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Lateral shading of stockplants enhances rooting performance of guava (*Psidium guajava* L.) cuttings

M.A. Hossain and M. Kamaluddin

Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong 4331, Bangladesh.
E-mail: aktar_forestry@hotmail.com

Abstract

The study considers the effects of different light levels on shoot morphology and rooting ability of shoots developed following topping of stockplants of guava (*Psidium guajava* L.). Two-year old seedling-originated stockplants were topped leaving 25 cm tall stump. Shoots were allowed to develop at three light levels: open sun (100% full sun), lateral shade (50% full sun) and overhead shade (12% full sun). Bud activity, shoot growth and morphology, and rooting ability were studied. Shading did not restrict bud activity in stockplants' stumps; rather active bud percentages were higher in shaded stockplants leading to the production of as many shoots as in 100% daylight. Though number of nodes per shoot tended to increase in shaded stockplants, estimates of cutting yield did not largely vary with the light regimes. Differences in stockplants exposure to light quantity did not significantly affect the rooting success of cuttings. However, shade cuttings produced significantly higher number of roots and root dry masses per cutting than those from 100% daylight. These benefits of shading on the rooting performance of cuttings were more pronounced in shoots developed in 50% daylight than those in 12% daylight. Lateral shade had a positive shade-effect on shoot development likely by improving physiological condition conducive for production of good performing rooted cuttings.

Key words: Rooting ability, non-mist propagator, stem - cutting, topping

Introduction

Mass propagation of trees by stem cuttings involves stockplant management for the production of juvenile shoots for making cuttings. Stockplants are usually managed as hedge or coppice forming stools for the production of large number of shoots (Libby *et al.*, 1972; Howard, 1994). Stockplants are decapitated at the beginning of the propagation season. Decapitation of the stockplants releases dormant buds from correlative inhibition by breaking apical dominance. Number of shoots produced following decapitation and the growth of the sprouted shoots are related to cutting yields. Light levels during growth of stockplants may be important for development and growth of shoots and rooting ability of cuttings.

Research on light responses of plants indicates that growth and morphology of plants are largely affected by light level during growth (Kamaluddin and Grace, 1996; Kamaluddin, 1999). Light level controls structure and function of plants. Sun grown plants have thicker leaves and contain more photosynthetically active mass per unit leaf area, and thereby mesophyll thickness is responsible for higher rates of photosynthesis (Fetcher *et al.*, 1983; Kamaluddin and Grace, 1993). High light accelerates growth, while low light limits growth. Thus light levels may affect shoot production and cutting yields of stockplants.

Rooting ability of cuttings is as important as cutting yield. Light level during growth and development of shoots in stockplants is known to influence the rooting ability of cuttings (Migita and Nakala, 1978; Leakey, 1985; Kamaluddin, 1999). In some cases, cuttings root more readily when stockplants are grown under low light (Leakey, 1985). In contrast, exposure of stockplants to high light before taking of cuttings can result in more rapid rooting in the cuttings (Migita and Nakala, 1978). Since, in some cases, high and low light levels may have contrasting effects on shoot production and rooting performance, responses of stockplants of a given species to a range of light levels may be important to adjust light condition that is conducive for high cutting yields and good rooting performances. Most of the studies on light treatments of stockplants considered whole-plant acclimation to partial shade, deep shade or full sun. Responses to a light regime that exposes stockplants to shade for parts of the day, and to direct sunlight for the other have not yet been fully examined. Such a light treatment may impart shade effect on morphology and physiology of shoots without limiting the photosynthetic inputs required for rapid shoot growth and high cutting yields.

Guava is a popular fruit tree of the tropics and the commercial importance of its fruits made it suitable for this study. Though vegetative propagation of guava by air layering is a common practice but it is a time-consuming and expensive method and has practical limitations to produce large numbers of stocks for commercial planting. Mass propagation by cuttings is assumed to be a better and cost-effective method over the traditional practice of vegetative propagation.

