Gas Exchange, Chlorophyll and Nitrogen Content of Mango Leaves as Influenced by Light Environment

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Abstract. Net CO₂ assimilation (A), stomatal conductance for CO₂ (gₛ), water-use efficiency (WUE), specific leaf density (Wₛ), and leaf chlorophyll and nitrogen (N) content were determined for mango (Mangifera indica L.) leaves that developed in full sun and 25%, 50%, and 75% shade. Leaves that developed in full sun had greater A and gₛ than leaves that grew in 75% shade. Leaf chlorophyll content and N content (dry-weight basis) increased as percent shading increased, but WUE and Wₛ were not significantly affected by shading. Light response curves for A had a steeper initial slope for leaves that developed in full sun and 25% shade than for leaves that developed in 50% and 75% shade. The data indicate a greater quantum-use efficiency for leaves developed in high light levels than for those developed in shade.

The adaptation of leaves to light environment is determined genetically and by previous light exposure (Bjorkman and Holmgren, 1963). Net CO₂ assimilation (A) rates under saturating light conditions are higher for leaves that develop in full sun than for leaves that develop in shade for several plant species (Barden, 1974; Bjorkman and Holmgren, 1963; Chabot and Chabot, 1977; Jurick et al., 1982; Kappel and Flore, 1983; Nobel, 1976; Syvertsen, 1984). However, under low-light conditions, shade-grown leaves are often more quantum-use efficient than sun-grown leaves (Syvertsen, 1984). Sun-grown leaves are often thicker than shade leaves (Barden, 1977; Chabot and Chabot, 1977; Ghosh, 1973; Syvertsen and Smith, 1984) and often exhibit greater specific leaf densities (Wₛ) (Barden, 1974; Kappel and Flore, 1983; Syvertsen and Smith, 1984).

Information about the effect of light environment on leaf physiology is lacking for mango trees. Commercially, mango trees are rarely pruned selectively, partly because information about optimal canopy design and light use within canopies is not available. Therefore, information concerning light use by mango leaves would be helpful in designing management systems that use light efficiently. This study was initiated to determine the effect of light level during leaf development on net gas exchange and on total chlorophyll and N content of mango leaves.

During May 1987, ‘Turpentine’ mango seeds were planted in flats containing a commercial peat-perlite potting mix (Promix). After 3 months, seedlings were potted in Promix in 20-cm-diameter (4 liters) plastic pots and fertilized weekly with N (240 mg liter⁻¹), P (104 mg liter⁻¹), and K (192 mg liter⁻¹) plus minor elements. All plants were well-irrigated. In Apr. 1988, seedlings were transferred to one of four light environments within an air-conditioned glasshouse by placing them in wooden frames surrounded by shade cloth. Treatments were: No shade (maximum photosynthetic photon flux (PPF) = 2200 μmol m⁻² s⁻¹), 25% shade (maximum PPF = 1650 μmol m⁻² s⁻¹), 50% shade (maximum PPF = 1100 μmol m⁻² s⁻¹), and 75% shade (maximum PPF = 550 μmol m⁻² s⁻¹). Shade cloths of different densities were used to obtain the desired degree of shading. Temperature in the glasshouse was maintained between 25 to 30℃. As soon as leaves emerged, one leaf per plant was tagged on six plants in each treatment for future gas exchange determinations. Each treatment consisted of six single-plant replicates in a completely randomized design. Light response curves for A were determined after leaves were fully expanded (4 weeks after emergence). Net CO₂ assimilation, gₛ, and WUE were determined for the same tagged leaves 4 weeks and 7 weeks after emergence. Determinations were made above light saturation (PPF = 800 μmol m⁻² s⁻¹) with a quantum sensor and LI-1000 data logger (LI-COR). Wₛ, chlorophyll content, and leaf N content were determined 7 weeks after leaves were tagged.

Fig. 1. Net CO₂ assimilation (A) and photosynthetic photon flux (PPF) of ‘Turpentine’ mango trees grown in 0%, 25%, 50%, or 75% shade, 4 weeks after leaf emergence. The regression lines are described by the following equations (significant at P = 0.01): For 0% shade: y = 6.21(1 - e⁻⁰.⁰⁵²x), r² = 0.76; for 25% shade: y = 5.81(1 - e⁻⁰.⁰⁰²x), r² = 0.65; for 50% shade: y = 4.1(1 - e⁻⁰.⁰⁰⁵x), r² = 0.62; for 75% shade: y = 4.3(1 - e⁻⁰.⁰⁰⁰x), r² = 0.59.
and off in pairs to generate 16 different light levels in the leaf chamber. Light response curves were calculated using nonlinear regression analysis, plotting the predicted values for $A$ at each PPF level.

