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EFFECT OF SHADE ON GROWTH OF *Greenwayodendron suaveolens* (Engl. & Diels) Verdc. SEEDLINGS

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ABSTRACT

Shading influences growth, survival and regeneration of tropical tree species such as *Greenwayodendron suaveolens,* especially during seedling establishment. This study investigated the influence of varying light intensities on early growth of *G. suaveolens* seedlings. Using light screening chambers, the effects of 50%, 75%, 100% light intensities on seedling total height, collar diameter, and number of leaves as well as biomass accumulation were assessed for sixteen weeks. Data obtained were analysed using descriptive and inferential statistics at $p < 0.05$ level of significance. The variation in light intensity and duration of growth had significant effects on all growth parameters; however, there was no interaction between the two factors. The height, collar diameter and number of leaves increased in the order 50 %< 75% <100% light intensity. On the contrary, relative growth rate (0.02 g g^{-1} day^{-1}) and biomass accumulation (1.64 – 1.76 g) were not significantly different across treatments with the least light intensity (50 %) producing the highest leaf (0.79 g) and root (0.51 g) biomass. *Greenwayodendron suaveolens* responded positively to shading and may be a good candidate for gap recovery and enrichment planting in natural forest.

Keywords: Varying light intensities, biomass accumulation, *Greenwayodendron suaveolens,* early growth.

INTRODUCTION

Establishment of tropical tree seedlings during the early stages is recognized as one of the most vulnerable phases in the life cycle of plants. Consequently, under field conditions, canopy structures can change environmental conditions through the reduction of the amount of soil surface area exposed to direct sunlight and air, and this could result in consequences such as a decrease in the photosynthetically active radiation, air and soil temperatures beneath the canopy. In addition, lower temperatures result in a reduction in rate of evapotranspiration, which ultimately results in greater availability of soil water for emerging plants (Holmgren, 2000; Carvajal *et al.*, 2014). Light supply is therefore, considered to be a key physical factor controlling the development of tree seedlings in tropical rain forests; affecting biological processes such as, photoperiodism, cell permeability, chlorophyll synthesis, photosynthesis, transpiration and respiration (Medina, 1998; Gehring, 2003).

Because variation in light intensity affects the germination and growth of various plants present in the seed bank; tree seedlings of tropical rain forests have to develop functional traits which assist in their ability to tolerate low light conditions (for example, efficient use of sunflecks and long leaf life spans). As a matter of fact, the light quantity and quality significantly influence seedling growth and architecture, such that, high light intensities cause the development of short, stocky stems while low light intensities cause etiolation, especially at the juvenile stage (Bartlett and Remphrey, 1998; Sack, 2004; Olajuyigbe and Agbo-Adediran, 2015).

Greenwayodendron suaveolens (Engl. & Diels) Verdc. a medium-sized to fairly large tree (35 – 45 m tall; diameter of 70-90 cm), with deciduous growth characteristics, belongs to the Annonaceae family. It is commonly known as Molinda (English), Moambe noir (French) and Muambapreta (Polish). The species is restricted to the understorey canopy in humid evergreen and semi-deciduous forest of sub-Saharan Africa (Dauby *et al.*, 2010).

In traditional medicine, the roots, bark and leaves of this species have been used for treating ailments such as headaches, stomach aches, rheumatic pains, fever, constipation, hernia, and also to facilitate childbirth and treat female infertility (Focho *et al.*, 2010). In recent times, modern medicine has identified *G. suaveolens* to be a highly valued medicinal plant because it contains a natural product called sesquiterpenyl indole compound which has been shown to have antibacterial, anticancer and anti-HIV properties (Yoo *et al.*, 2005; Ding *et al.*, 2010; Marcos *et al.*, 2013). For example, Indole-sesquiterpenes and suaveolindole extracts from *G. suaveolens* manifested significant antibacterial activity against gram-positive bacteria such as *Bacillus subtilis*, *Staphylococcus aureus* and methicillin resistant *Staphylococcus aureus* (Yoo *et al.*, 2005; Ding *et al.*, 2010). To this end a lot of efforts have gone into the characterisation of the active ingredients in this tree species. However, little information is available on its silvicultural requirements, early stage development and light tolerance levels. Hence, attempts to establish plantations of such lesser known species may be constrained by inadequate knowledge on its early growth behaviour.