In the present study, we examined the development and growth of shoots, following topping of guava stockplants, and the rooting abilities of their cuttings, exposing the stumps to three light regimes: overhead shade, lateral shade, and full sun. The lateral shade regime allowed the decapitated stockplants to have low light in the morning and in the afternoon, and to receive direct sunlight at the mid-day. We examined the hypothesis that lateral shade imparts shade effects on morphology and physiology of shoots without limiting the cutting yields and that these shade effects improve rooting performances of cuttings.

Materials and methods

Growing of stockplants and light regimes: Stockplants of guava (*Psidium guajava* L.), derived from seedlings, were grown at a north- south direction in open nursery beds at spacing of 1 x 1 m. They were topped 25 cm above ground level at the age of 2 years. The shock plants were then immediately assigned to three light levels: open sun (100% daylight), lateral shade (50% daylight), and overhead shade (12% daylight). Locally available materials like bamboo slates and sungrasses were used for shading the stockplants. Overhead shade was employed putting a bamboo slat at a height of 1 m above ground level covering 10 stumps. A layer of dry sungrasses (5 cm thick) was spread over the slat to intensify the shade. Lateral shade was provided erecting 1 m high bamboo slates lined with a layer of sungrasses along the sides of the bed, covering 10 stumps. Control plot was an area with 10 stumps kept exposed to full sun. In this way, each light level was replicated thrice covering 30 stumps under each light level. In overhead shade regime, the stockplants received direct sunlight only in the early morning and in the late afternoon. In lateral shade regime, direct sunlight reached the bed only in the noon. Photon flux was measured using quantum sensors (SKP 215, Skye Instrument Ltd., Powys, UK) and a data logger (Datahog2, SDL5360, Skye Instrument Ltd., Powys, UK), for a single day. Control plots received a total daily photon flux of 24 mol m^{-2} d^{-1} while the lateral shade and the overhead shade plots experienced 13 and 3 mol m^{-2} d^{-1}, respectively. As such the light regimes were defined as percentage daylight, 100% for control, 50% for lateral shade, and 12% for overhead shade. The experiment was conducted during March-August when mean maximum and minimum temperatures were 32 and 24^{o}C, respectively, and day-length was around 12.7 h. The plots were irrigated and kept weed free.

Bud activity and shoot morphology: Bud activity in the stockplants was monitored regularly and number of buds, activated in each stump was recorded at every alternate day. Eight weeks after topping, total number of shoots and internodes were counted and recorded for each stockplant.

Shoot morphology was studied eight weeks after topping by harvesting six shoots from six individual stumps for each light regime, two shoots from each plot selecting at random. The shoots were measured for number of nodes, length and diameter of internodes and leaf area.

Internodes with fully developed leaf at the upper part of the shoot was taken as the topmost internode of the shoot, and as such tip of the shoot was not included in the measurement since it usually fails to root. Diameter was measured at the mid-point of internode. Dry weights of the internode and leaf samples were recorded after drying them in an oven at 70^{o}C for 48 h. With these primary data, specific internode length (internode length/ internode dry weight), specific leaf area (leaf area/leaf dry weight) and specific internode volume (internode volume/ internode dry weight) were derived.

Rooting trials: Single node cuttings were made out of shoots with one leaf. Thirty cuttings from each light regime were taken for rooting trials. The cuttings were immersed briefly in a solution of fungicide, (Diathane M45, Rohm & Co. Ltd., France; 2 g per liter of water) to avoid fungal infection. Then they were rinsed and kept under shade for 10 minutes in open air. The cuttings were then planted into a non-mist propagator in three completely randomized blocks. The propagator was made out of metal frame and polythene sheet (Kamaluddin, 1997). The cuttings were planted into perforated plastic trays (12 cm depth) filled with coarse sand mixed with fine gravel. Each tray contained 10 cuttings and served as a plot. Thus number of replicate cuttings per light regime was 30. The cuttings were watered once only just after setting into the propagator and no watering was required till the transfer of rooted cuttings from the propagator.

