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# Measuring the effect of water stress on wheat evapotranspiration

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## Introduction

The focus of irrigated agriculture has traditionally been to irrigate crops to meet crop water requirements during the entire growing season, aiming at maximising crop yield. As water becomes scarce in many areas, full irrigation of crops to meet their water requirements is not a viable option for many growers. Therefore, they have to allow some level of crop water stress, accepting reduced yield (Payero et al., 2008; Payero et al., 2009). The challenge is to know how much and when to stress crops to minimise the impact on yield and profits. This is a difficult question for growers to answer, especially when the stochastic nature of rainfall is considered. Crop growth and irrigation scheduling models can provide some assistance if relationships between water stress and crop evapotranspiration (ETc) (and its relationship to yield) are known for specific crops. The FAO-56 model (Allen et al., 1998), perhaps the most popular approach used in irrigation scheduling, uses a generic relationship to explain the impact of stress on ETc. This approach does not reduce ETc when soil water depletion is less than a maximum allowable value at which the crop is presumed to have no stress, and when this depletion value is exceeded, ETc is linearly decreased until the soil water reaches the permanent wilting point level in soil . The objective of this study was to test the FAO-56 model under a controlled environment for wheat. This information is critical for developing reliable models to predict the impact of water stress on crop development and yield.

## Methods and Materials

A greenhouse experiment was conducted with wheat at the University of Southern Queensland in Toowoomba during the winter of 2008. The experiment consisted of four irrigation treatments with three replications. Each experimental unit consisted of one pot in which three wheat plants were grown. An automatic weighing system was constructed to measure and record the mass of each pot every 10 minutes. From this information, the daily crop evapotranspiration of each pot was determined. The four irrigation treatments T40, T50, T70, and T80 were irrigated when the pot soil moisture were 40, 50, 70, or 80% of field capacity, respectively. At the end of the season, grain yield and plant biomass were measured. Weather data were measured concurrently inside the greenhouse. From the weather data, daily grass-reference evapotranspiration (ETo) was calculated using the Penman-Monteith method (Allen et al., 1998), which combined with the daily measurement of ETc allowed calculation of daily crop coefficients (Kc=ETc/ETo) values.

## Results & Discussion

It was found that water stress had a big impact on the measured daily ETc and the calculated Kc values. For instance, while the peak ETc for the fully-irrigated treatment (T80) was about 11 mm/d, the corresponding value for the more severely stressed treatment (T40) was less than 6 mm/d. This resulted in a seasonal reduction of ETc from 284 mm to 176 mm (38% reduction), which reflected on a significant reduction in yield and biomass production. Daily relative Kc values for each treatment were calculated by dividing the treatment Kc by that of the fully-irrigated treatment (T80). The relative Kc for the different treatments were plotted as a function of soil water depletion fraction (WDF) (WDF=0 at field capacity, FC and WDF=1.0 at permanent wilting point, pwp) separated by soil drying cycles (Fig.1). Figure 1 shows that the response to water stress was different for the three irrigation treatments and for each soil drying cycle within each treatment. The more severely stressed treatment (T40) showed distinctly different responses for each drying cycle. These results indicate that for crops subjected to severe stress conditions, the unique relationship suggested by FAO-56 does not apply. For this treatment, the relative Kc after each irrigation event decreased from an initial value of 1.0 for the first drying cycle to about 0.65 for the second, and about 0.4 for the third. These results can be explained by a reduction in leaf area index and a corresponding reduction in ETc as the crop is stressed. For the T50 treatment, which had less stress than T40, although there are distinct relationships for each drying cycle, the general response roughly follows that proposed in FAO-56, with the relative Kc starting to decrease at a value of WDF≈0.35. However, the relative Kc after irrigation tended to decrease with soil drying cycle from an initial value of 1.0 for the first irrigation to about 0.75 for the last. Similar results regarding the relative Kc after irrigation were observed for the T70 treatment. These results suggest that more dynamic approaches need to be developed to adjust evapotranspiration under water stressed conditions, which not only consider water depletion fraction, but also the impact of decreased biomass or leaf area index resulting from water stress.

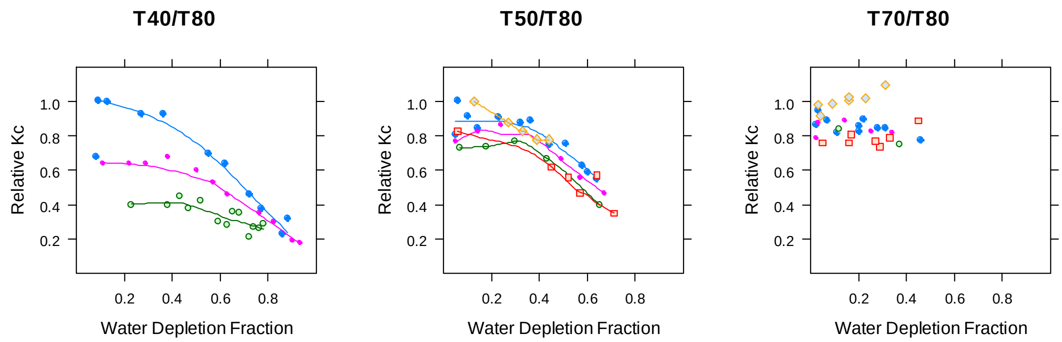


Figure 1. Relative wheat crop coefficient (Kc) of three deficit-irrigated treatments (T40, T50 and T70) with respect to a fully-irrigated treatment (T80) as a function of soil water depletion fraction measured in a greenhouse. (FC=0 WDF, pwp=1 WDF). Points and lines of different colors represent different soil drying cycles.

## References

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