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Template for poster

Controlling and Monitoring Water Stress in Contrasting Environment for Drought Tolerance Phenotyping of Cereals and Legumes

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Theme: Exploiting Allelic Diversity

Abstract

Drought is considered the main source of grain yield instability for cereals and legumes in tropical regions among other environmental stresses. The drought process studies require knowledge of some target environment factors and how these factors interact with plants genotypes performance under water constraint condition. The objectives of this work are to describe the procedures and practices of controlling and monitoring water stress in contrasting environment for drought tolerance phenotyping of cereals and legumes to better understand the effects of plants genetic and environmental (GxE) interactions for grain yield, identifying and characterizing the causes which will result in genotypes yield reduction due to water shortage. Irrigation water needs are being determined through computation of reference (ETo) and crop (ETc) evapotranspiration, using modified Penman-Monteith equation and crop coefficient (kc). Each genotype ETc is being determined through multiplying ETo by Kc. Irrigation management strategy and timing criteria are being performed based on a spreadsheet water balance program, including ETo, ETc, and soil water content at different depths. The water stress treatments are being obtained with different ETc replacement, generating different water depth applications in the plots at pre-defined crop growth phases, defined for each genotype, in order to establish the water stress level.

Introduction

Drought is the main source of grain yield instability for cereals and legumes in tropical regions among other environmental stresses. The drought process studies require knowledge of some target environment factors and how these factors interact with plants genotypes performance under water constraint condition. The objectives of this work are to describe the procedures and practices of controlling and monitoring water stress in contrasting environment for drought tolerance phenotyping of cereals and legumes to better understand the effects of plants genetic and environmental (GxE) interactions for grain yield, identifying and characterizing the causes which will result in genotypes yield reduction due to water shortage.

Irrigation Water Control

The correct irrigation scheme design and layout on the site-specific experimental area are essential in the selection process of drought tolerant genotypes to make possible and easy the irrigation water control and management.

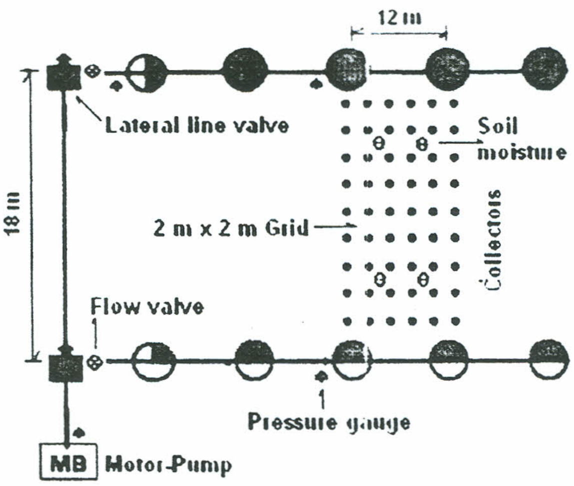

Figure 1. Conventional sprinkler irrigation system water control and measurements (sprinklers spacing, operating pressure, flow rate, application depth, uniform water distribution, and soil moisture).

Crop Water Requirements and Water Stress

Crop water needs (ET≡ Evapotranspiration) are being computed by means of modified Penman-Monteith equation and crop coefficient (kc) (ETo≡ reference, ETc≡ crop). Each genotype ETc is being calculated multiplying ETo by Kc. Irrigation management strategy and timing criteria are being performed based on a spreadsheet water balance program, including ETo, ETc, and soil water content at different depths. The water stress treatments are being obtained with different ETc replacement, generating different water depth applications in the plots at pre-defined crop growth phases, defined for each genotype, in order to establish the water stress level. The following crop water stress index (CWSI) is being used to quantify the water stress (ETcact & ETcpot are ETc actual & potential):

$$CWSI = 1 - \frac{ETc_{act}}{ETc_{pot}}$$

The crop water stress index results considered for analysis were taken from an irrigated beans field under four different water regimes from the growth period between the 29 and 80 days after seedling (DAS). All four water treatments received a total of 118.8 mm of applied water from seedling to 28 DAS, with 4-day average irrigation interval. Just after the 28 DAS, treatment differentiation started, with the application of pre-determined depths of water, according to the irrigation intervals. From seedling to harvest, the total amounts of applied water, including 66 mm of rainfall, were 439.6, 385 6, 326.5, and 290.4 mm for T4, T8, T12 and T16 treatments, respectively.

