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# Thermal Conduction and Energy Budget in Leaves of Some Mountain Plant Species along an Altitudinal Gradient

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The thermal conduction between the two surfaces of the leaves and the total energy budget were worked out for 15 trees and 5 shrub species from different altitudes in Garhwal Himalaya. The energy balance sheet of these plant species indicates that most of the energy absorbed by the leaves dissipates by radiation, transpiration and thermal conduction across leaf surfaces and these all energy parameters decrease with increasing altitude. It is concluded that the thermal conduction between the two surfaces of the leaves has significant effect on the status of the leaf energy balance ($r=0.9818$).

**Key Words: Conduction, Leaf energy balance, Altitude**

## Introduction

The variations in microclimate influence the form and functions of plants through energy exchange (Cernusca & Seeber 1981). A large number of publications had appeared in the field of biophysical ecology, specially on the mechanism of energy exchange between plants and their environment (Raschke 1960, Tibbals et al. 1964, Knoerr & Gay 1965, Idso et al. 1966, Thom 1976, Campbell 1977, Gates 1980, Grace et al. 1980, Jones 1983). These authors have reported that the total energy absorbed by the leaf will be lost by radiation, convection and latent heat exchange through transpiration. The leaf can gain energy through convection, if leaf temperature is lower than the air temperature or through latent heat in condensation if leaf temperature falls below the dew point. Energy flux through conduction and metabolic processes is considered negligible by these workers. Gates (1980) reported that both surfaces of the leaves remain at the same temperature and therefore the energy conducted between the two surfaces of the leaves is also negligible. However, Loomis (1965) concluded that leaves are heated rapidly by radiant energy and cooled primarily by conduction of energy to the air. Nobel (1983) also reported that when the wind is flowing around the leaf surface a boundary layer is formed in which the heat is transferred by molecular heat conductivity. It is also reasonable to believe that since leaf length, width, area and thickness are influenced to a great extent by the environment in which a plant grows (Korner et al. 1983) the temperature of two surfaces of leaf will vary considerably and thereby conduction across leaf will have significant effect on the status of leaf energy balance. Therefore, this study on the magnitude of energy flux through conduction in the leaves of different trees and shrubs growing at different altitudes in Garhwal Himalaya has been undertaken.

## Methods of Study

The study was conducted on 15 trees and 5 shrubs growing at Srinagar (550 m), Pauri (1700 m), Dogalbitta (2576 m), Chopta (2900 m) and Tungnath (3600 m) in Garhwal Himalaya during the month of October, 1983. The observations were recorded on three randomly selected mature leaves of each species at 800 hr, 1200 hr and 1600 hr on both surfaces of the leaves by Portable Steady State Porometer (LI-COR, model LI-1600). The recordings from lower and upper surfaces of

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a leaf were taken at a lapse of about 30 sec. The average values of the observations for the day were used in the calculations. The details of the methodologies in recording different parameters by Porometer are described elsewhere (Purohit et al. 1983). Wind speed was measured with the help of a Photoelectric Air Flow Meter. The area of the leaves was measured with the help of a Area Meter (LI-COR, model LI-3000). The free hand sections were used to measure the thickness of the leaves with the help of a microscope and the average values of 30 cross sections were used in computation. Stomatal resistance was calculated as a ratio of water vapour partial pressure gradient and the transpiration rate and was used to calculate the leaf thermal resistance following Monteith (1981).

*Theory*

If the energy loss by conduction from leaf of air ($Q_g^{la}$) and across leaf surfaces ($Q_g^l$) are also taken into consideration, the energy equation, neglecting the storage and photosynthetic terms in steady state condition, can be written as:

$$Q_a = Q_r + Q_t + Q_c + Q_g^{la} + Q_g^l$$

where,

$Q_a$ = Total energy absorbed by the leaf,
$Q_r$ = Energy loss by radiation,
$Q_t$ = Energy loss by transpiration,
$Q_c$ = Energy loss by convection,
$Q_g^{la}$ = Energy loss by conduction from leaf to air, and
$Q_g^l$ = Energy loss by conduction across leaf surfaces.

