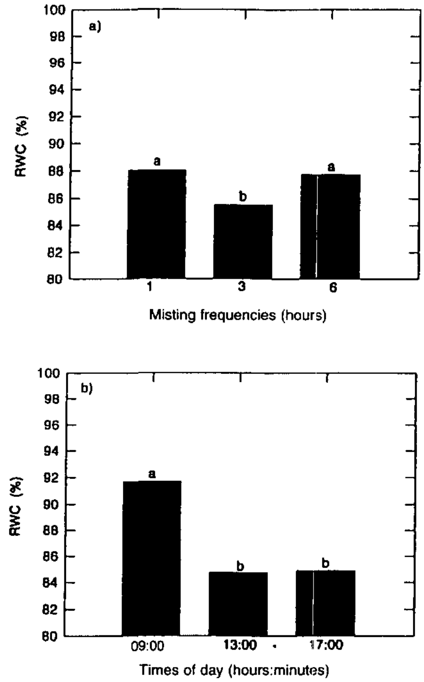


Figure 4. a) Effect of misting frequencies on mean RWC of *S. leprosula* stem cuttings pior to rooting; b) Influence of times of day on mean RWC of *S. leprosula* stem cuttings prior to rooting (means with the same letters are not significantly different at p≤0.05; n=24 per treatment per time per day of measurement)

This temporary water deficit, however, seemed not to affect the rooting of *S. leprosula* stem cuttings. Presumably cuttings were able to tolerate this temporary water deficit and regain turgor during the nocturnal period of low VPD. This was supported by the high RWC and g_s obtained in the morning. The increase in RWC and g_s on day 21 may reflect recovery of the cuttings from water deficit experienced after insertion. The ability of cuttings of other tropical species to tolerate and recover from this temporary water deficit and eventually root has been reported by Mesen (1993) and Newton and Jones (1993).

Direct comparison of the physiological and microclimate data recorded in the present study with other dipterocarp species could not be made since previously no detailed studies have been reported on the physiology and microclimates or cutting water status while on propagation beds. However, several workers have attempted to test the effect of misting frequency and duration on rooting. For example, Srivastava and Manggil (1981) found that intermittent misting of 5-min duration at an interval of 1.5 to 2.5 h yielded reasonable rooting success with some dipterocarp species while Yahaya (1979) stated that 2 min of misting every 2 h was inadequate for rooting of related species. Noraini and Ling (1993) obtained more than 65% rooting of *S. parvifolia* and *S. acuminata* in open misting with 0.5-h interval and 2-min duration. Cuttings of these species seemed to tolerate more water stress judging from the mean

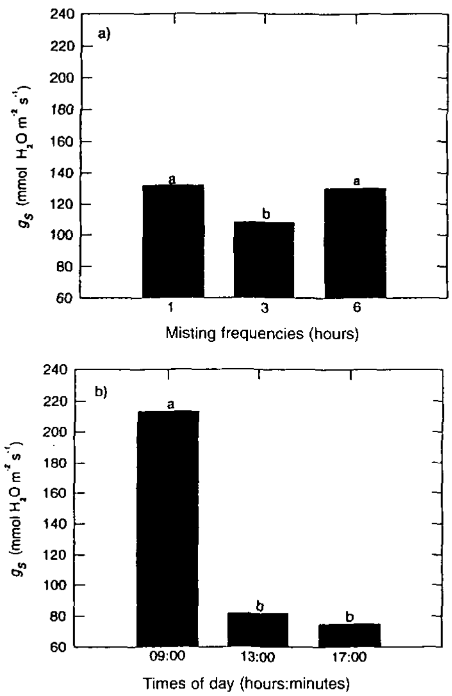


Figure 5. a) Effect of misting frequencies on mean g_s of *S. leprosula* stem cuttings prior to rooting; b) Influence of times of day on mean g_s of *S. leprosula* stem cuttings prior to rooting (means with the same letters are not significantly different at $p \leq 0.05$; n=24 per treatment per time per day of measurement)

relative humidity in their experiment which was kept around 60% with air temperature of 27 °C (Noraini & Ling 1993). In contrast, Lo (1985) found that *S. macrophylla* required continuous misting or alternate misting during daytime followed by continuous misting at night. Absence of misting at night resulted in high mortality of 75%. The author attributed death of cuttings to water deficit experienced by cuttings at night; the results would be more informative if accompanied by environmental data.