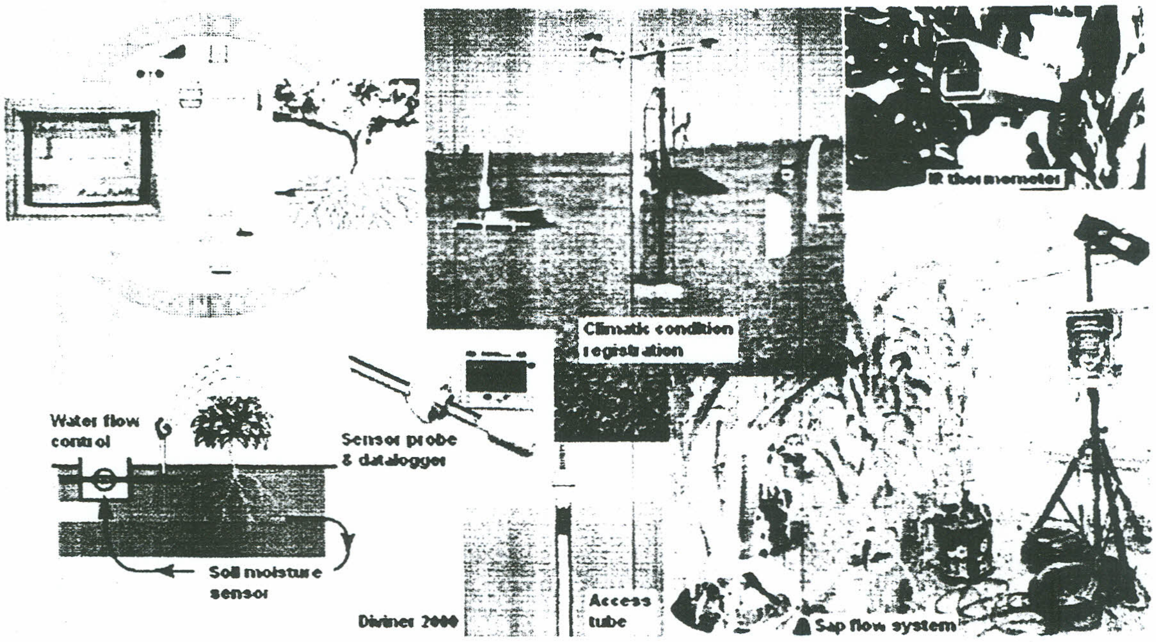

Figure 2. Environment characterization with monitoring & controlling sensors/ equipments/ devices/ systems based on feedback measurements of the real time local micro-climatic condition, irrigation water application, and soil and plants water status.

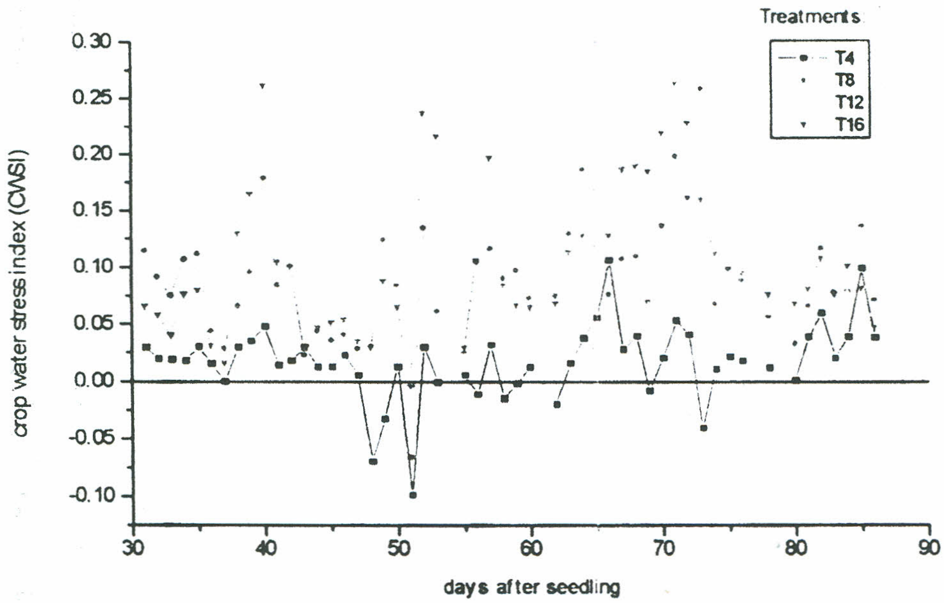

Figure 3. Crop water stress index for beans versus crop growth period (expressed as days after seedling) at four irrigation frequencies (T4, T8, T12, and T16) for measurements in the morning period (EMBRAPA, Sete Lagoas, MG, Brazil, 2002).