The energy absorbed by the leaf ($Q_a$), energy loss by radiation ($Q_r$), transpiration ($Q_t$) and convection ($Q_c$) of the individual species at different times of the day were computed following the derivations by Gates (1980). For calculating the thermal resistance across the boundary layer and heat flux by conduction from one side of the conductor to the other, we used the following fundamental equation of heat conduction through any conductor (Slavik 1974) as:

$$Q = \frac{KA(T_1 - T_2)t}{d} \quad \ldots (1)$$

where,

$Q$ = Total amount of heat flow ($J$),
$K$ = Thermal conductivity of the medium ($W\ m^{-1}°C^{-1}$),
$A$ = Area of the surface ($m^2$),
$T_1$ = Temperature of the first surface (°C),
$T_2$ = Temperature of the second surface (°C),
$t$ = Time for heat flow (s), and
$d$ = Distance between the surfaces of the conductor (m)

**Table 1** *Average daily day time (8 am to 4 pm at four hourly intervals) relative humidity, photosynthetically active radiation, air temperature and wind velocity (±SD) on the day of observations at different altitudes in Garhwal Himalaya*

| Altitude (m) | Relative humidity (%) | PAR ($Wm^{-2}$) | Air temperature (°C) | Wind-velocity $\times 10^{-2}$ ($ms^{-1}$) |
|---|---|---|---|---|
| 550 | 40.2±0.8 | 146.0±8.8 | 27.2±0.5 | 40.0±1.9 |
| 1700 | 51.8±0.7 | 188.3±5.8 | 20.6±0.1 | 56.7±1.3 |
| 2576 | 55.2±1.1 | 206.4±8.2 | 19.9±0.4 | 70.0±1.8 |
| 2900 | 66.8±0.9 | 178.9±9.2 | 14.7±0.4 | 126.7±2.9 |
| 3600 | 72.6±0.2 | 71.5±10.6 | 10.3±0.2 | 233.3±2.9 |

For heat flux density ($Q_{fd}$) the same equation can be written as:

$$Q_{fd} = \frac{Q}{A\ t} = \frac{T_1 - T_2}{r}\ (W\ m^{-2}) \quad \ldots (2)$$

where,

$r$ = $d/k$ ($W^{-1}m^{2}$°C) is the thermal resistance of the conductor.

In case of heat flow by conduction between the leaf and laminar boundary layer ($Q_g^{la}$) of uniform thickness ($\delta^a$), equation (2) may be written as:

$$Q_g^{la} = \frac{\Delta T^{la}}{r_h^{la}} \quad \ldots (3)$$

and,

$$r_h^{la} = \frac{\delta^a}{K^a} \quad \ldots (4)$$

where, $\Delta T^{la}$ is the temperature difference between the leaf surface and the boundary layer; $r_h^{la}$, the boundary layer thermal resistance; $\delta^a$, the boundary layer thickness; and $K^a$, the thermal conductivity of the air at different temperatures.

When two surfaces of a leaf are at different temperatures and each surface of a leaf attains its own local temperature, i.e. the condition of steady state arises, there must be a net flow of heat from the hot surface to the cold surface of the leaf. In such cases equation (3) and (4) may be expressed for a leaf as:

$$Q_g^l = \frac{\Delta T^l}{r_h^l} \quad \ldots (5)$$

and,

$$r_h^l = \frac{\delta^l}{K_h^l} \quad \ldots (6)$$

Where, $\Delta T^l$ is the temperature differences between the two surfaces of the leaf; $r_h^l$, the leaf thermal resistance; $\delta^l$, the thickness of the leaf; and $K_h^l$, the thermal conductivity of the leaf.

**Table 2(a)** *The average values of leaf length (cm ± SD) and width (in parenthesis — cm ± SD) in trees and shrub species at different altitudes in Garhwal Himalaya*