Specific leaf density was determined for each plant from the dry weight of four 0.32-cm$^2$ leaf disks. Total leaf chlorophyll content was determined as described by Marini and Marini (1983). For chlorophyll determinations, eight 0.32-cm$^2$ leaf disks from each leaf were placed in 10 ml of 80% methanol and held in darkness at room temperature for 48 hr. Leaf chlorophyll content was calculated from absorption values obtained at 642 and 664 nm with a Bausch and Lomb Spectronic 21 spectrophotometer. Leaf $N$ content was determined using the micro-Kjeldahl technique (Bremner and Mulvaney, 1982).

Light response curves for $A$ were defined by the equation $y = a(1 - e^{-bx})$, where $a$ and $b$ are the regression coefficients (Fig. 1). Net CO$_2$ assimilation was greater for leaves developed under full sun than for leaves of plants in any of the other treatments at each PPF level. Leaves developed in 25% shade had the next greatest $A$ rates. Light response curves were similar for the 50% and 75% shade treatments. The light saturation point with respect to $A$ for all treatments was $\approx 350 \mu$mol s$^{-1}$ m$^{-2}$ (Fig. 1). The initial slopes of the light response curves were significantly greater for the 0% and 25% shade treatments than for the 50% and 75% shade treatments according to a standard t test ($P < 0.05$). This difference indicates that mango leaves developed under high light intensity were more quantum-use efficient than those grown under lower light intensities. This result is in contrast to observations made for many other plant species (Bazzaz and Carlson, 1982; Kappel and Flore, 1983; Syvertsen, 1984); although Barden (1977) found that, under low irradiance levels, sun-grown apple leaves had the same photosynthetic rates as shade leaves.

Three weeks after initial gas exchange measurements, $A$ and $g$, of leaves developed in full sun were 7.2 $\mu$mol s$^{-1}$ m$^{-2}$ and 100 $\mu$mol s$^{-1}$ m$^{-2}$, respectively (Fig. 2). These rates were 50% lower than rates observed previously for mature sun-grown mango leaves in an orchard in India (Chacko and Ananthnarayanan, 1985). Four (data not shown) and 7 weeks after leaf emergence (Fig. 2), $A$ and $g$, of leaves grown in full sun were significantly greater than for leaves from the 75% shade treatment. There was no significant difference in WUE among treatments, since developmental light environment affected $A$ and $g$ similarly (Fig. 1, data not shown for $E$).

Total leaf chlorophyll content on dry-weight and area bases increased as percent shade increased (Figs. 3 and 4). Similar observations have been made with other species, including Citrus spp. (Syvertsen, 1984), peach (Prunus persica) (Kappel and Flore, 1984), and Solidago virgaurea (Holmgren, 1968).

Leaf $N$ content, on a dry-weight basis, was positively correlated with percent shade during leaf development (Fig. 3). However, on an area basis, leaf $N$ was not significantly correlated with percent shade (Fig. 4). Syvertsen (1984) found that total N content (area basis) of orange and grapefruit leaves was negatively correlated with percent shade. Juricke et al. (1982) observed that N content, on a dry-weight basis, of wild strawberry (Fragaria virginiana) was higher in shade-grown than in sun-grown leaves. However, on a leaf-area basis, N content of wild strawberry was greater for sun leaves than shade leaves. Although there was no significant difference in $W_a$ among treatments in the present study, sun-grown leaves tended to have higher $W_a$ than shade-grown leaves (Fig. 3). This same observation has been made for several other plant species (Barden, 1974; Fails et al., 1982; Kappel and Flore, 1983; Syvertsen, 1984). The lack of correlation between leaf N (area basis) and percent shade during leaf development, in our study, may be due to higher $W_a$ for sun-grown leaves.

Mango leaves that developed in full sun appeared to be more photosynthetically efficient than leaves that grew in shade. The reason for greater $A$ of sun-grown leaves is not clear, since both leaf chlorophyll and N content (dry-weight basis) were lower in sun-leaves than shade-leaves. In the present study, stomatal density was not determined. Fails et al. (1982) observed that stomatal density was greater for sun-grown leaves of Ficus benjamina than for shade-grown leaves. Since observed that $g$, decreased as percent shade increased, it is possible that the increased photosynthetic capacity of sun-grown mango leaves is related to stomatal density. Further studies are needed to determine the mechanisms for greater gas exchange for sun-leaves than for shade-leaves of mango.

**Literature Cited**


Fig. 3. Specific leaf density (W_s) total chlorophyll content (Chl; dry-weight basis) and N content (dry-weight basis) of mango leaves grown in 0%, 25%, 50%, or 75% shade. Symbols represent means ±1 se.

Fig. 4. Total chlorophyll content (Chl; area basis) and N content (area basis) of mango leaves grown in 0%, 25%, 50%, or 75% shade. Symbols represent means ±1 se.


