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Original Article

LIGHT-INDUCED GROWTH RESPONSES IN WARBURGIA UGANDENSIS AND POLYSCIAS FULVA: A COMPARATIVE ANALYSIS

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Abstract: The deforestation of tropical lands presents multifaceted environmental challenges with both local and global implications. Locally, deforestation exacerbates climate extremes, triggers soil degradation, and disrupts regional hydrological cycles. Moreover, the alteration of albedo and water balances due to extensive deforestation can significantly impact weather patterns, with potential ramifications for regional climates. A particularly alarming consequence is the contribution to global warming through the release of greenhouse gases from the burning of tropical biomass. This paper synthesizes insights from Myers (1983) and other scholarly works to elucidate the far-reaching consequences of tropical deforestation. Of paramount concern is the unprecedented loss of biological diversity resulting from habitat fragmentation within tropical forests. The loss of these diverse ecosystems poses significant threats to global biodiversity and ecosystem stability, with cascading effects on ecological processes and services. Key areas of focus include the mechanisms driving habitat fragmentation and biodiversity loss, the socio-economic drivers of deforestation, and the ecological resilience of tropical ecosystems. By examining the interplay between human activities, environmental changes, and ecological responses, this paper aims to provide a comprehensive understanding of the complexities surrounding tropical deforestation and its impacts on local and global environments.

Keywords: Deforestation, Tropical lands, Climate extremes, Biodiversity loss, Habitat fragmentation.

INTRODUCTION

Deforestation of tropical lands can have both local and global consequences. Locally, climate may become more extreme, soil may suffer physical and chemical deterioration, and regional hydrological balances may be disturbed. Massive deforestation, resulting in altered albedo and regional water balances, could affect weather patterns, and there is particular concern at the possible contribution to global warming through the addition of greenhouse gases into the atmosphere from the burning of the tropical trees biomass (Myers, 1983). Perhaps the single greatest cause for concern over the loss of tropical forest is the considerable body of evidence that suggests that it is leading to unprecedented loss of the biological diversity through habitat fragmentation that these forests contain (Myers, 1983).

In Kenya, many areas of natural forests have been heavily disturbed through selective logging and clearing, and the degraded areas vary in size from scattered canopy gaps to large abandoned clearings (Kigomo, 1990). These areas need to be rehabilitated for both protective and productive purposes and there is a growing interest to rehabilitate the damaged areas by re-planting with indigenous tree species. However, there is little experience and inadequate understanding of silvicultural management and ecological requirements of many of the tropical tree species, especially in Kenya. In addition to being slow growing, many of the various genera of tropical hard woods are also very difficult to establish in production plantations. This is largely because their biology and ecological requirements are not well understood and silvicultural knowledge concerning how to handle them is also inadequate (Engel and Poggiani, 1992).

Forest under canopy environments are often characterised by light-limited conditions for plant growth. Tree species differ in their requirements for light and respond differently to environmental conditions associated with canopy gaps of different sizes (Vincent, 2006). Hence, the survival of under storey seedlings and saplings is a critical factor for tree regeneration in forest ecosystems. Pioneer species show enhanced capacity to utilize high irradiance in gaps and clearings (Coomes and Grubb, 1998). These species are highly amenable to silvicultural management and can help in recovery of forest structures after disturbance.

The present study was intended as a contribution to the autecology of two economically important tree species of Kenya, namely *W. ugandensis* and *P. fulva*. This study was set out to evaluate the morphological and growth responses of *W. ugandensis* and *P. fulva* grown under varying light regimes simulating what may occur in the natural ecosystem.

MATERIALS AND METHODS

The study was located at a nursery of the Kenya Forestry Research Institute, Muguga, Kenya. A randomised-block design of three replications was used. The light treatments were randomised within the blocks while the species were randomised within the light treatments. A distance of 1 metre separated the blocks. The different light levels were 1 metre apart. Fourteen seedlings were planted in each sub-plot in a 2 x 7 arrangement. There were 12 subplots with a total of 168 seedlings.