It was possible to maintain about 85-90% humidity 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 a bamboo made shed (Kamaluddin, 1999) to avoid excessive heat accumulation. Photosynthetic photon flux inside the propagator was about 12% full sun. During the experiment, mean maximum temperature was 32°C and the mean minimum temperature was 25^{o}C.

Six weeks after planting, the cuttings were subjected to weaning before transfer them from the propagator. For weaning, the propagator was kept open at night for three days, and at day and night for another three days. Rooting success and number of roots produced in each rooted cutting were recorded seven weeks after setting. Roots from each cutting were extracted carefully. Root, leaf and stem samples were dried in an oven at 70°C for 48 h and then dry weights recorded.

Analysis of variance and Duncan's Multiple Range Test (DMRT) were employed to explore the possible differences among the effect of light regimes. Data on rooting percentages were transformed to arc sign values before analysis of variance.

Results and discussion

Bud activity in the stockplants: Topping of stockplants induced dormant buds in the stumps to shoot up. Growing buds emerged out of the barks within 10 days after topping in 50% and 12% light regimes whereas in 100% light level they emerged 12 days after topping. Sprouting of buds in the stumps continued over another 20-25 days. All the sprouted buds, however did not survive as some ceased growth immediately after emergence and ultimately died. Active buds that survived and turned into shoots varied with light regimes. Active bud percentage (percentage of active buds out of total buds sprouted), 60 days after topping, was significantly higher (P = 0.03) in 50 and 12% light regimes (85 and 82%, respectively) than those in 100% light level (76%). However, average number of shoots per stump did not significantly (P = 0.45) differ with the light levels which ranged between 30 and 37.

Shoot growth and shoot morphology: Different light levels significantly affected the growth and morphology of shoots (Table 1 and Fig. 1). Average number of nodes varied significantly with light levels. Laterally shaded stockplants (50% light) produced higher number of nodes per shoot than those in 100% light level. This variable did not vary between 50 and 12% light regimes. Different light regimes significantly affected mean leaf area.

Shading of stockplants increased mean leaf area; 50 or 12% light regime produced leaves with higher mean leaf area than those in 100% light. Mean leaf dry weight was not significantly affected due to different light conditions. Specific leaf area (SLA) was highest in 12% light level. This variable did not significantly vary between 100 and 50% light regimes.

Table 1. Effect of different light regimes on shoots growth and leaf characterstics

Variables	Daylight (%)			*P*
	100	50	12	
Nodes per shoot (number)	7.3 b	9.2 a	8.2 ab	*
Leaf area (cm^2)	17.8 b	24.3 a	26.4 a	***
Leaf dry weight (mg)	288 a	360 a	272 a	NS
Specific leaf area (cm^2 g^{-1})	67.3 b	68.4 b	106.0 a	*****

Significance levels: ***** =$P < 0.0001$; ***= $P < 0.005$; *= $P < 0.05$; NS= not significant at $P < 0.05$. The same superscript letters indicate no significant difference at $P < 0.$ 05 (DMRT)

Rooting responses: Different light regime exposure to stockplants did not significantly affect rooting percentage of cuttings. All the cuttings planted rooted with 100% rooting successes across the stockplants in different light regimes. Root number per cutting differed with light regimes stockplants (Table 2 and Fig. 2). Cuttings developed in 50 or 12% light regime produced higher number of roots than those at full daylight level. Root dry weight per cutting was significantly higher in 50% light than in full sunlight. This variable did not significantly vary between 100 and 12% light level.

Table 2. Effects of stockplants' light levels on rooting ability of cuttings

Variables	Daylight (%)			*P*
	100	50	12	
Rooting percentage	100	100	100	NS
Root number per cutting	14.2 b	21.3 a	20.7 a	*
Root dry weight per cutting (mg)	72.9 b	103.5 a	85.7 ab	*

Significance levels *= $P < 0.05$; NS,=not significant at $P < 0.05$. The same letters indicate no significant difference at $P < 0.05$ (DMRT).