| Plant species | Altitude (m) | | | | |
|---|---|---|---|---|---|
| | 550 | 1700 | 2576 | 2900 | 3600 |
| **Trees** | | | | | |
| 1. *Acer caesium* | | | 12.5 ± 0.9 (8.0 ± 0.4) | 10.0 ± 1.3 (7.5 ± 0.3) | |
| 2. *A. villosum* | | | 19.0 ± 1.2 (11.0 ± 0.5) | 13.0 ± 0.9 (10.0 ± 0.6) | |
| 3. *Aesculus indica* | | 16.0 ± 0.5 (5.0 ± 0.6) | 15.0 ± 0.6 (4.5 ± 0.4) | | |
| 4. *Cedrela toona* | 15.0 ± 1.0 (3.5 ± 0.6) | 10.5 ± 1.0 (3.2 ± 0.4) | | | |
| 5. *Celtis australis* | 9.5 ± 1.0 (3.5 ± 0.4) | 9.0 ± 0.7 (3.0 ± 0.3) | | | |
| 6. *Eucalyptus globulus* | 12.0 ± 1.4 (5.5 ± 0.4) | 11.0 ± 1.0 (5.0 ± 0.6) | | | |
| 7. *Eucalyptus longifolia* | 15.0 ± 1.4 (3.4 ± 0.5) | 14.0 ± 0.8 (3.0 ± 0.3) | | | |
| 8. *Ficus palmata* | 13.0 ± 0.8 (13.0 ± 0.4) | 7.5 ± 1.0 (11.5 ± 0.6) | | | |
| 9. *Juglans regia* | | 15.0 ± 1.0 (4.3 ± 0.6) | 14.0 ± 1.4 (4.0 ± 0.5) | | |
| 10. *Melia azedarach* | 5.0 ± 0.9 (1.5 ± 0.5) | 4.5 ± 0.8 (1.0 ± 0.3) | | | |
| 11. *Populus hybrida* | 18.0 ± 1.1 (15.0 ± 0.9) | 12.0 ± 0.8 (10.5 ± 0.5) | | | |
| 12. *Quercus semecarpifolia* | | | 10.0 ± 1.7 (4.0 ± 0.4) | 7.0 ± 1.2 (4.0 ± 0.5) | |
| 13. *Rhododendron arboreum* | | 14.5 ± 0.9 (4.0 ± 0.3) | 13.5 ± 1.0 (3.5 ± 0.4) | 12.5 ± 1.8 (2.8 ± 0.5) | |
| 14. *Sapindus muckorossi* | 13.0 ± 1.1 (2.5 ± 0.6) | 10.0 ± 0.7 (2.0 ± 0.4) | | | |
| 15. *Viburnum foetens* | | | 12.5 ± 0.5 (5.0 ± 0.3) | 10.0 ± 0.8 (4.5 ± 0.5) | 6.5 ± 0.8 (3.0 ± 0.3) |
| **Shrubs** | | | | | |
| 1. *Berberis asiatica* | 5.2 ± 0.9 (2.5 ± 0.4) | 4.3 ± 0.6 (2.3 ± 0.2) | | | |
| 2. *B. chitria* | 3.5 ± 0.4 (0.9 ± 0.1) | 3.4 ± 0.4 (0.8 ± 0.1) | 3.0 ± 0.4 (0.7 ± 0.1) | | |
| 3. *B. jaeschkeana* | | | | 2.3 ± 0.3 (1.0 ± 0.1) | 2.0 ± 0.1 (1.0 ± 0.1) |
| 4. *B. kumaonensis* | | | | 1.5 ± 0.4 (0.6 ± 0.1) | 1.0 ± 0.3 (0.6 ± 0.1) |
| 5. *B. lycium* | 3.1 ± 0.2 (0.8 ± 0.1) | 3.0 ± 0.3 (0.7 ± 0.1) | 3.0 ± 0.2 (0.6 ± 0.1) | | |

**Table 2(b)** *The average values of leaf area ($cm^2 \pm SD$) and thickness (in parenthesis — $\mu m \pm SD$) in trees and shrub species at different altitudes in Garhwal Himalaya*