Figures 3 and 4 show the crop water stress index variation with the crop growth period (expressed as days after seedling) at four irrigation frequencies (T4, T8, T12, and T16) and two measuring periods (morning and afternoon), respectively. Treatment T4 was assumed to have a crop with adequate water supply and maximum or potential evapotranspiration rate in the CWSI determination. The results show that T4 presented less oscillation in the CWSI values which were maintained close to the zero level. Therefore, four-day irrigation frequency did not cause water stress damage to the crop. By analyzing the two measuring periods (morning and afternoon), it can be noticed a similar tendency in the CWSI variation. But the highest CWSI values were obtained during afternoon readings. At first, this suggests that the best time for canopy temperature (Tc) reading is between 13:00 and 14:00 hours for CWSI studies.

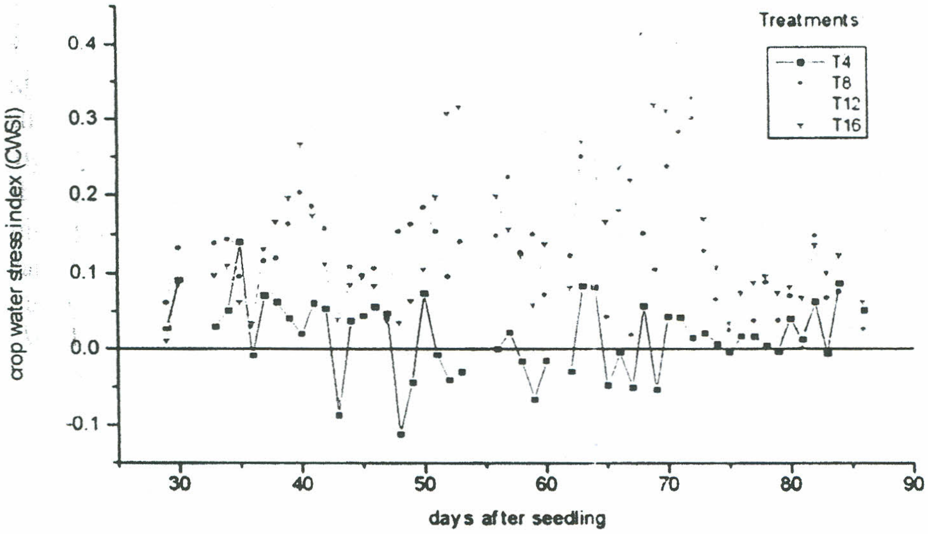

Figure 4. Crop water stress index for beans versus crop growth period (expressed as days after seedling) at four irrigation frequencies (T4, T8, T12, and T16) for measurements in the afternoon period (EMBRAPA, Sete Lagoas, MG, Brazil, 2002).

The treatment that caused most water stress was T16, where the CWSI reached values of 0.26 and 0.40 for morning and afternoon periods, respectively. Overall, the results show that a CWSI value of about 0.15 may be used as a limit for irrigation water management strategies to differentiate the irrigated crop from a non-stressed to a stressed condition, in order to avoid significant yield loss. This limit of 0.15 derives from the observation that T4 and T8 treatments presented maximum CWSI values of roughly 0.10 and 0.20, respectively. At T4, results indicate that the crop was also adequately supplied with water (no-stress). On the other hand, at T8 the crop may have experienced a certain degree of water stress.

Consideration, Recommendation and Conclusions

- Collecting environment data on water (irrigation & rainfall), climate condition, soils (moisture content), and cropping systems (phenology & physiology) is essential when water is in short supply (drought) and evaporative demand of the atmosphere is high in order to better understand the effects of genotypes and environmental (GxE) interactions.

- Irrigation water management involves three decisions: i) How to apply the irrigation water (Scheme), ii) When to irrigate (Timing), and iii) How much water to apply (Quantity).

- Wherever environment conditions are short in water supply and evaporative demand of the atmosphere is high, a localized scheme (micro-sprinkler or drip) is indicated because the amount of water and the frequency of application can be controlled very finely, direct to the crops root zone.