Cutting morphology: Single node cuttings taken from shoots of different light levels significantly differed in mean cutting length, mean cutting diameter, and cutting volume (Table 3). Cutting length was significantly higher in 12% daylight than in 100% daylight. This variable did not significantly vary between 50 and 12% daylight. Cutting diameter was significantly higher in 50% daylight than in 100% daylight but there was no significant difference between 50 and 12% daylight. Cutting volume, cutting leaf area or cutting dry weight was significantly higher in 50 or 12% daylight than in 100% daylight regime.

Table 3. Morphology of cuttings taken from shoots developed in different light regimes

Variables	Percentage daylight to stockplants			*P*
	100	50	12	
Cutting length (cm)	5.1 b	5.6 ab	5.9 a	*
Cutting diameter (mm)	2.7 b	3.3 a	3.0 ab	*
Cutting volume (cm^3)	0.4 b	0.6 a	0.5 a	***
Cutting leaf area (cm^2)	56.1 b	82.6 a	81.6 a	***
Cutting dry weight (mg)	600.0 b	825.1a	804.9 a	***

Significance levels: ***, $P < 0.005$; *, $P < 0.05$. The same letters indicate no significant difference at $P < 0.05$ (DMRT).

Lower light regimes, used in the present study, did not restrict bud activity in stockplants stumps, rather exhibited early and high bud activity resulting in higher percentages of active buds than that in 100% light. Forcing dormant buds in stockplants' stumps into growth by topping produced several shoots in a stump within a period of days. The new shoots grew vigorously and produced several nodes within a period of weeks. Lateral shade with 50% daylight produced significantly higher numbers of nodes per shoot than 100% daylight (Table 1). However, since numbers of shoots per stockplant did not significantly differ due to the light regimes, estimates on cutting yields would not largely differ between the shade regimes and 100% daylight. Number of shoots developed on stumps following decapitation depends on the availability of dormant buds in the stumps. Number of shoots normally increases with stump diameter (Kamaluddin, 1998). Since in the present experiment stockplants were of the same age and received the similar site treatments before decapitation, light levels after decapitation did not significantly affect the number of shoots per stump. Shoot growth is expected to depend on current photosynthesis and the carbohydrate reserves in the stump. Root carbohydrate reserves normally support early-season growth flush with the onset of growing season (Dickmann and Hendrick, 1994). In our experiment, shoot growth and number of nodes per shoot were not largely affected in 12% daylight suggesting an important role of stump carbohydrates on shoot growth.

Though rooting successes of cuttings were not affected by the light levels, numbers of roots produced per cutting and their dry masses were significantly higher in 50% light than in full sunlight suggesting beneficial effects of shading of stockplants on rooting performances of cuttings. Shoots developed in low light are usually less lignified, including reduced sclerenchymatous fibre development in the cortex, which may facilitate the physical emergence of roots or simply provide a large number of parenchyma cells capable of dedifferentiation and formation of root initials (Beakbane 1969; Howard, 1994). Biosynthesis and destruction of both auxin and lignin, and the role of light in auxin breakdown suggest that auxin enrichment may occur at the expense of lignification (Howard, 1994), and that this might be a major causal factor for the production of larger number of roots in cuttings derived from the shaded stockplants.

