Foliage temperature measurement and its application to agronomic research

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The advent of low cost accurate hand held infrared thermometers makes possible the routine once-a-day measurement of foliage temperatures (T_f). Research at the CSIRO Centre for Irrigation Research has indicated several potential applications to the understanding of yield variations in field crops. These have been

(1) Measurement of transpiration rate (E_f) using the energy balance equation:

$$\lambda E_f = IRn - \rho C_p (T_f - T_a)/r_a \qquad W\ m^{-2} \qquad 1$$

where λ is the latent heat, Rn net radiation, I the proportion of Rn intercepted, ρ air density, C heat capacity of air, T ambient temperature and r_a the aerodynamic resistance calculated from crop height and windspeed.

(2) Canopy stomatal resistance (r_c) derived from substituting E_f into the equation for vapour flux and solving for r_c :

$$r_c = \rho C_p \ (e^*(T_f) - e_a)/\gamma E_f - r_a \qquad sec m^{-1} \qquad 2$$

where $e^*(T_f)$ is the saturated vapour pressure at T_f , e_a is ambient vapour pressure and γ the pschyrometric constant.

(3) Detecting the onset of stress. This is based on comparing the measured T_f with the theoretical foliage ambient-differential of a non stressed crop $(T_f\text{-}T_a)_{ns}$ predicted from meteorological data using the equation:

$$(T_f - T_a)_{ns} = \frac{r_a IRn}{\rho C_p} \ \frac{\gamma(1 + r_c'/r_a)}{\Delta + (1 + r_c'/r_a)} - \frac{e^*(T_a) - e_a}{\Delta + (1 + r_c'/r_a)} \qquad {}^{o}C \qquad 3$$

where Δ is the slope of the saturation vapour pressure ambient temperature curve, $e^*(T_a)$ is the saturation vapour pressure at T_a and r_c' is the non stressed canopy stomatal resistance which for$_2$wheat we have predicted as a function of LAI and vapour pressure deficit (r =0.83).

4) The residual resistant to CO_2 fixation (r_m) using the vapour flux equation for photosynthesis of:

$$P_n = dCO_2/(r_a + 1.6\ r_c - r_m) \qquad gm^{-2} sec^{-1} \qquad 4$$

where P_n is the net photosynthetic rate measured with a portable canopy technique, dCO_2 the concentration gradient and 1.6 the ratio between the molecular diffusivities of H_2O/CO_2.

Once-a-day measurements of foliage temperature around solar noon by infrared thermometry enable the above four equations to be used to analyse the importance of several key yield determining parameters in agronomic experiments or commercial field crops. Application of these equations requires associated meteorological data and for the last equation a transient measurement of photosynthetic rate at the time of T_f measurement is .needed. Consequently with the use of infrared thermometry crop parameters which previously have been mainly measured in leaf chambers can now be easily estimated for real crop situations. Examples using the above 4 equations will be given in the associated talk using data from cotton, maize and wheat.