On morphological characteristics, regression analysis revealed that rooting of *S. leprosula* stem cuttings was negatively associated with initial volume of cuttings. This would indicate that cuttings with large volume were less suitable for rooting, and they were found to be more prone to die. Cuttings with higher volume in the present study could be associated with larger diameter since cuttings in the present experiment were of the same length. Larger diameter cuttings may have increased lignification which is often associated with poor rooting as lignification is believed to form a physical barrier to rooting (Hartmann *et al.* 1990, Liew 1992). It is also interesting to note that following a steady rate of root emergence (Figure 1), all treatments exhibited a period when no cutting rooted (at weeks 10 to 13). It is possible that roots took a longer time to emerge through the sclerenchyma layer. The negative relationship between volume of cuttings and rooting could also indicate that rooting was not

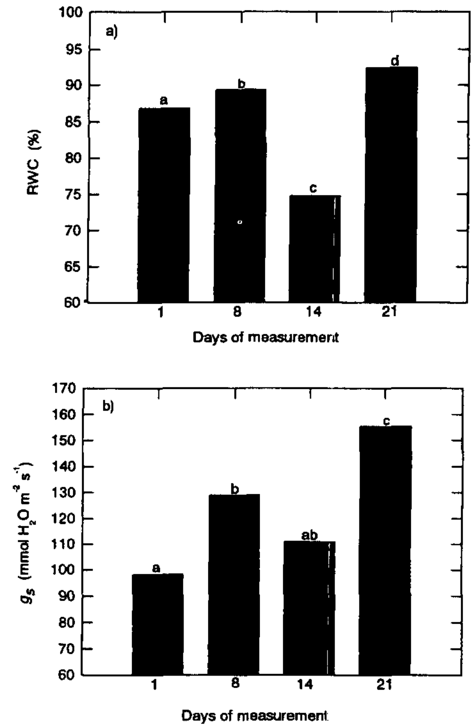


Figure 6. Influence of days of measurement on a) mean RWC; b) mean g_s of *S. leprosula* stem cuttings prior to rooting (means with the same letters are not signidicantly different at p≤0.05; n=216 per day of measurement)

influenced by initial carbohydrates reserves or these carborhydrates were not available for rooting.

Cuttings planted under a misting interval of 6 h produced the least number of roots. The low P_n obtained under this treatment may be responsible for the reduction in the number of roots. The results obtained were supported by other workers who also reported that carbohydrates, either from reserves or through current P_n, have greater influence on root development than on root initiation which is thought to be hormonally controlled (Haaland 1976, Moe & Andersen 1988, Mesen 1993). The lower photosynthesis under 6-h misting could possibly be due to low PAR received by cuttings. Photosynthesis was closely correlated with PAR as indicated by the P_n measured at different times of the day. The problems in experimental layout may have contributed to the differences in PAR received by each treatment. Differences in PAR also led to lower VPD of the rooting bed with 6-h compared to 3-h misting interval. Simultaneously, this difference in VPD affected other physiological measurements such as RWC and g_s which were higher in cuttings planted under 6- than 3-h misting intervals.

A critical examination of the results from the 1-, 3- and 6-h misting intervals could not be made since there were problems in the layout of this experiments. Although

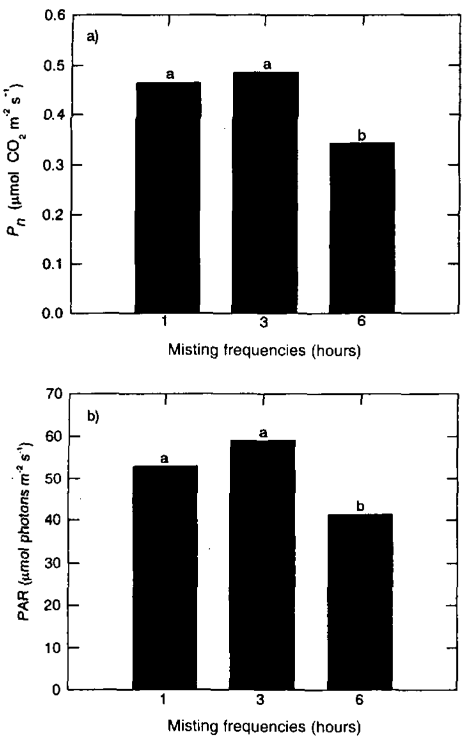


Figure 7. Effect of misting frequencies on a) mean P_n of *S. leprosula* stem cuttings prior to rooting; b) mean PAR when the measurements of P_n were made (means with the same letters are not significantly different at $p \leq 0.05$; n=24 per treatment per time per day of measurement)

improved water relation in 6-h misting with low irradiance could be achieved, low irradiance seemed to limit photosynthetic activity of cuttings. A proper evaluation for this type of experiment can only be made if misting frequencies are regulated by blocks. This is to ensure that blocks can be completely randomised to avoid bias from the effect of irradiance as happened in this experiment. However, this study clearly shows that there is interaction between irradiance and misting frequency.