| Plant species | Altitude (m) | | | | |
|---|---|---|---|---|---|
| | 550 | 1700 | 2576 | 2900 | 3600 |
| **Trees** | | | | | |
| 1. *Acer caesium* | | | 88.6 ± 1.8 (137.8 ± 5.7) | 85.1 ± 0.1 (158.1 ± 8.7) | |
| 2. *A. villosum* | | | 144.5 ± 2.0 (100.0 ± 15.6) | 143.2 ± 1.1 (125.7 ± 13.7) | |
| 3. *Aesculus indica* | | 65.5 ± 1.8 (180.9 ± 20.3) | 64.7 ± 1.7 (212.0 ± 16.9) | | |
| 4. *Cedrela toona* | 60.2 ± 2.1 (122.7 ± 9.5) | 32.2 ± 2.0 (133.4 ± 9.8) | | | |
| 5. *Celtis australis* | 39.2 ± 2.1 (171.2 ± 11.0) | 29.1 ± 1.6 (186.8 ± 8.7) | | | |
| 6. *Eucalyptus globulus* | 45.3 ± 2.1 (100.1 ± 22.7) | 40.2 ± 2.1 (113.8 ± 25.7) | | | |
| 7. *E. longifolia* | 37.3 ± 1.8 (103.0 ± 16.3) | 34.3 ± 1.6 (143.9 ± 22.6) | | | |
| 8. *Ficus palmata* | 123.5 ± 1.8 (115.1 ± 6.8) | 65.9 ± 2.1 (137.8 ± 9.9) | | | |
| 9. *Juglans regia* | | 55.6 ± 2.3 (162.6 ± 13.4) | 55.2 ± 2.1 (189.5 ± 10.6) | | |
| 10. *Melia azedarach* | 10.3 ± 1.6 (125.6 ± 14.8) | 6.4 ± 2.0 (146.9 ± 10.6) | | | |
| 11. *Populus hybrida* | 143.2 ± 1.5 (142.3 ± 12.4) | 85.9 ± 1.5 (153.0 ± 14.6) | | | |
| 12. *Quercus semecarpifolia* | | | 36.5 ± 2.0 (185.4 ± 14.1) | 30.6 ± 1.6 (212.1 ± 15.9) | |
| 13. *Rhododendron arboreum* | | 50.5 ± 1.8 (211.8 ± 19.4) | 48.9 ± 2.1 (259.9 ± 24.0) | 47.4 ± 1.7 (303.6 ± 17.2) | |
| 14. *Sapindus muckorossi* | 35.7 ± 1.9 (136.3 ± 12.9) | 25.6 ± 2.0 (150.0 ± 10.6) | | | |
| 15. *Viburnum foetens* | | | 57.6 ± 1.8 (100.9 ± 13.8) | 52.6 ± 1.2 (125.8 ± 12.9) | 16.8 ± 1.3 (175.6 ± 10.6) |
| **Shrubs** | | | | | |
| 1. *Berberis asiatica* | 18.3 ± 1.9 (219.7 ± 15.8) | 13.0 ± 1.3 (341.0 ± 12.9) | | | |
| 2. *B. chitria* | 3.9 ± 1.1 (212.1 ± 11.2) | 3.8 ± 1.0 (331.8 ± 9.5) | 3.8 ± 0.8 (334.9 ± 14.6) | | |
| 3. *B. jaeschkeana* | | | | 5.8 ± 0.4 (166.6 ± 11.0) | 2.0 ± 0.3 (194.8 ± 9.4) |
| 4. *B. kumaonensis* | | | | 2.3 ± 0.2 (293.3 ± 10.4) | 1.6 ± 0.1 (253.6 ± 8.1) |
| 5. *B. lycium* | 3.6 ± 1.0 (319.7 ± 20.2) | 3.3 ± 0.7 (341.1 ± 24.8) | 2.2 ± 0.5 (352.1 ± 19.6) | | |

**Results and Discussion**

The average values of environmental parameters at different altitudes on the day of observations are given in table 1. While the relative humidity and wind velocity increased with altitude, the air temperature decreased progressively. Photosynthetically active radiation (PAR) decreased at higher altitudes due to the prevailing cloud conditions. Similar result was earlier reported by Caldwell (1980) in Southern Alps, New Zealand.

The leaf dimensions (length, width, area and thickness) of different trees and shrubs growing at different altitudes are given in tables 2(a) to 2(b). The species were not available at the altitudes where no figures are given in the tables. In most of the tree species the leaf length decrease more rapidly than the width while in shrubs the width was affected more than the length due to the increase in the altitude. Leaf length, width and area decreased with increasing altitude. However, the thickness of the leaves increased with increase in the altitude.

The average values of boundary layer thickness and some of its properties are given in table 3. While the boundary layer thickness and its conductivity decreased the conductance of the boundary layer increased with increase in the altitude. The observations on the differences between leaf and air temperature at different altitudes showed that the average values ranged from $-0.04$°C to $-0.7$°C which were not as sharp as reported earlier by other workers (Larcher & Wagner 1976, Korner & Cochrane 1983).