Seeds of *W. ugandensis* and *P. fulva* were acquired from the Seed Centre, Kenya Forestry Research Institute, Nairobi, Kenya. The light conditions prevailing under the full sunlight represented a clearing in the natural environment and the dense shade a small gap. The partial and moderate shades represented large gaps in the forest.

The seeds were sown separately in germination trays with sand as the medium and then transferred to the greenhouse for germination. After eight weeks, seedlings of the two species were transplanted separately into 20 cm-long by 6.5 cm in diameter polythene pots which had been previously filled with forest topsoil, cow manure and gravel mixed into a ratio of 5:2:1 by volume respectively. These were perforated at the bottom to allow easy draining of water. After transplanting, the seedlings were removed from the greenhouse and kept in the open for a period of one month in order to harden. The seedlings were later transferred into the different light regimes where they stayed for one month to acclimatise to the new environment before measurements were taken.

The shade levels were obtained by use of factory made artificial black shade materials. Each shade house was 1 m long, 1 m wide and 1 m high. The artificial shades used in this experiment gave photosynthetic photon flux densities of 25% (dense shade), 42% (moderate shade) and 65% of full sunlight (partial shade).

Seedling growth

Growth measurements included seedling height, leaf area, dry weight, specific leaf area, shoot/root ratio and leaf number as follows:

Seedling height: Seedling heights of all the seedlings in each plot were determined by taking measurements from the stem base to the apical meristem. Heights were measured after a fortnight.

Leaf area: *In situ* leaf areas were determined by tracing the leaves on paper. The area covered on paper was carefully cut out and the area determined using an automatic leaf area meter (AAC-400, Hayashi Denkoh Co. Ltd, Tokyo, Japan). Calibrations were done by running a metal disc of known area (100 cm^2) through the machine.

Seedling harvesting

One last harvest was made to determine the final leaf areas, dry weights, specific leaf areas and shoot/root ratios. The harvested seedlings were divided into leaves, stems and roots and kept in polythene bags to minimise water loss.

Dry weight: Harvested seedlings were dried separately in a wellventilated oven at around 80ºC for 24 h, and the dry weights of each plant part were determined using an analytical balance. Total dry weight of the whole plant was then computed.

Specific leaf area (SLA): Using the dry weights and the leaf area, the specific leaf area was computed thus:

$$\mathrm{SLA} = \frac{\mathrm{SA}}{\mathrm{LM}}$$

Where,

SLA = specific leaf area (cm^2/g) **SA** = leaf surface area (cm^2)

LM = leaf mass (g)

Leaf number

The number of both living and dead leaves was determined every week. A leaf was considered dead if a proportion of yellow/brown tissue exceeded 50%.

All data were analysed using ANOVA and level of significance determined using Tukey's Multiple Range Test (Steel et al., 1997).

RESULTS

Leaf area

Leaf area of the harvested seedlings was significantly ($P<0.001$) higher under shade than in full sunlight for the two species (Figure 1). However, leaf area in full sunlight was significantly ($P<0.001$) higher in *P. fulva* than in *W. ugandensis.* Leaf areas in dense and moderate shades differed significantly ($P<0.05$) from those of full light and partial shade treatments. Thus both species showed highest rates in leaf expansion under shade treatments than in full sunlight (Figure 1). Highest growth in leaf area was attained when seedlings of both species were grown under dense shade. Rate of leaf expansion was significantly ($P<0.001$) higher in *P. fulva* than *W. ugandensis* when grown under dense and moderate shades. Rate of leaf area expansion was not significantly ($P>0.05$) differ-