In this study, we used a controlled experimental approach to assess how varying light intensities would affect early growth and biomass accumulation of *G. suaveolens* seedlings. We tested the hypothesis that intermediate levels of shading maximize seedling growth with sufficient light penetration for biomass accumulation during the early developmental stages (Carvajal *et al.*, 2014).

MATERIALS AND METHODS

Study Area

This study was carried out at the nursery of the Department of Forest Resources Management University of Ibadan, Ibadan, Nigeria. University of Ibadan is situated at the northern part of Ibadan along Oyo road at approximately latitude 7° 28´N and longitude 3° 52´E. The location experiences a West African tropical humid climate which is characterised by dry (November – March) and wet (April – October) seasons.

Experimental procedure

Seeds of *G. suaveolens*, collected from a mother tree at the Botanical Garden of the University of Ibadan, Nigeria were de-pulped, washed and then sown in germination beds. After 5 weeks, 180 seedlings were picked and transferred into polypots which were watered with 100 mls of water per seedling. Using a completely randomised design, the selected seedlings were exposed to three light intensity treatments (50%, 75% and 100%) with 20 plants per treatment replicated three times.

The artificial light environments were simulated by constructing light screening chambers with wooden frames (1.65 m x 1 m x 0.8 m) covered on all sides with layers of 1 mm green mesh and placed in the screen house. To achieve varying levels of light intensity reduction; one and two layers of green mesh were used to tightly cover each wooden frame; thus resulting in 75% and 50% of light supply to seedlings, respectively. While, seedlings exposed to 100% light intensity were not placed under a light screening chamber. The light available under each light screening chamber was checked using a light meter and the readings corresponded with the assertion of Olajuyigbe and Agbo-Adediran (2015). The seedling collar diameters were measured using vernier mini-calliper and heights measured with measuring tape every fortnight for 16 weeks. Number of leaves formed were counted. At 16 weeks, the trial was terminated and total biomass accumulation was assessed by destructively sampling six seedlings from each treatment. The seedlings were uprooted, washed under running water to clean the plant of dirt. The plants were oven dried at 80°C until constant weight was attained. Plant dry weights were determined using a weighing balance (A & D Compact Scale HL-2000).

Data Analysis

Data were analysed using descriptive statistics and analysis of variance at $p<0.05$ level of significance. Data were normalized using square root transformation and the two-way ANOVA was used to determine the main and interaction effects of light intensity and growth duration on the growth parameters. The Holm-Sidak method was used for pairwise multiple comparisons of means of significantly different variables. The relative growth rate and biomass accumulated in roots, shoots and leaf components were assessed after 16 weeks. Statistical analyses were conducted using SigmaStat 11 for Windows.

RESULTS

Seedlings exposed to 100% light intensity had the highest mean height (17.58 ± 0.64 cm) while those exposed to 50% had the lowest (14.85 ± 0.45 cm) (Table 1). The growth curve revealed a 60.1%, 69.2% and 79.6% increase in total height of seedlings exposed to 50%, 75% and 100% light intensities, after 16 weeks. There were significant differences in the main effects of duration of growth ($p < 0.001$) and light intensity ($p < 0.001$) on the height development. However, no interaction effect was observed between the two factors ($p = 0.653$). The follow up test revealed that only 100% light supply differed from the other two treatments in its cumulative effect on height growth. Also, seedling height in the first 6 weeks did not differ within each treatment (Table 1).

