A BIOLOGICALLY MEANINGFUL DESCRIPTION OF ECOSYSTEM MOISTURE REGIME

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Prepared for the Forest Microclimate Symposium -
Kananaskis Forest Experiment Station, September 1969.

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INTRODUCTION

The main purpose of the following paper is to generate some thought and effort toward the improvement of the measurement and description of ecosystem moisture regime.

Under ecosystem moisture regime I understand the closely interacting system of atmospheric, edaphic and vegetation moisture regimes of a particular site. Moisture regime of the ecostem may be studied from hydrological or biological point of view. In hydrological studies the quantitative exchange of water between the three components and the total gain or loss of water in the ecosystem is under consideration. For biological purposes the qualitative aspect of the water is of the great importance i.e. the water potential in the soil and plants and the vapor pressure of the air and their relationship. For example the hydrologist wants to know the amount of water lost through transpiration while the plant physiologist or ecologist is interested in the internal water potential of the plant when transpiring at a particular rate.

Importance of Water to Plant Growth

When water supply is adequate and the transpiration demand of the air is low plants are in state of full turgidity. At high transpiration demand and low soil water potential, loss of water from plants exceeds uptake and their water content becomes less than at full turgidity. This relative water content (RWC) was expressed by Weatherly (1950) as the ratio of existing water content to the water content at full turgidity on a dry weight basis and was called relative turgidity (RT).

$$RT = \frac{\text{Fresh Weight - Dry Weight}}{\text{Fully Turgid Weight - Dry Weight}} \quad 100$$

Slatyer (1955) reported reduction of growth in cotton, sorghum and peanuts when RWC decreased to 90 %. Catsky (1965) found that 5 - 10 % reduction in RWC caused 50 % decrease in photosynthesis. Slatyer (1955, 1960) also found that reduction of RWC is caused by the lowering of water potential in the tissues (fig. 1). Plants with unlimited water supply lose water into the air through transpiration in a varying rate according to atmospheric conditions. The water loss from the plant is replaced with a continuous stream of water from the soil to the leaves. This transpirational stream encounters resistances to flow in the soil and within the plants. To maintain the flow against all resistances a potential gradient must exist from soil to leaves. Therefore the magnitude of water potential in the leaves is a function of the sum of resistances and the transpiration demand. Consequently the external factors regulating transpiration potential and soil water availability need to be measured for the study of ecosystem moisture regime.

FACTORS CONSIDERED FOR THE MEASUREMENT OF ECOSYSTEM MOISTURE REGIME

(1) Soil Water Potential

Soil water potential is the sum of matric and osmotic potentials. In most forest soils osmotic potential is negligible and matric potential is often measured with calibrated fibre glass resistance units. Total water potential may be measured with thermocouple psychrometer developed by Richards and Ogata (1958).

(2) Soil Temperature

Cupier (1963) found a decrease in water uptake by tomato roots with falling root temperatures (fig. 2). Babalola et al. (1968) studied the effect of soil temperature on the transpiration rate of Monterey pine and reported sharp reductions with decreasing soil temperatures especially at high soil water potentials. Therefore measurement of soil temperature is also necessary for the study of water availability.

(3) Transpiration Demand

Transpiration from leaves was expressed by Tanner (1967) according to the following equation:

$$E = \frac{\rho \varepsilon}{P} \cdot \frac{e_i - e_z}{r_i - r_a}$$

Where ρ, ε and P are density of moist air, ratio molecular weight water vapor to air and atmospheric pressure respctively; e_i and e_z internal and external vapor pressure, r_i and r_a resistances to vapor movement. Resistnaces to vapor movement are controlled by plant properties and $\frac{\rho \varepsilon}{P}$ can be regarded as constant. Therfore the driving force of transpiration is $e_i - e_z$. According to Covan and Milthorpe (1968) e_i is not less than 95 % of the saturation vapor pressure at leaf temperature.