Provided the physiological state of cuttings is conducive to rooting, carbohydrate status of cuttings can play an important role. An abundance of stored carbohydrates is generally correlated with high rooting ability of cuttings (Veierskov, 1988). Shoots developed in 12% daylight became shade acclimated as was evident from their significantly higher SLA than those from other two light levels. Formation of thinner leaf results in a high SLA (Kamaluddin and Grace, 1995) and shade leaves with a high SLA has a lower photosynthetic capacity than those developed in high light conditions (Kamaluddin and Grace, 1993). A difference in photosynthetic capacity, as generally observed in sun vs. shade leaves, is attributed to the differences in photosynthetically active mass per unit leaf area (Hoflacher and Bauer, 1982). SLA in 50% daylight did not vary from that in 100% daylight suggesting no appreciable change in leaf thickness. Thus the shoots developed in 50% daylight had maintained a high photosynthetic capacity similar to those of 100% daylight. Cuttings derived from 100% daylight might be expected to have adequate amounts of carbohydrates to serve the rooting demands. But they produced fewer numbers of roots per cutting with less root dry masses than those from 50% daylight suggesting a possible limitation in the utilization of reserved carbohydrates. Physiological state of the cuttings can have an

Fig. 1

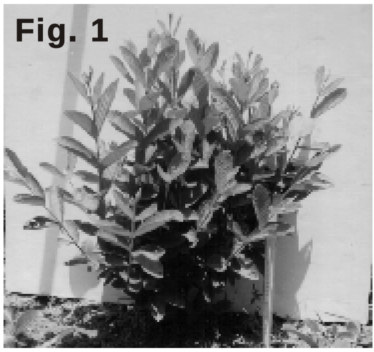

Fig. 2

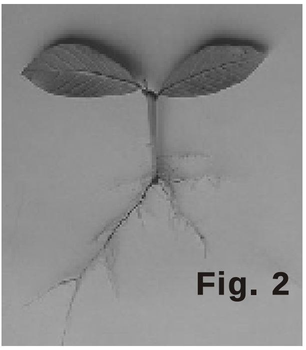

Fig. 1. Profuse shoots developed in a topped stockplant under lateral shade.
Fig. 2. Cuttings rooted six weeks after setting in non-mist propagator.

overriding influence and result in poor rooting even in cuttings with high carbohydrate concentrations (Friend *et al.,* 1994). This might explain why cuttings derived from full sunlight failed to produce as much root dry mass or as many roots per cutting as those from 50% daylight regime.

A conspicuous effect of shade was the formation of longer internodes (Table 3) and thus of longer single-node cuttings. Cuttings from 50% daylight were as long as those of 12% light indicating a shade effect on internode development. Shade cuttings with higher cutting diameters had significantly higher cutting volumes than those developed in full sunlight. Rooting performance can be related to cutting volume. Larger volume means a larger amount of assimilates that are utilised to produce more roots and higher root dry masses (Kamaluddin, 1999). Cuttings from 50% daylight had significantly higher cutting volume than those from 100% daylight. Another important difference among light regimes was the leaf area of the cuttings. Shade cuttings had significantly higher leaf areas than those from 100% daylight. Leaf area of cuttings is known to affect rooting of cuttings through the production of reflux carbohydrates, apparently derived from the current photosynthesis during rooting in a propagation unit (Leakey and Storeton-West, 1992). Cuttings with larger leaf areas can significantly increase number of roots and root dry masses in rooted cuttings (Kamaluddin and Ali, 1996). Therefore, the possible effect of leaf area of cuttings on the formation of higher number of roots and high root dry masses as observed in the rooted cuttings from 50 or 12% daylight cannot be discounted.

The results suggest that lateral shade of stockplants induced shade effects modulating the morphology and possibly the physiology of shoots. These changes were conducive to producing higher numbers of roots and root dry masses per cutting. This has an important practical implication since shading of stockplants will increase the number of roots and the root dry masses in cuttings of guava without using any rooting hormone. Lateral shade can be imposed either using shade nets or growing nurse plants along the stoolbeds.

References

Beakbane, A.B. 1969. Relationships between structure and adventitious rooting. *Proceedings of The International Plant Propagators' Society,* 19: 191-201.

Dickmann, D.I. and R.L. Hendrick, 1994. Modeling adventitious root system development in trees: clonal poplars. In: *Biology of adventitious root formation.* (Davis, T.D. and Haissig, B.E. Eds). Plenum Press, New York, USA, pp. 203-18.