Similarly, there was a continuous increase in collar diameter with seedlings exposed to 100% light intensity producing the highest mean collar diameter (2.95 ± 0.08 mm) while those exposed to 50% light intensity had the least (2.73 ± 0.05 mm). After 16 weeks, collar diameter increased by 63.6%, 74.9% and 71% for seedlings subjected to 50%, 75% and 100% light intensities, respectively. There were significant differences in the main effects of duration of growth ($p < 0.001$) and light intensity ($p < 0.001$) on collar diameter development. But, there was no significant interaction effect ($p = 0.868$) between the two factors. Coincidentally, the follow up test showed that only the main effect of exposure to 100% light intensity differed from the other two light treatments. While the treatment effect at the 2nd, 4th and 10th week, were not different for all light intensities (Table 1).

The highest number of leaves (7.62 ± 0.30) was observed in seedlings exposed to 100% light intensity while those exposed to 75% light intensity had the least (6.58 ± 0.24). Over time, the number of leaves increased by 241%, 229% and 281% in 50%, 75% and 100% light intensities, respectively.

Table 1. Growth response of *Greenwayodendron suaveolens* seedlings to varying light intensities

Time (weeks)	**Seedling height (cm)**		
	50% LI	**75% LI**	**100% LI**
2	$9.27\pm0.31_{a}^{A}$	$8.93\pm0.23_{a}^{AB}$	$9.79\pm0.35_{a}^{A}$
4	$9.27\pm0.31_{a}^{A}$	$8.94\pm0.23_{a}^{A}$	$9.79\pm0.35_{a}^{A}$
6	$9.71\pm0.31_{a}^{AB}$	$9.32\pm0.23_{a}^{A}$	$10.39\pm0.34_{a}^{AB}$
8	$10.67\pm0.32_{ab}^{B}$	$10.09\pm0.23_{b}^{B}$	$11.56\pm0.35_{a}^{B}$
10	$11.63\pm0.36_{a}^{C}$	$11.55\pm0.30_{a}^{C}$	$13.24\pm0.39_{b}^{C}$
12	$12.66\pm0.35_{a}^{CD}$	$12.66\pm0.30_{a}^{CD}$	$14.34\pm0.41_{b}^{CD}$
14	$13.50\pm0.41_{a}^{DE}$	$13.23\pm0.45_{a}^{D}$	$15.40\pm0.48_{b}^{D}$
16	$14.85\pm0.45_{a}^{E}$	$15.11\pm0.55_{a}^{E}$	$17.58\pm0.64_{b}^{E}$
	Collar diameter (mm)		
2	$1.67\pm0.05_{a}^{A}$	$1.60\pm0.04_{a}^{A}$	$1.72\pm0.04_{a}^{A}$
4	$1.67\pm0.05_{a}^{AB}$	$1.60\pm0.04_{a}^{A}$	$1.72\pm0.04_{a}^{A}$
6	$1.82\pm0.05_{a}^{B}$	$1.75\pm0.04_{a}^{B}$	$2.01\pm0.04_{b}^{B}$
8	$2.06\pm0.04_{a}^{C}$	$2.02\pm0.04_{a}^{C}$	$2.23\pm0.05_{b}^{C}$
10	$2.11\pm0.05_{a}^{C}$	$2.10\pm0.04_{a}^{C}$	$2.32\pm0.05_{b}^{CD}$
12	$2.34\pm0.05_{a}^{D}$	$2.37\pm0.06_{a}^{D}$	$2.51\pm0.05_{a}^{D}$
14	$2.49\pm0.05_{a}^{D}$	$2.52\pm0.07_{a}^{D}$	$2.73\pm0.07_{b}^{E}$
16	$2.73\pm0.05_{a}^{E}$	$2.79\pm0.07_{a}^{E}$	$2.95\pm0.08_{a}^{F}$
	Number of leaves		
2	2_{a}^{A}	2_{a}^{A}	2_{a}^{A}
4	$3.5\pm0.11_{a}^{B}$	$3.35\pm0.13_{a}^{B}$	$3.35\pm0.10_{a}^{B}$
6	$3.62\pm0.12_{a}^{B}$	$3.53\pm0.14_{a}^{B}$	$3.73\pm0.13_{a}^{B}$
8	$4.38\pm0.14_{a}^{C}$	$4.24\pm0.14_{a}^{C}$	$4.5\pm0.15_{a}^{C}$
10	$5.06\pm0.15_{a}^{D}$	$5.06\pm0.20_{a}^{D}$	$5.37\pm0.20_{a}^{D}$
12	$5.40\pm0.17_{a}^{DE}$	$5.20\pm0.19_{a}^{D}$	$5.87\pm0.24_{a}^{DE}$
14	$6.07\pm0.21_{a}^{E}$	$5.44\pm023_{a}^{D}$	$6.42\pm0.24_{ab}^{E}$
16	$6.81\pm0.26_{a}^{F}$	$6.58\pm0.24_{a}^{E}$	$7.62\pm0.30_{b}^{F}$