The findings in this experiment showed that rooting of *S. leprosula* stem cuttings was not affected by the difference in misting frequencies applied. Use of polythene enclosures enabled mean VPD in general to be kept below 0.5 kPa in spite of substantial differences in misting intervals applied. Temporary water deficit which occurred during peak irradiance could be tolerated by *S. leprosula* stem cuttings. However, a misting interval of 3 h or more is not recommended since there was tendency of water deficit to develop in cuttings as indicated by the lower RWC and g_s values obtained compared to 1-h misting interval. More frequent misting such as at 0.5-h interval may be worth testing. This study also showed that cuttings with large volume or diameter were less suitable for rooting and they were found to be more prone to die.

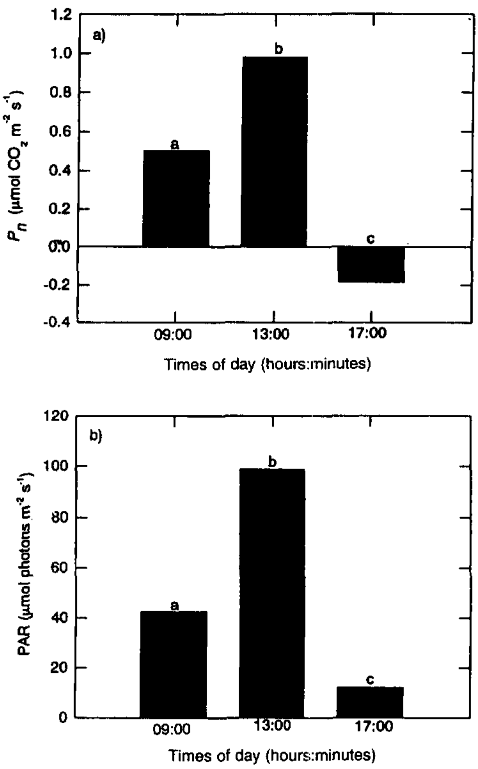


Figure 8. Influence of times of day on a) mean P_n of *S. leprosula* stem cuttings prior to rooting; b) mean PAR when the measurements of P_n were made (means with the same letters are not signidicantly different at $p \leq 0.05$; n=24 per treatment per time per day of measurement)

Acknowledgements

We are grateful to the British High Commission and Overseas Development and Administration (ODA) for their financial support. H. Staines would like to thank the British Council and the Carnegie Trust for the Universities of Scotland for financial assistance. The encouragement from R. R. B. Leakey, Institute of Terrestial Ecology, in carrying out this study is greatly appreciated.

References

Aminah, H. 1991. Rooting ability of stem cuttings of eleven dipterocarp species. *Journal of Malaysian Applied Biology* 20:155–159.

Aminah, H. 1995. Vegetative Propagation of *Shorea leprosula* Miq. by Stem Cuttings. Ph.D. thesis, University of Edinburgh, Scotland, UK. 261 pp.

Aminah, H., Dick, J. McP & Grace, J. 1995. Effect of indole butyric acid (IBA) on stem cuttings of *Shorea leprosula*. *Forest Ecology and Management* 72:199–206.

Beadle, C. L., Ludlow, M. M. & Honeysett, J. L. 1987. Water relations. Pp. 50–61 in Coomb, J., Hall, D.O., Long, S. P. & Scurlock, M. O. (Eds.) *Techniques in Bioproductivity and Photosynthesis*. 2nd edition. Pergamon Press, Oxford.

GAY, A. P. & LOACH, K. 1977. Leaf conductance changes on leafy cuttings of *Cornus* and *Rhododendron* during propagation. *Journal of Horticultural Science*. 509–516.

GRANGE, R. I. & LOACH, K. 1983. Environmental factors affecting water loss from leafy cuttings in different propagation systems. *Journal of Horticultural Science* 58:1–7.