Fetcher, N., B.R. Stain and S.F. Oberbauer, 1983. Effect of light regime on the growth, leaf morphology and water relations of seedlings of two species of tropical trees. *Oecologia,* 58: 314-9.

Friend, A.L., M.D. Coleman and J.G. Isebrands, 1994. Carbon allocation to root and shoot systems woody plants. In: *Biology of adventitious root formation.* (Davis, T.D. and Haissig, B.E. Eds). Plenum Press, New York, USA, pp. 245-73.

Hoflacher, H. and H. Bauer, 1982. Light acclimation in leaves of the juvenile and adult life phases in Ivy (*Hedera helix*). *Physiologia Plantarum*, 56: 177-82.

Howard, B.H. 1994. Manipulating rooting potential in stockplants before collecting cuttings. In: *Biology of adventitious root formation.* (Davis, T.D. and Haissig, B.E. Eds). Plenum Press, New York, USA, pp. 123-42.

Kamaluddin, M. 1997. Production of quality planting stock for agroforestry plantations. In: *Agroforestry: Bangladesh perspective.* (Alam, M.K., Ahmed, F.U. and Amin, S.M.R. Eds). Bangladesh Agricultural Research Council, Dhaka, Bangladesh, pp. 151-64.

Kamaluddin, M. 1998. Mass clonal propagation of tropical forest trees for improvement in timber yield and quality. In: *Tree Improvement: Applied Research and Technology Transfer* (Puri, S. Ed). Science Publishers inc., USA, pp. 263-72.

Kamaluddin, M. 1999. Propagation of *Hopea odorata* and *Chickrassia velutina* by cutting: shoot production in stock-plants and rooting ability of cuttings as influenced by growth light condition of stock-plants. *Proceedings of the 6th Round Table Conference on Dipterocarps, India,* (Cox, M.C. and Elouard, C. Eds).

Kamaluddin, M. and M. Ali, 1996. Effect of leaf area and auxin on rooting and growth of rooted stem cuttings of neem. *New Forests,* 12: 11-8.

Kamaluddin, M. and J. Grace, 1996. Acclimation in seedlings of tropical forest trees (*Bischofia javanica* Blume and *Hopea odorata* Roxb.) in relation to light and nutrient supply. *Malaysian Forester,* 59: 177-88.

Kamaluddin, M. and J. Grace, 1995. Photoinhibition and recovery in seedlings of *Anthocephalus chinensis* following a stepwise increase in light. *Bangladesh Journal of Botany,* 24: 157-64.

Kamaluddin, M. and J. Grace, 1993. Growth and photosynthesis of tropical forest tree seedlings (*Bischofia javanica*) as influenced by a change in light availability. *Tree Physiology,* 13: 189-01.

Leakey, R.R.B. 1985. The capacity for vegetative propagation in trees. In: *Attributes of trees as crop plants.* (Cannell, M.G.R. and Jackson, J.E. Eds), pp. 110-133.

Leakey, R.R.B. and R. Storeton-West, 1992. The rooting ability of *Triplochiton scleroxylon* cuttings: the interaction between stockplant irradiance, light availability and nutrients. *Forest Ecology and Management,* 49: 133-150.

Libby, W.J., A.G. Brown and J.M. Fielding, 1972. Effects of hedging radiata pine on production, rooting and early growth of cuttings. *New Zealand Journal of Forest Science*, 2: 263-283.

Migita, K. and G. Nakala, 1978. Effect of the light supply before taking cuttings on the rooting of *Cryptomeria japonica. Journal of Agricultural Science,* 23: 52-58.

Veierskov, B. 1988. Relations between carbohydrates and adventitious root formation. In: *Adventitious root formation in cuttings.* (Davis, T.D., Haissig, B.E. and Sankhia, N. Eds). Dioscorides Press, Portland, USA, pp. 70-80.