Gates (1965) found that leaf temperature does not exceeds air temperature when the radiation absorbed is less than 0.5 cal cm^{-2} min^{-1} (fig. 3). This condition exists if the micro environment is shaded or the sky is overcast with alto cumulus or heavier clouds. For bright sunny conditions difference between leaf and air temperature ($T_l - T_z$) may be found from the energy diagram of Gates (1965) (fig. 4) if the air temperature, wind speed and radiation absorbed by leaves is known. Radiation absorbed can be calculated from measured or computed insolation using 0.7 as the mean absorptance factor. If a minimum wind speed of 1 mile/hour, air temperature not less than 10° C and a maximum insolation of 1.4 cal cm^{-2} min^{-1} are assumed the following $T_l - T_2$ values may be used in the noon hours during summer:

0° C	-	in shade or under heavy clouds
$+7^\circ$ C	-	under cirrus clouds
$+10^\circ$ C	-	under bright sunshine

The above $T_l - T_z$ values may be used for the estimation of $e_i - e_z$. If $T_l \cong T_z$ than $e_i - e_z$ will be approximately equal to the saturation deficity of the air at measured air temperature and relative humidity. Under light overcast or bright sunny condition $e_l - e_z$ will be approximately equal to the saturation deficit of the air calculated at air temperature + $(T_l - T_z)$ and at measured relative humidity of the air. Saturation deficity values can be found quickly from figure 5. Because of great day to day variations in atmospheric condition, saturation deficit values should be calculated daily from the maximum air temperature and associated minimum relative humidity to represent the most severe conditions of the day.

In summary the measurements considered necessary for the recording of ecosystem moisture regime are

(a) Soil water potential

(b) Soil temperature

(c) Air temperature) to calculate saturation

(d) Relative humidity) deficit

The march of these factors through the growing season would give a biologically meaningful description of the ecosystem moisture regime, because relationships between these factors and water potential in plants can be found experimentally and the moisture regime could be expressed as the march of expected maximum water potential in a certain plant species.

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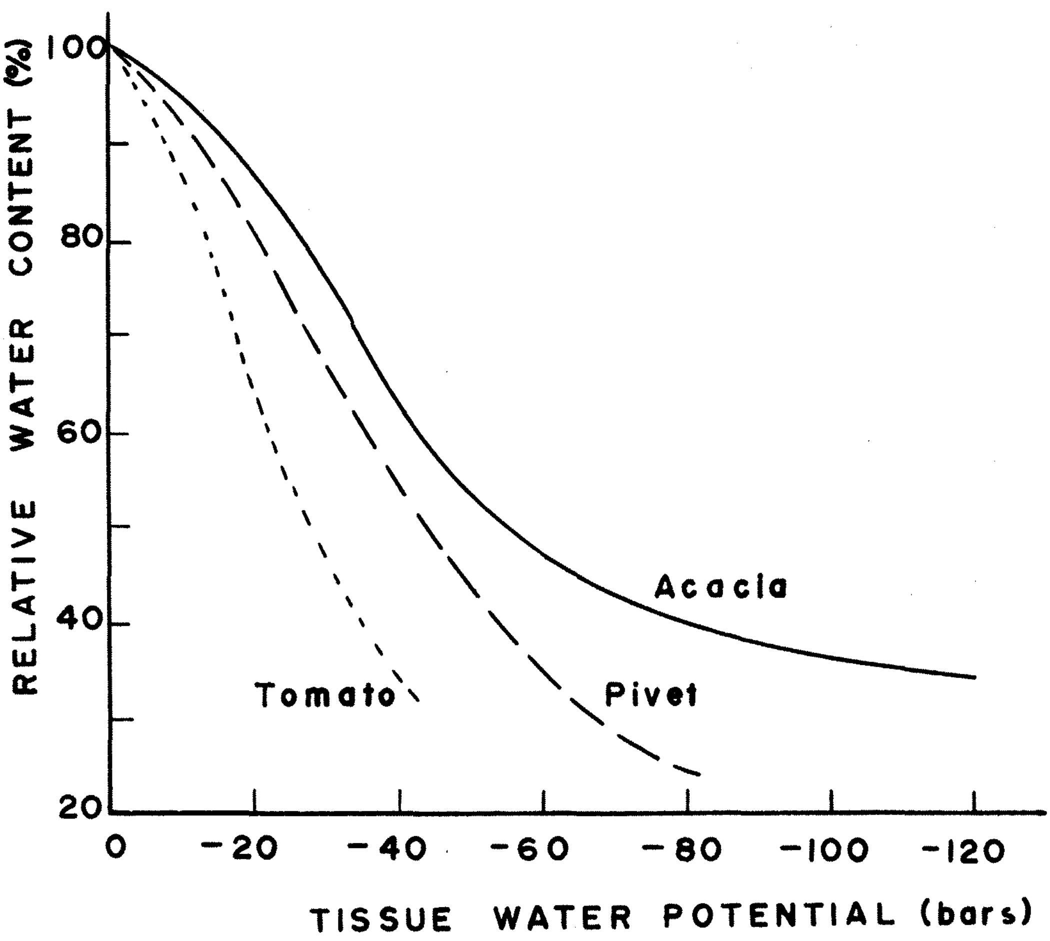