The average values of the thermal conductivity of leaves, their thermal conductance and the temperature gradient between the upper and lower leaf surfaces are shown in table 4. While the temperature differences between upper and lower leaf surfaces increased with altitude the thermal conductivity and the thermal conductance of leaves decreased progressively. The observations on the temperature differences across the leaf surfaces clearly show that the average values ranged from 0.2°C to 0.4°C which can be considered fairly large as compared to 0.1°C difference causing considerable change in the thermal gradient, heterogeneity and heat transfer in leaves reported earlier by Perrier (1971). Although, no physiological significance has been assigned to the temperature differences between upper and lower surfaces of the leaves, we propose that these differences may be indicative of the catabolic changes going on inside the plant and will reflect the adaptive as well as survival potential of the plant species to the increasing altitude. However, more work is obviously needed in this direction. The temperature of the upper surfaces of the leaves was found to be significantly higher than that of the lower leaf surfaces.

The total values of thermal conduction from leaf to air and across leaf surfaces are shown in table 5. The leaf and air temperature differences as well as the temperature differences across the leaf surfaces influence the heat conduction from leaf to air and also across leaf. Higher the differences between leaf and air, more is the conduction of heat from leaf to air. However, the conduction across the leaf surfaces seems to be dependent more on the thermal conductivity of the leaves and on the leaf thermal conductance. The conduction from leaf to air does not show a definite pattern with the changing altitude. However, the thermal conduction across leaf surfaces decreased with the increasing altitude in all the plant species.

**Table 3** *Average values of boundary layer thickness, thermal conductivity of air, boundary layer thermal conductance and differences between leaf and air temperatures at different altitudes in Garhwal Himalaya*

| Altitude (m) | Boundary layer thickness $\times 10^{-2}$(m) | Thermal conductivity of air $\times 10^{-2}$ ($Wm^{-1}$ $°C^{-1}$) | Boundary layer thermal conductance ($Wm^{-2}$ $°C^{-1}$) | Leaf-air temperature (°C) |
|---|---|---|---|---|
| 550 | 0.1 ±0.06 | 2.4±0.003 | 23.6±10.8 | −0.04±0.02 |
| 1700 | 0.1 ±0.04 | 2.4±0.001 | 28.2±12.6 | −0.3 ±0.02 |
| 2576 | 0.1 ±0.04 | 2.3±0.003 | 30.5±17.5 | −0.7 ±0.01 |
| 2900 | 0.1 ±0.03 | 2.3±0.003 | 42.8±23.3 | −0.3 ±0.01 |
| 3600 | 0.03±0.01 | 2.3±0.002 | 89.5±36.2 | −0.1 ±0.02 |

**Table 4** *Average values of thermal conductivity of leaves, leaf thermal conductance and temperature differences between two surfaces of the leaves at different altitudes in Garhwal Himalaya*

| Altitude (m) | Thermal conductivity of leaves $\times 10^{-4}$ ($Wm^{-1}°C^{-1}$) | Leaf thermal conductance ($Wm^{-2}°C^{-1}$) | Upper-lower leaf surface temperature (°C) |
|---|---|---|---|
| 550 | 13.2±2.5 | 9.0±2.5 | 0.2±0.1 |
| 1700 | 8.5±2.9 | 4.7±1.6 | 0.3±0.1 |
| 2576 | 6.9±3.3 | 3.7±1.4 | 0.3±0.2 |
| 2900 | 3.8±1.3 | 2.0±0.3 | 0.3±0.1 |
| 3600 | 3.1±0.4 | 1.5±0.2 | 0.4±0.01 |

**Table 5** *The total values of energy loss or gain by conduction from leaf to air ($Wm^{-2}$) in trees and shrub species at different altitudes in Garhwal Himalaya. (The energy loss by conduction between two surfaces of the leaves ($Wm^{-2}$) is given in the parenthesis)*