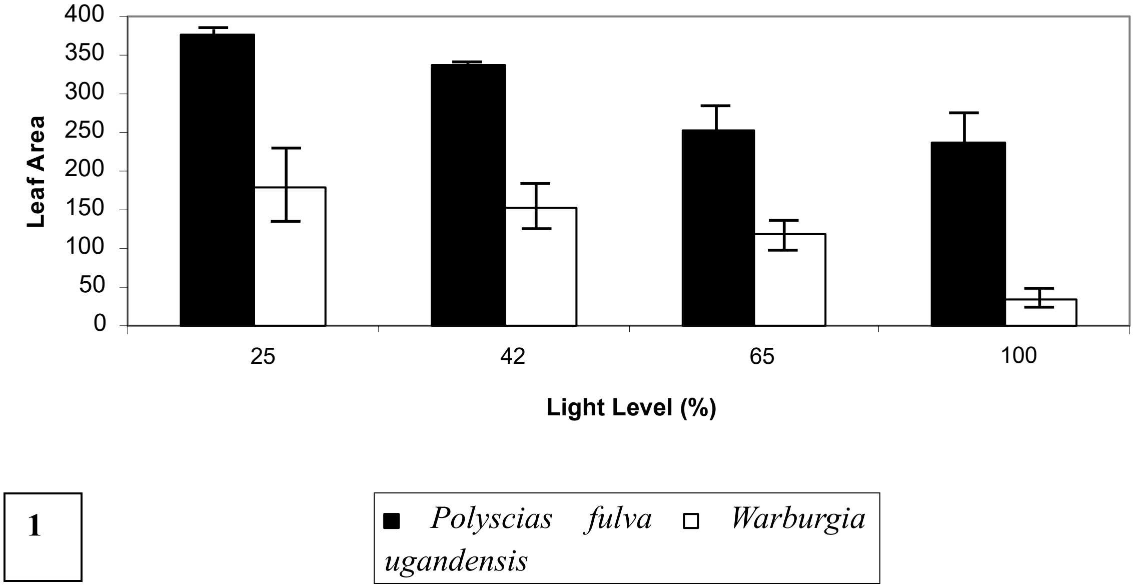


Figure 1. Growth parameters for seedlings of *Warburgia ugandensis* and *Polyscias fulva* under contrasting light conditions; leaf area (cm^2). Vertical bars are SE of the mean ment for the two species in full sunlight and partial shade. Rates of leaf area expansion did not differ significantly ($P>0.001$) in seedlings of W. ugandensis grown under partial, moderate and dense shade.

W. ugandensis increased its rate of leaf area growth from 0.04 to 0.1 cm2/day in partial shade (65% sunlight) and further shading seemed not to affect the rate. P. fulva increased its rate of leaf area growth from 0.1 cm2/day in full sunlight to 0.5 cm2/day under dense shade.

Leaf number

P. fulva had the highest number of surviving leaves than *W. ugandensis* in all the light regimes (Figure 2). Leaf number was significantly ($P< 0.01$) higher in moderate and dense shades than in full sunlight and partial shade for seedlings of the two species. *P. fulva* exhibited a leaf formation rate of 1.4 leaves/day in full sunlight and this increased to 2.2 leaves/day under dense shade while for *W. ugandensis* the rate was 1.1 leaves/day in full sunlight and 1.9 leaves/day under dense shade.

That the two species responded to decreasing light by increasing the number of leaves can be regarded as an adaptation to shade in the two species. The greater leaf number under shade treatments enabled the species to increase their leaf area index and hence surface area for harvesting light. In *P. fulva*, leaf number and high rates of leaf expansion ensured higher leaf area than in *W. ugandensis* in the four treatments. It is, therefore, possible that leaf number, leaf architecture, and leaf orientation played an important role in light harvesting capacities of the two species and thus rates of photosynthesis and dry matter accumulation.