Same subscript letters in the same row indicate no significant ($p< 0.05$) differences in the mean values across light intensity treatments, while same superscript letters in the same column indicate no significant ($p< 0.05$) differences in the mean values over time.

There were significant variations in the number of leaves found on seedlings due to the effect of varying light intensities (Table 1). Consequently, the main effects of time ($p < 0.001$) and light intensity ($p < 0.001$) were significantly different, while the interaction effect was not ($p = 0.296$). But, the follow up test indicate that only the foliage of seedlings exposed to 100% light intensity were significantly higher than the other treatments.

The biomass accumulated by leaves (mean = 0.79g) and roots (mean = 0.50g) were highest for seedlings subjected to 50% light intensity (Table 2) while biomass allocation to shoot was highest for those receiving 100% light intensity (mean = 0.51 g). Biomass allocation to leaves was highest with 45%, 43% and 39% of dry matter allotted to leaves; shoot accumulated 27%, 28% and 31% while roots stored 28%, 28% and 30% of the total biomass in 50%, 75% and 100% light intensities, respectively. Nevertheless, the mean relative growth rates did not differ among treatments, with 0.018 g g^{-1} day^{-1} reported for seedlings in all three treatments.

Table 2. Biomass accumulation of *Greenwayodendron suaveolens* seedlings under varying light intensities for 16 weeks

Plant part	**Light intensity**		
	50%	75%	100%
Leaves (g)	0.79	0.71	0.64
Shoot (g)	0.47	0.47	0.51
Roots (g)	0.50	0.46	0.49
Total (g)	1.76	1.64	1.64

DISCUSSION

Shade is important in the initial establishment of seedlings; particularly influencing growth and development at all levels of organization. However, seedlings of rain forest trees respond differently to varying amounts of light (Ashton *et al.*, 2006; Olajuyigbe and Agbo-Adediran, 2015). To this end, plants with the capacity for rapid height and diameter growth as well as efficient resource capture, have a competitive advantage in shade (Valio, 2001). In this study, the height and collar diameter development decreased with light intensity, as a physiological response to light inhibition especially during the early stages of establishment (Ashton *et al.*, 2006; Carvajal *et al.*, 2014). Invariably the ability to survive under shade (up to 50%) and continue growth increments suggests that *G. suavelens* may be potentially useful in enrichment planting of degraded forest where gaps are present. In addition, foliage production was highest for seedlings exposed to 100% light intensity, indicating that the tree species was able to maximise the use of available solar radiation for photosynthetic activity (Medina, 1998; Valio, 2001).