Fig. 1 Relative water content/water potential for tree types of leaf tissue (after Slatyer, 1967).

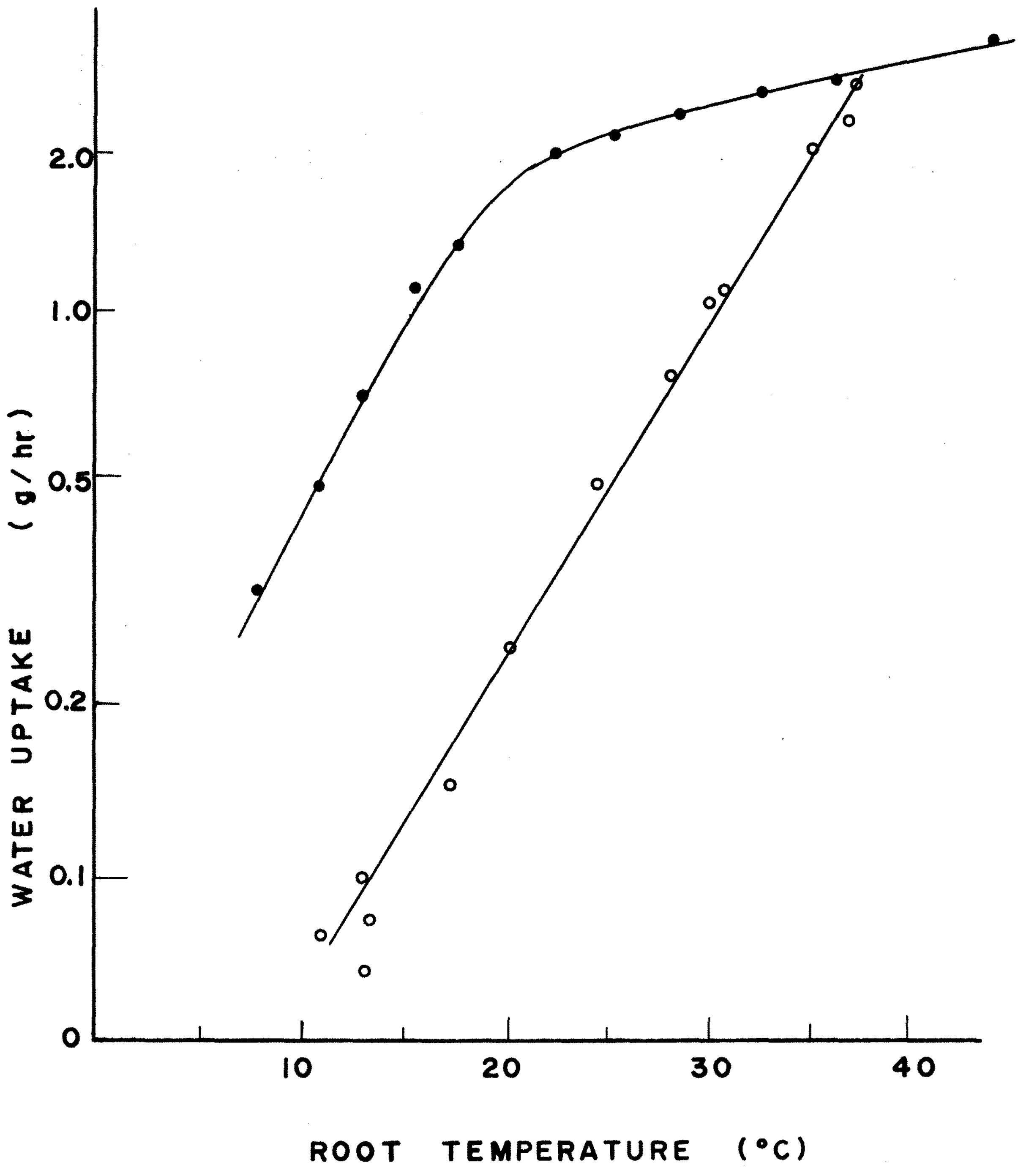

Fig. 2. Water uptake by bean roots grown under low (17°) (O), and normal (24°) (●) temperatures, as a function of increasing temperature (after Kupier, 1964).