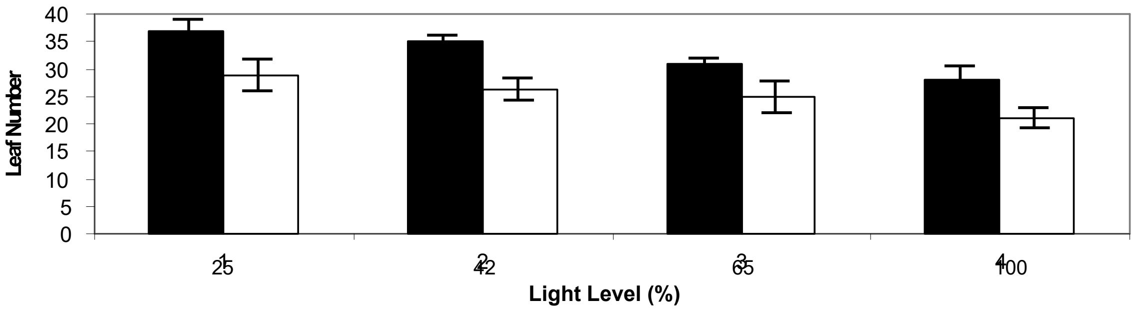
Plant height

Plant height was higher under shade treatments than in full sunlight (Figure 3). Height growth in both species was inversely proportional to the photosynthetic photo flux density (PPFD) available in each light regime. High PPFD suppressed height growth, while low PPFD promoted stem elongation in both species, though at varying rates of growth. Height increment was significantly ($P<0.001$) higher in *W. ugandensis* than in *P. fulva* when the seedlings of the two species were grown under dense, moderate and partial shades. Height growth in seedlings of the two species growing in full sunlight was not significantly ($P>0.05$) different. Height growth was therefore relatively faster in seedlings of *W. ugandensis* when compared with those of *P. fulva* in all the treatments.

Dry weight

P. fulva exhibited greater dry matter accumulation in all the treatments than *W. ugandensis* (Figure 4). For *P. fulva,* dry weight increased from dense shade to full sunlight. *W. ugandensis* exhibited higher dry matter accumulation in shaded treatments than in full sunlight. The highest dry matter accumulation was observed in *P. fulva* grown in full sunlight. The mean dry weight for *P. fulva* grown in full sunlight was 8.9 and 4.0 g under dense shade. *W. ugandensis* showed a mean dry weight of 0.6 g when grown in full sunlight and 1.4 g under dense shade. In general, dry matter accumulation in *P. fulva* increased more under high PPFD when compared to *W. ugandensis*. Dry matter accumulation was significantly ($P < 0.01$) higher in *P. fulva* in full sunlight and partial shade than *W. ugandensis*. Under moderate and dense shade dry matter accumulation was not significantly ($P>0.05$) different for the two species.

Figure 2. Growth parameters for seedlings of *Warburgia ugandensis* and *Polyscias fulva* under contrasting light conditions; leaf numbers. Vertical bars are SE of the mean.



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■ Polyscias fulva □ Warburgia ugandensis