GRANGE, R. I. & LOACH, K. 1984. Comparative rooting of eighty-one species of leafy cuttings in open and polythene-enclosed mist systems. *Journal of Horticultural Science* 59:15–22.

GRANGE, R. I. & LOACH, K. 1985. The effect of light on the rooting of leafy cuttings. *Scientia Horticulturae* 27:105–111.

HAALAND, E. 1976. The effect of light and CO_2 on the carbohydrates in stock plants and cuttings of *Campanula isophylla* Moretti. *Scientia Horticulturae* 5:352–361.

HALLE, F. & KAMIL, H. 1981. Vegetative propagation of dipterocarps by stem cuttings and layering. *Malaysian Forester* 44:314–318.

HARTMANN, H. T., KESTER, D. E. & DAVIES, F. T., JR. 1990. *Plant Propagation – Principle and Practices*. 5th edition. Prentice-Hall International Editions, Eaglewood Cliffs, New Jersey. 647 pp.

LIEW, T. S. 1992. Effect of IBA, Cutting Position and Rooting Media on the Rooting Ability of *Shorea leprosula* Miq. and *Shorea curtisii* Dyer ex King. Cuttings. B.Sc.(For.) thesis, Universiti Pertanian, Serdang, Selangor, Malaysia. 64 pp.

LO, Y. N. 1985. Root initiation of *Shorea macrophylla* cuttings: effect of node position, growth regulators and misting regime. *Forest Ecology and Management* 12:42–52.

LOACH, K. 1977. Leaf water potential and the rooting of cuttings under mist and polythene. *Physiologia Plantarum* 40:191–197.

LOACH, K. 1988a. Controlling environmental conditions to improve adventitious rooting. Pp. 248–273 in Davis, T. D., Haissig, B. E. & Sankhla, N. (Eds.) *Adventitious Root Formation in Cuttings*. Dioscorides Press, Portland, Oregon.

LOACH, K. 1988b. Water relations and adventitious rooting. Pp. 102–116 in Davis, T. D., Haissig, B. E. & Sankhla, N. (Eds.) *Adventitious Root Formation in Cuttings*. Dioscorides Press, Portland, Oregon.

MCCULLAGH, P. & NELDER, J. A. 1983. *Generalised Linear Model*. Chapman and Hall, New York.

MESEN, J. F. 1993. Vegetative Propagation of Central American Hardwoods. Ph.D. thesis, University of Edinburgh, UK. 294 pp.

MOE, R. & ANDERSEN, A. S. 1988. Stock plant environment and subsequent adventitious rooting. Pp. 214–234 in Davis, T. D., Haissig, B. E. & Sankhla, N. (Eds.) *Adventitious Root Formation in Cuttings*. Dioscorides Press, Portland, Oregon.

MOMOSE, Y. 1978. Vegetative propagation of Malaysian trees. *Malaysian Forester* 44:219–223.

MOURA-COSTA, P. H. & LUNDOH, L. 1994. A method for vegetative propagation of *Dryobalanops lanceolata* (Dipterocarpaceae) by cuttings. *Journal of Tropical Forestry Science* 6:533–541.

MUCKADELL, J. S. & MALIM, P. 1978. *Preliminary Results from Rooting Juvenile Cuttings of Some Dipterocarp Species*. Working Paper FAO No. 2. Forest Research Centre Sepilok, Sabah, Malaysia. 43 pp.

NEWTON, A. C. & JONES, A. C. 1993. The water status of leafy cuttings of four tropical tree species in mist and non-mist propagation system. *Journal of Horticultural Science* 68:653–663.

NORAINI AB. S. & LING, T. T. 1993. A note on the rooting of *Shorea acuminata* and *Shorea parvifolia* leafy stem cuttings. *Journal of Tropical Forest Science* 6:206–208.

SRIVASTAVA, P. B. L. & MANGGIL, P. 1981. Vegetative propagation of some dipterocarps by cuttings. *Malaysian Forester* 44: 301–313.

YAHAYA, M. 1979. Effect of Position, Presence of Leaves and Hormone Treatment on Rooting of *Anisoptera scaphula*, *Shorea leprosula* and *Dryobalanops aromatica*. B.Sc. (For.) thesis, Universiti Pertanian Malaysia, Serdang, Selangor, Malaysia. 61 pp.