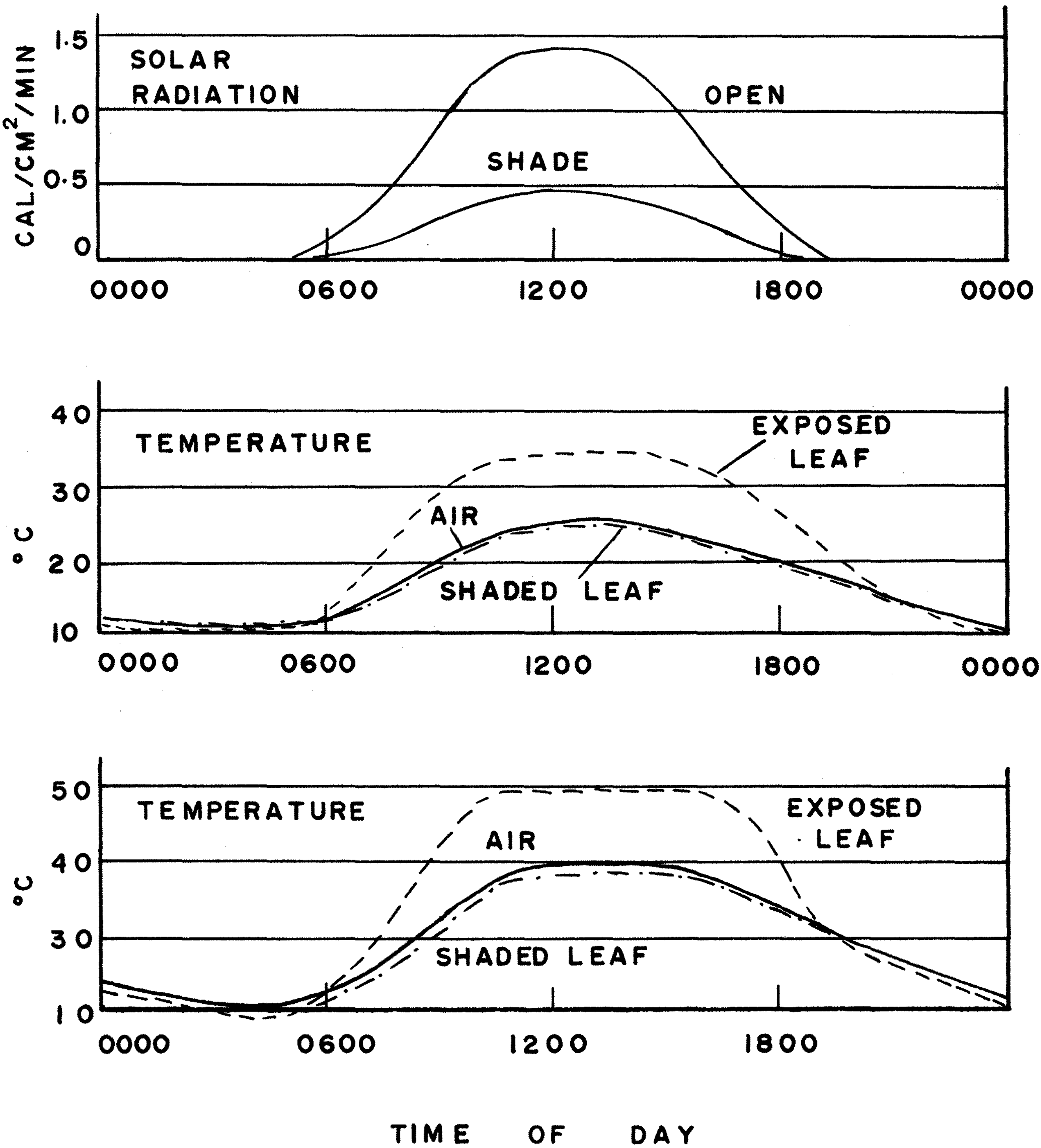

Fig. 3. Illustration of solar radiation, air temperature and leaf temperature relationships on a cool and a warm summer day with clear sky (after Gates, 1965).