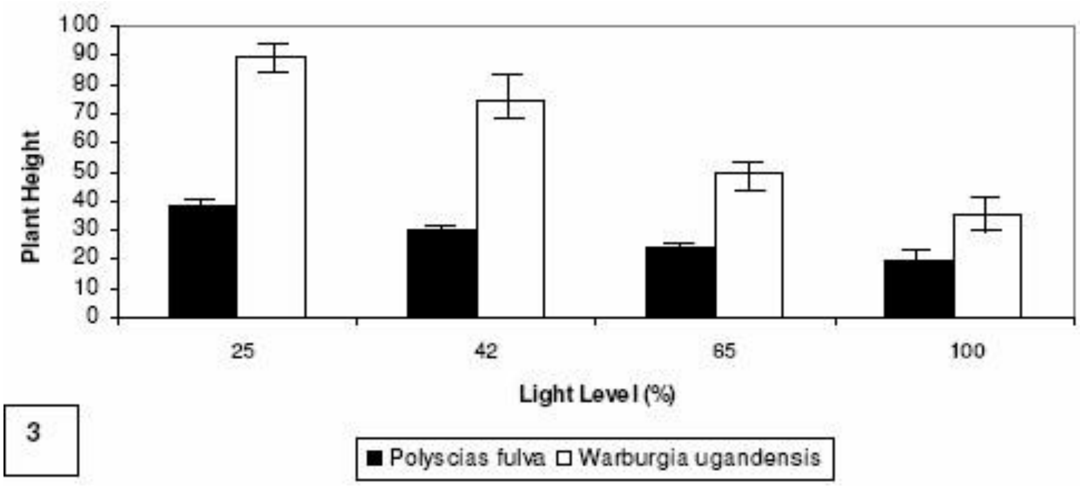

Figure 3. Growth parameters for seedlings of *Warburgia ugandensis* and *Polyscias fulva* under contrasting light conditions; seedling plant height (cm). Vertical bars are SE of the mean.

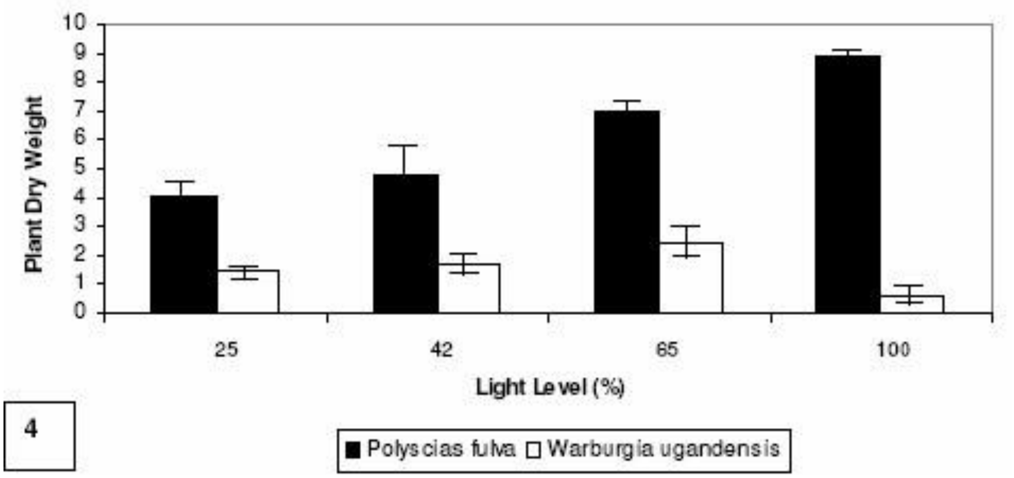

Figure 4. Growth parameters for seedlings of *Warburgia ugandensis* and *Polyscias fulva* under contrasting light conditions; seedling plant weight (g). Vertical bars are SE of the mean.

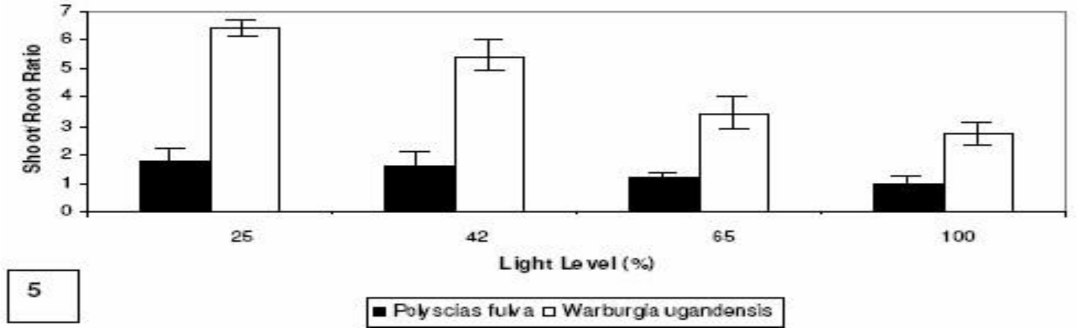

Figure 5. Growth parameters for seedlings of *Warburgia ugandensis* and *Polyscias fulva* under contrasting light conditions; shoot/root ratio. Vertical bars are SE of the mean.

