Poster No 39

Prospects of using infrared thermography for irrigation scheduling of Wheat crop.

Jyotiprakash Padhi[2,3], Rabindra K. Misra[2,3,4] , Jose O. Payero[1*]

[1] Agri-Science Queensland, Department of Employment, Economic Development and Innovation, Toowoomba, QLD 4350, Australia
[2] CRC for Irrigation Futures and National Centre for Engineering in Agriculture, Toowoomba, University of Southern Queensland, QLD 4350, Australia
[3] Faculty of Engineering and Surveying, University of Southern Queensland, QLD 4350, Australia
[4] Australian Centre for Sustainable Catchments, University of Southern Queensland, QLD 4350, Australia
* corresponding and presenting author, jose.payero@deedi.qld.gov.au

Introduction

Plant stress sensing might be considered as an ideal approach in irrigation scheduling of crop plants because the plant is a good integrator of the soil, water and climatic parameters. Most of the past studies on detection of water stress in plants have been based on infrared thermometry (Alderfasi and Nielsen, 2001). Recent development of portable thermal imagers and the associated image analysis software has overcome some of the uncertainties associated with infrared thermometers. Rigorous testing of thermal imaging against more traditional physiological techniques of measuring water status of plants under field conditions is still required (Grant et al., 2006). Earlier studies which have used infrared methods for irrigation scheduling are able to indicate stomatal closure or transpiration rate but they give no information on the amount of soil water available or that needs to be supplemented via irrigation at that time (Jones, 2004). Therefore, experiment was conducted in a wheat field to test whether thermal imaging can be used as an irrigation scheduling technique by growing wheat under various irrigation treatments and examining the effectiveness of crop water stress indices (ICWSI and I_G) to estimate soil water status.

Materials and Methods

This field experiment consisted of four irrigation treatments with three replications using a randomized complete block design. Thermal images of wheat plants located close to neutron access tubes were taken from each replicate plot with a thermal infrared camera on six occasions. Profiles of soil water content were also measured with a neutron probe on the same day of thermal image acquisition. Wheat leaves were sprayed with water on both sides for about 1 min to simulate the condition of a fully transpiring leaf immediately before images were taken to estimate the temperature of wet reference leaf (T_{wet}). Additional reference leaves were covered with petroleum jelly to simulate the condition of a non-transpiring leaf for estimation of dry reference leaf (T_{dry}). The temperatures of normal, wet and dry reference leaves were used in the calculation of ICWSI and I_G.

Results & Discussion

Effect of soil water on canopy temperature

To investigate the effects of soil water on canopy temperature for the wheat crop, canopy temperature was plotted against soil water within the root zone (Fig. 1). It can be seen from Fig. 1 that for the combined data over the entire season of the wheat crop canopy temperature appeared to increase with increase in soil water content. Overall trend in the data tends to contradict the general notion that canopy temperature should be low at high soil water content as increased water supply in the root zone of a plant should allow it to maintain adequate transpiration and cooling of leaves. Apparent contradictory situation in Fig. 1 may have arisen as a result of seasonal variation in weather conditions. Cooling of leaves usually occur in relation to the ambient temperature as heat is exchanged between the leaf surface and the surrounding air during transpiration. As the capacity of stomata to control transpiration from leaves varies with species and cultivars, a hydraulic feedback within the control system of stomata (Jones, 1998) may limit the maximum conductance and transpiration rate when weather conditions (e.g. atmospheric vapour pressure deficit, VPD) differ substantially during the measurements of canopy temperature. One of the possible reasons for the dependency of canopy temperature-soil water relationship on weather conditions (VPD) for wheat is due to a distinct seasonal change expected during the growth period.

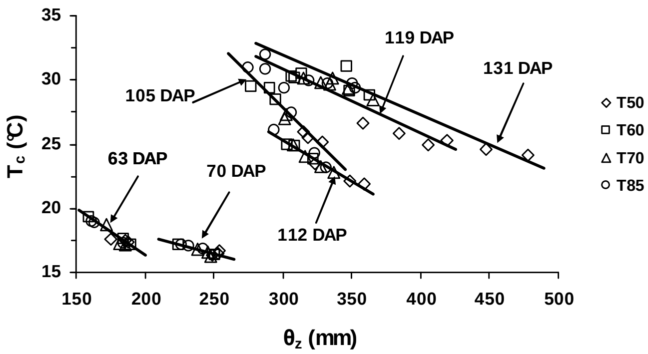

Figure 1: Variation in canopy temperature (T_c) with soil water within the root zone (θ_z) for various irrigation treatments of wheat in the field. Six solid lines within this graph show a local decreasing trend in canopy temperature with increasing soil water within the root zone for the specific date of measurement shown as days after planting (DAP).

Since no unique relationship was found between T_c and θ_z when all the measurements were considered together, fitted values of T_c against θ_z are shown separately for each measurement date in Fig. 1. It can be observed from Fig. 1 that canopy temperature decreases with an increase in soil water within the root zone for each individual date of measurement. Therefore it may be appropriate to use thermal imaging for irrigation scheduling on the day of measurement rather than combining all the measurements over the entire season.

Crop water deficit indices and their implications to irrigation scheduling

Crop water deficit indices are used as scaling variables by combining T_c with air temperature (T_a) and/or T_{wet} and T_{dry}. There was no consistent relationship between crop water stress indices (ICWSI and I_G) and soil water within the root zone as seen for canopy temperature in Fig. 1. However, these variables were found to be reasonably suitable for irrigation scheduling for the day of measurement (specific growth stage) of wheat crop. The major difference between these two indices was that, unlike ICWSI, I_G was high when the soil water within the root zone was high. The coefficient of determination (R^2) of all the fitted regressions at various times during the growth season varied from 0.76 – 0.95 in case of ICWSI and 0.73 – 0.92 for I_G and were all highly significant ($P \leq 0.001$). ICWSI may be considered more appropriate for irrigation scheduling than I_G, because there is no fixed range of variation for this index where as ICWSI varied from 0 to 1. Thus, multiple thermal images may be required for irrigation scheduling of wheat in the field.

References

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