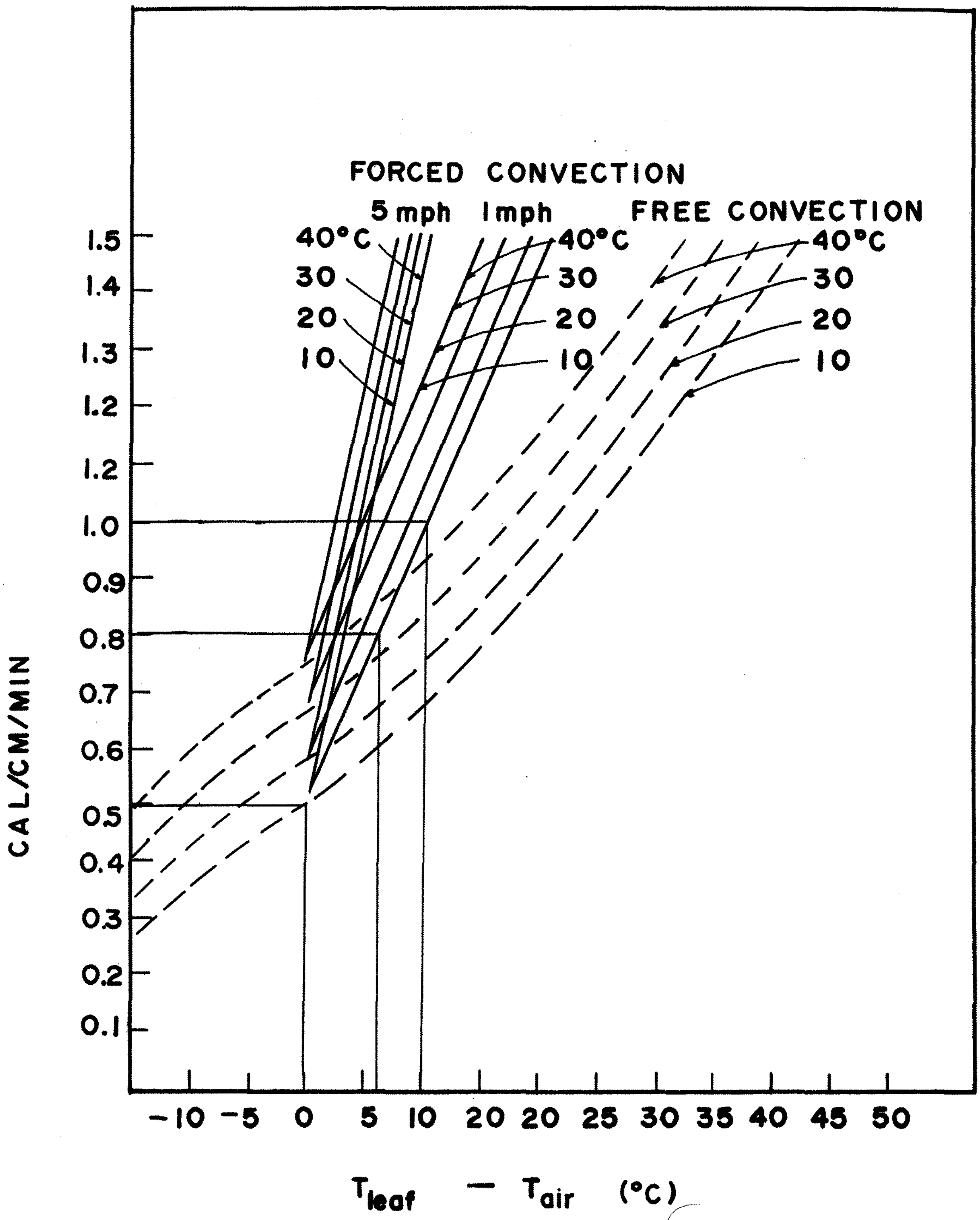

Fig. 4. Energy diagram for computing leaf to air temperature difference when the radiation absorbed is given. Curves represent energy dissipation by leaf through reradiation + free convection and reradiation + forced convection at 10°, 20°, 30°, and 40° C (after Gates, 1965).