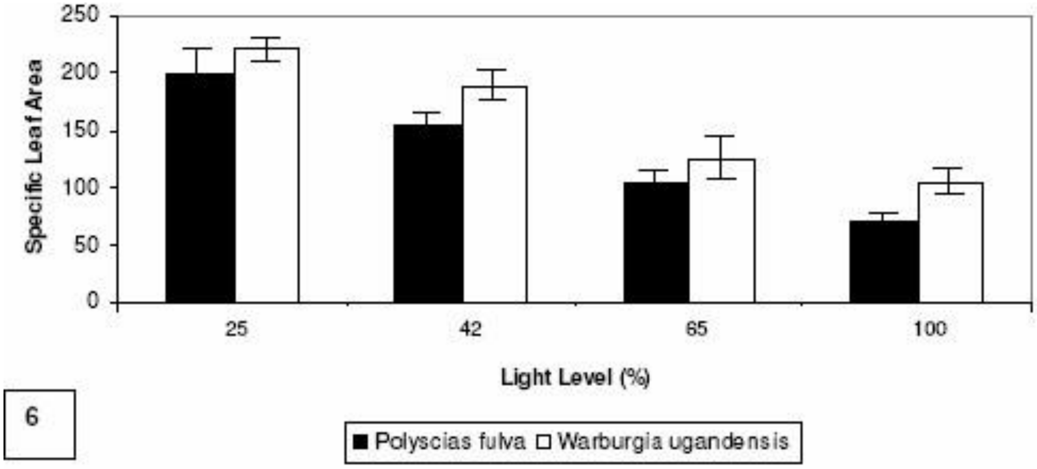

Figure 6. Growth parameters for seedlings of *Warburgia ugandensis* and *Polyscias fulva* under contrasting light conditions; specific leaf area (cm^2/g). Vertical bars are SE of the mean.

Shoot/root ratio (S/R ratio)

Shoot/root ratios were lowest in full sunlight for seedlings of the two species (Figure 5). *W. ugandensis* exhibited higher S/R ratios in all the light regimes than *P. fulva.* Shoot/root ratios were significantly ($P<0.01$) higher for seedlings of the two species grown under moderate and dense shades than in full sunlight and partial shade. *P. fulva* exhibited little variation in S/R ratios in the four light levels, with values ranging from 0.97 to 1.84 g/g, while in *W. ugandensis* the values ranged from 2.73 to 6.42 g/g in the four the treatments. The S/R ratio for *W. ugandensis* was approximately 50% higher in the dense shade than in full sunlight.

Specific leaf area (SLA)

The two species had the greatest ($P<0.001$) SLA under moderate and dense shades (Figure 6). The highest SLA in both species was observed in seedlings growing under dense shade, with *W. ugandensis* recording 220.7 and 198.1cm^2/g in *P. fulva.* In both species SLA decreased with increasing light. This response was, therefore, similar with that observed in leaf number, leaf area, height, and shoot/root ratio. Seedlings of the two species showed no significant ($P>0.05$) difference in SLA when growing under full sunlight and partial shade.

DISCUSSION

The growth parameters studied in both species indicate clear-cut responses to light intensities. As indicated by the significant differences in nearly all the parameters studied, the two species responded differently to the light treatments. The results of this study are in line with findings of other studies in that tropical tree species differ in their requirements for light (Oguchi et al., 2006; Vincent, 2006). The results of this study indicated that individuals of the same species grown in contrasting light conditions exhibit morphological and physiological differences (Theuri et al., 1998). It appears that the two species responded to shade by increasing their leaf areas, but with varying degree of plasticity. This response can be regarded as an adaptation to shade (Engel and

Poggiani, 1992; Takahashi and Rustandi, 2006; Vincent, 2006). The current study found that leaf area varied with the amount of light received (Kriebitzsch et al*.,* 1997; Takahashi and Rustandi, 2006).