The shading had little effect on biomass accumulation, with 50% light intensity resulting in a slightly higher dry matter accumulation especially for leaves. Shading slightly increased the aboveground dry mass/root dry mass ratio, reducing root growth relative to leaf and shoot growth. This pattern of biomass allocation favour relative increases in photosynthetic apparatus. However, this did not have a serious impact on root biomass as 28% to 30%

of the total was allotted to roots, thus it may not have a negative impact on belowground biomass assimilation nor would it compromise seedling survival during sudden exposures to higher light intensities (Valio, 2001). Furthermore, variation in light intensity did not affect the relative growth rate (0.0018 g g^{-1} day^{-1}) of the seedlings indicating that growth was not affected by shade and that the seedlings were well adapted to the reduced solar radiation (Veenendaal *et al.*, 1996). It is suggested that this adaptive morphological shift results in an increase in the ratio of photosynthesis to respiration, thus allowing the plant to maximize growth under shade (Gehring, 2003).

To a large extent, some level of shading is essential for the growth and development of juvenile plants as excess light increases the temperature of leaves and this may have an adverse effect on net photosynthesis. Thus, the slightly lower biomass observed in seedlings exposed to 100% light intensity may be partially attributed to higher temperature conditions. Temperature can be controlled and regulated under protected conditions, and better growth of plants might be expected under protected culture (Reddy *et al.*, 1999). In addition, the maximization of photosynthetically active area per total plant mass is achieved in a low light environment by increasing the proportion of total dry matter that is allocated to leaves or by reducing leaf thickness, or both (Wiebel *et al.*, 1994).

Past studies have opined that tropical trees require reduced light intensities during the juvenile stages. For instance, Chaudhry *et al.* (2004) reported that *Acacia nilotica,* though a light demander may require minimal shading at the early stage of seedling development to enhance survival. Also, variation in growth and biomass accumulation in response to light availability have been documented for tree species such as *Bombax buonopozense, Khaya ivorensis, Cedrella odorata, Entandrophragma angolense, Trema micrantha* and *Garcinia mangostana* (Nwoboshi, 1972; Wiebel *et al.*, 1994; Valio, 2001; Gyimah *et al.*, 2003; Olajuyigbe and Agbo-Adediran, 2015). In this study, reduction of light intensity (up to 50%) did not reduce growth but resulted in better performance corroborating the assertion that *G. suavolens* is shade tolerant. Furthermore, the 100% survival observed, suggest that the shading was not strong enough to result in seedling mortality.

CONCLUSION

In this study, reducing light intensity resulted in slightly lower diameter and height but did not negatively affect growth and development of *G. suaveolens* seedlings. On the contrary, biomass production increased with decreasing light availability probably due to enhanced biomass distribution. We conclude that *G. suaveolens* seedlings could survive in forest gaps as well as for enrichment planting as the species survived under limited light conditions of up to 50%. These findings are also useful in mass propagation and nursery management of the species.

REFERENCES

Ashton, M.S., Singhakumara, B. and Gamage, H.K., 2006. Interaction between light and drought affect performance of Asian tropical tree species that have differing topographic affinities. *Forest Ecology and Management* 221, 42-51.

Bartlett, G.A. andRemphrey, W.R., 1998. The effect of reduced quantities of photosynthetically active radiation on *Fraxinus pennsylvanica* growth and architecture. *Canadian Journal of Botany* 76, 1359-1365.

Carvajal, D.E., Loayza, A.P., Lopez, R.P., Toro, P.J. and Squeo, F.A., 2014. Growth and early seedling survival of four Atacama Desert shrub species under experimental light and water availability regimes. *Revista Chilena De Historia Natural* 87 (28), 1-8.

Chaudhry, A.K., Ali, Z., Rashid, C.A. and Chughtai, N.M., 2004. Shade requirement of *Acacia nilotica* at nursery stage. *Pakistan Journal of Agricultural Sciences* 41, 134-136.

Dauby, G., Duminil, J., Heuertz, M. and Hardy, O.J., 2010. Chloroplast DNA polymorphism and phylogeography of a Central African tree species widespread in mature rainforests: *Greenwayodendron suaveolens* (Annonaceae). *Tropical Plant Biology* 3, 4-13.