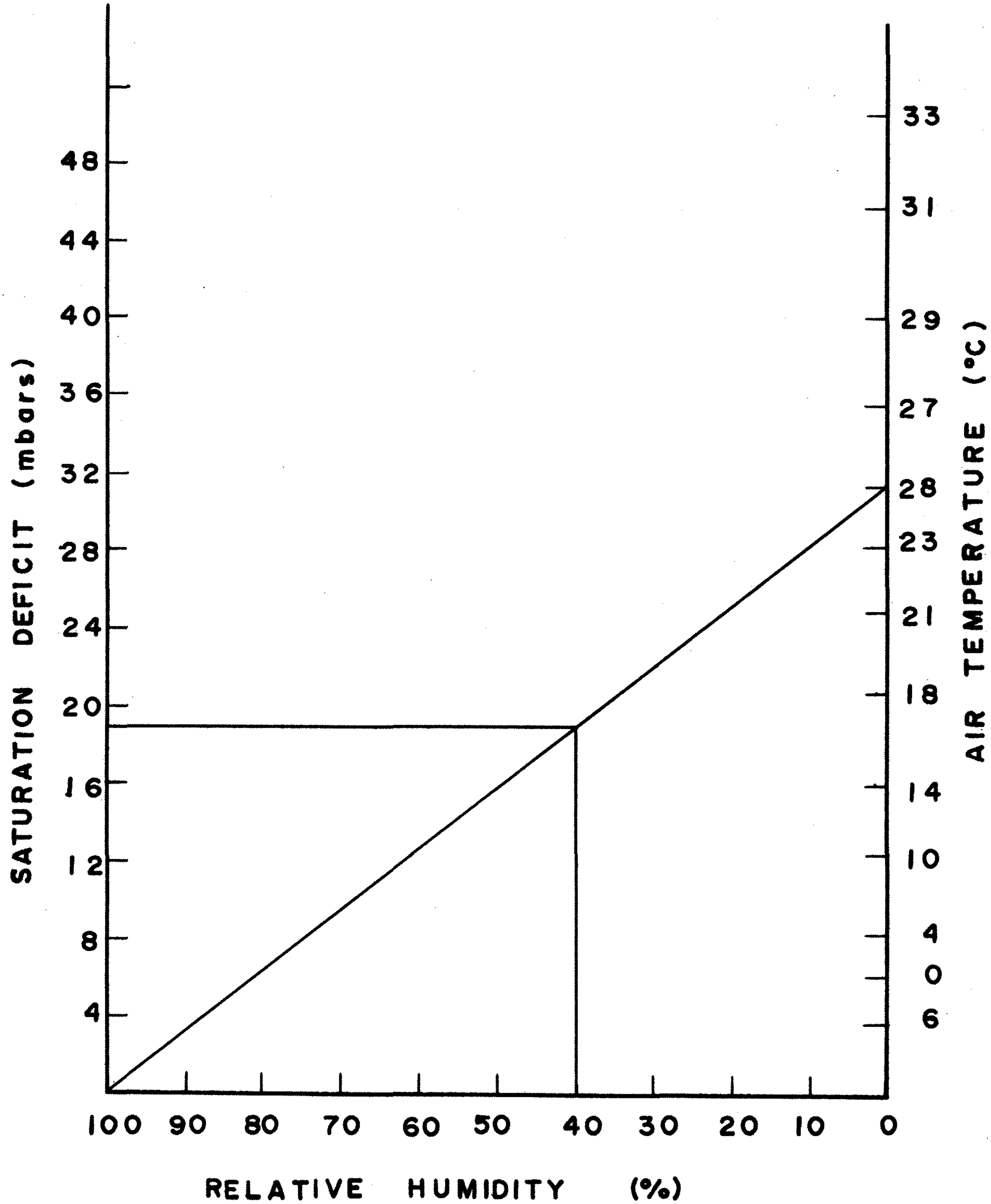

Fig. 5. A diagram for computing saturation deficit from relative humidity and air temperature. Finding saturation deficit at 40 % relative humidity and 28° C air temperature is illustrated on the diagram.