Seedlings of *W. ugandensis* appeared to perform better under shade resulting in higher dry weights under shade than under full light conditions. Dry weights were reduced in full sunlight indicating that the plant is a shade tolerant species when compared to *P. fulva*. The lower dry matter accumulation when seedlings of *W. ugandensis* were exposed to full sunlight was probably due to high heat load, increasing leaf temperatures, transpiration and respiration. The slow growth of seedlings of *P*. *fulva* under shade and fast growth in full sunlight showed that seedlings growth in the nursery, and possibly in nature is limited by high light regimes.

Kriebitzsh et al. (1997) found that leaf numbers in *Intsia palembanica* and *Hopea odorata* were higher in shade than in full light. However, differences in number of leaves do occur in tropical trees in response to light. For example, leaf number in *B. huillensis* was higher in full light than in shaded treatments (Kigomo, 1990). The high rate of leaf loss in *P. fulva* can be important in the natural environment because it can provide good mulch and also make the soil under the tree quite fertile, this, together with the spreading, open crown make it a potentially excellent agroforestry species.

Various researchers have studied height growths of tropical trees. The trend in results observed in our study were similar to those found from other studies (Kigomo, 1990; Takahashi and Rustandi, 2006).

Leaf number, height, leaf area shoot/root ratio and specific leaf area increased as seedlings of the two tree species approached lower light levels, and these may be adaptive features to a certain range of light intensities. Plants require a high degree of plasticity in their photosynthesis and morphological parameters in order to adapt to shade (Vincent, 2006). In *P. fulva* this plasticity is clearly manifested in morphological parameters. Increased SLA in the two species implied important anatomical changes in mesophyll and palisade layers. Variations in light produce change in leaf anatomical and biochemical structure (Oguchi et al., 2006; Vincent, 2006) that determine net photosynthetic CO_2 fixation. The extent of mesophyll development largely determines the photosynthe- tic capacity of a leaf (Oguchi et al., 2006), although intracellular effects of other factors such as nutrient supply also influence photosynthetic capacity. Thus, specific leaf area can potentially be used as an indirect measure of the photosynthetic characteristics of a leaf, while also giving a direct measurement of allocations of biomass in a plant. The changes in specific leaf area early in leaf growth are presumably due to changes in relative rates of cell division and cell expansion (Oguchi et al., 2006).

The two species generally showed differences in their light requirements and *P. fulva* was the more light-demanding of the two species. *P. fulva* displayed the greatest growth under full sunlight conditions and is, therefore, suitable for planting in clearings or open areas and that it is not suitable for planting in small or medium size canopy gaps. *W. ugandensis* grew best under shaded conditions and under full sunlight environment, its height growth and dry matter accumulation was severely reduced. *W. ugandensis* is, therefore, suitable for planting into medium and large canopy gaps such as those caused through selective felling.

Kigomo (1990) observed that seedlings of *Brachylaena huillensis* exhibited higher rates of accumulation of dry matter when grown in full sunlight than in shaded environments. The response of *B. huillensis* is similar to that of *P. fulva* in the present study. Kwesiga and Grace (1986) made similar observations in seedlings of *Kassina* *senegalensis* and *Terminalia ivorensis* in West Africa. Similar results were observed in others studies (Kriebitzsch et al., 1997; Andrews et al., 2006).

Kigomo (1990) observed that seedlings of *B. huillensis* grown in high light intensities exhibited lower shoot/root ratios than under shade. Kriebitzsch et al. (1997) and Andrews et al. (2006) noted that tree seedlings responded to reduced light intensities by increasing their S/R ratios. The results in the present study are similar to those observed in seedlings of other tropical trees (Kriebitzsch et al*.,* 1997). It is possible that the leaves growing under less than full light conditions accumulated more N per leaf area and hence more supply of N to the leaf metabolism that those in full sunlight and hence the higher shoot: root ratios (Oguchi et al., 2006). The results observed in *W. ugandensis* and *P. fulva* are therefore similar with findings on other plants growing under similar conditions (Anten, 2005; Selaya et al., 2007).

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