Ding, L., Münch, J., Goerls, H., Maier, A., Fiebig, H.-H., Lin, W.-H. and Hertweck, C., 2010. Xiamycin, a pentacyclic indolosesquiterpene with selective anti-HIV activity from a bacterial mangrove endophyte. *Bioorganic and Medicinal Chemistry Letters* 20, 6685-6687.

Focho, D., Egbe, E., Chuyong, G., Fongod, A. and Fonge, B., Ndam, W., Youssoufa, B., 2010. An ethnobotanical investigation of the Annonaceae on Mount Cameroon. *Journal of Medicinal Plants Research* 4, 2148-2158.

Gehring, C.A., 2003. Growth responses to arbuscular mycorrhizae by rain forest seedlings vary with light intensity and tree species. *Plant Ecology* 167, 127-139.

Gyimah, R., Nakao, T. and Oo, M.Z., 2003. Effects of light intensity and nutrient on growth and electron transport rate of tropical trees (*Bombax buonopozense, Khaya ivorensis* and *Cedrela odorata*) found in Ghana. *Bulletin of the Faculty of Agriclulture, Miyazaki University* 49, 69-78.

Holmgren, M., 2000. Combined effects of shade and drought on tulip poplar seedlings: tradeoff in tolerance or facilitation? *Oikos* 90, 67-78.

Marcos, I.S., Moro, R.F., Costales, I., Basabe, P. and Díez, D., 2013. Sesquiterpenyl indoles. *Natural Product Reports* 30, 1509-1526.

Medina, E., 1998. Seedling establishment and endurance in tropical forests: ecophysiology of stress during early stages of growth. *Oecologia Australis* 4, 23-43.

Nwoboshi, L.C., 1972. Responses of Teak (*Tectona grandis* L. F.), Idigbo (*Terminalia ivorensis* A. Chev) and Opepe (*Nauclea diderichii* Merill.) seedlings to various light intensity. *Nigerian Journal of Forestry* 2, 48 - 53.

Olajuyigbe, S. andAgbo-Adediran, A., 2015. Effect of shade and drought stress on early growth and biomass accumulation of Tiama Mahogany (*Entandrophragma angolense* (Welw.) C. Dc) seedlings. *Academic Journal of Science* 4, 27-36.

Reddy, M., Ismail, S. and Reddy, Y., 1999. Shade and allelopathic effects of ber on growth, productivity and quality of radish (*Raphanus sativus* L.) under pot culture. *South Indian Horticulture* 47, 77-80.

Sack, L., 2004. Responses of temperate woody seedlings to shade and drought: do trade-offs limit potential niche differentiation? *Oikos* 107, 110-127.

Valio, I., 2001. Effects of shading and removal of plant parts on growth of *Trema micrantha* seedlings. *Tree Physiology* 21, 65-70.

Veenendaal, E.M., Swaine, M.D., Lecha, R.T., Walsh, M.F., Abebrese, I.K. and Owusu-Afriyie, K., 1996. Responses of West African forest tree seedlings to irradiance and soil fertility. *Functional Ecology* 10, 501-511.

Wiebel, J., Chacko, E., Downton, W. and Lüdders, P., 1994. Influence of irradiance on photosynthesis, morphology and growth of mangosteen (*Garcinia mangostana* L.) seedlings. *Tree Physiology* 14, 263-274.

Yoo, H.-D., Cremin, P.A., Zeng, L., Garo, E., Williams, C.T., Lee, C.M., Goering, M.G., O'Neil-Johnson, M., Eldridge, G.R. and Hu, J.-F., 2005. Suaveolindole, a new mass-limited antibacterial indolosesquiterpene from *Greenwayodendron suaveolens* obtained via High-Throughput Natural Products Chemistry Methods. *Journal of Natural Products* 68, 122-124.