| Plant species | Altitude (m) | | | | |
|---|---|---|---|---|---|
| | 550 | 1700 | 2576 | 2900 | 3600 |
| **Trees** | | | | | |
| 1. *Acer caesium* | | | −25.1 (0.6) | −16.6 (0.4) | |
| 2. *A. villosum* | | | −34.2 (0.3) | −31.0 (0.2) | |
| 3. *Aesculus indica* | | 36.6 (1.3) | −42.1 (1.2) | | |
| 4. *Cedrela toona* | 27.5 (1.5) | −29,0 (1.5) | | | |
| 5. *Celtis australis* | −40.0 (2.6) | −31.5 (2.0) | | | |
| 6. *Eucalyptus globulus* | −33.9 (1.0) | −37.0 (0.9) | | | |
| 7. *E. longifolia* | −42.4 (1.0) | −37.4 (0.9) | | | |
| 8. *Ficus palmata* | 17.2 (3.0) | 10.5 (2.2) | | | |
| 9. *Juglans regia* | | −43.2 (1.3) | −40.0 (1.1) | | |
| 10. *Melia azedarach* | 38.7 (0.9) | −57.3 (0.5) | | | |
| 11. *Populus hybrida* | 13.1 (1.5) | −29.0 (1.5) | | | |
| 12. *Quercus semecarpifolia* | | | −36.5 (1.0) | −29.7 (1.0) | |
| 13. *Rhododendron arboreum* | | 33.8 (1.8) | −37.1 (1.8) | −14.0 (1.0) | |
| 14. *Sapindus muckorossi* | 39.0 (2.2) | −52.5 (1.9) | | | |
| 15. *Viburnum foetens* | | | −39.3 (0.7) | −24.7 (0.6) | −25.8 (0.6) |
| **Shrubs** | | | | | |
| 1. *Berberis asiatica* | −16.4 (2.6) | −14.4 (1.4) | | | |
| 2. *B. chitria* | −28.0 (2.2) | −29.5 (1.1) | −16.5 (0.9) | | |
| 3. *B. jaeschkeana* | | | | −12.7 (0.5) | −15.4 (0.5) |
| 4. *B. kumaonensis* | | | | −20.8 (0.5) | −21.2 (0.5) |
| 5. *B. lycium* | −31.3 (3.3) | −28.4 (1.6) | −15.0 (1.1) | | |

**Table 6** *Average values of leaf energy exchange parameters at different altitudes in Garhwal Himalaya. ($Q_r$ = energy loss by radiation, $Q_t$ = energy loss by transpiration, $Q_c$ = energy gain by convection, $Q_g^{la}$ = energy gain by conduction from air to leaf, $Q_g^l$ = energy loss by conduction across leaf surfaces and $Q_a$ = total energy absorbed by the leaves)*

| Altitude (m) | $Q_r$ | $Q_t$ | $Q_c$ | $Q^{la}{}_g$ | $Q^l{}_g$ | $Q_a$ |
|---|---|---|---|---|---|---|
| | | | (W $m^{-2}$) | | | |
| 550 | 444.3 | 14.5 | −0.2 | − 2.6 | 1.9 | 457.9 |
| 1700 | 404.9 | 9.7 | −1.1 | −10.7 | 1.4 | 404.2 |
| 2576 | 398.8 | 8.1 | −1.8 | −15.9 | 1.0 | 390.2 |
| 2900 | 372.3 | 5.5 | −0.7 | −10.7 | 0.6 | 367.0 |
| 3600 | 352.0 | 4.3 | −0.3 | − 9.4 | 0.5 | 347.1 |

The general trend of the energy exchange parameters is shown in table 6. The leaf energy balance sheet of these plant species indicated that the total energy absorbed by the leaves was lost by radiation, transpiration and thermal conduction across leaf surfaces and all these energy parameters decreased with the increasing altitude. The two energy parameters, namely convection and air to leaf conduction, do not show a definite pattern with the changing altitude. The leaves gained energy by the convection of heat as well as by boundary layer thermal conduction which is basically due to lower leaf temperature than that of the surrounding air. This seems to be a characteristic feature of the tropical mountain plants. The lower leaf temperature and negative convection as well as conductional energy will help these plant species to survive under considerable higher air thermal load by cooling down the surrounding air and by reducing the surface evaporation under these and maintain the relatively higher soil moisture content. Similar advantages of lower leaf temperature as compared to the surrounding air as well as negative convectional energy have been reported earlier by Dhyani and Purohit (1983, 1984).

The correlation coefficients between leaf dimensions and boundary layer thermal coductance indicates a higher significant role of leaf width in determining the boundary layer thermal conductance ($r = 0.9592$) which in turn plays a significant role in the energy balance of the plant ($r = -0.7713$). The process of conduction from air to leaf affected the total energy budget of leaves through the effect of lea and air temperature differences on conduction ($r = 0.\not{}196$). On the other hand, thermal conduction across leaf surfaces is more affected by the thermal conductivity of leaves ($r = 0.9927$) which in turn has significant effect on the status of the total leaf energy balance ($r = 0.9818$). Therefore, it is proposed that the thermal conduction across leaf surfaces is an important parameter in calculating the total energy budget of a leaf.

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