- The $ETc = Kc \times ETo$ computation is used to apply water in the whole area (all the field is wetted). For reduced wetted area, when only part of the soil surface is wetted (drip), the ETc must be calculated different (ETc localized), using a reduction factor $Kr = GC + 0.5\ (1 - GC)]$ and a ground cover (GC = fraction of the total surface area actually covered by the crop foliage) by

$$ETcloc = Kr \,.\, ETc = Kr \,.\, Kc \,.\, ETo$$

- For drought tolerance phenotyping of cereals and legumes studies, the CWSI values are in the range of 0.6 to 0.7 at the Embrapa´s contrasting environment.

It was verified a similar tendency of the CWSI variation in the periods of measurement (morning and afternoon). The highest CWSI values were obtained during afternoon readings, suggesting that as the best period for canopy temperature (Tc) measurements. The highest water stress was obtained with 16-day irrigation frequency, when the CWSI reached values of 0.26 and 0.40, for morning and afternoon periods, respectively.

A crop water stress index value of about 0.15 to 0.20 may be used as a limit for irrigation water management to differentiate the irrigated crop from a non-stressed to a stressed condition, as criteria to avoid significant yield loss.

The infrared thermometry and energy balance/Bowen ratio techniques can be used to determine crop water requirements, to detect crop water stress indexes, and to schedule irrigation.

References

--------. 1973. Principles of environmental physics. Amer. Elsevier. N.Y. 243 pp.

Andrews, P.K., Chalmers, D.J. and Moremong, M. 1992. Canopy-air temperature differences and soil water as predictors of water stress of apple trees grown in a humid, temperate climate. *Journal American Society Horticultural Science*, Mount Vernon. Vol.117, pp.453-8.

Clawson, K.L., Jackson, R.D. and Pinter Jr., P.J. 1989. Evaluating plant water stress with canopy temperature differences. *Agronomy Journal.*, Madison, Vol.81, pp.858-63.

Gomide, R. L. 1998. *Instrumentacao e metodos de medicao na planta*. In: Gomide, R.L. ed Monitoramento para manejo da irrigacao: instrumentacao, automacao e metodos. ed. : Suprema Grafica e Editora, p. 158-168.

Gomide, R. L., Sediyama, G. C. 1998. *Instrumentacao e metodos de medicao meteorologicos.* In: Gomide, R.L. ed. Monitoramento para manejo da irrigacao: instrumentacao, automacao e metodos. ed. : Suprema Grafica e Editora. P. 137-158.

Gomide, R.L.; Albuquerque, P.E.P.; Kobayashi, M.K.; Inamasu, R.Y. Microprocessor and Automation Techniques for Registration of Water Requirements, Stress Indexes, and Irrigation Timing Criteria of Corn and Beans Crops in the Brazilian South-East Irrigated Fields. *ASAE Annual International Meeting*, ASAE, Sacramento, California, USA, July 30-August 1, 2001. *Paper Number: 01-2049.*

Idso, S.B., Jackson, R.D., Pinter Jr., P.J., Reginato, R G. and Hatfield, J.L. 1981. Normalizing the stress-degree-day parameter for environmental variability. *Agricultural Meteorology*, Amsterdam, Vol.24, pp.45-55.

Inoue, Y. 1991. Remote and visualized sensing of physiological depression in crop plants with infrared thermal imagery. *Japan Agricultural Research Quarterly*, Ibaraki, Vol.25, pp.1-5.

Jackson, R.D. 1982. Canopy temperature and crop water stress. *Advances in irrigation.* New York, Vol.1, pp.43-85.

Jackson, R.D., Idso, S.B., Reginato, R.J. and Pinter Jr., P.J. 1981. Canopy temperature as a crop water stress indicator. *Water Resource Research*, Washington, Vol.17, pp.1133-8.

Jackson, R.D., Kustas, W.P. and Choudhury, B.J. 1988. A reexamination of the crop water stress index. *Irrigation Science*, Heidelberg, Vol.9, pp.309-17.

Jensen, M.E., Burman, R.D. and Allen, R.G. 1990. *Evapotranspiration and irrigation water requirements.* New York: ASCE, 332p. (ASCE - Manual and reports on engineering practice, 70).

Monteith, J. L. 1965. Evaporation and environment. In: The state and movement of water in living organisms. New York Academic Press. Proc. Symp. Soc. Exp. Biol. 19: 205-234.

Sediyama, G C., kobayashi, M. K., Gomide, R. L., Magalhães, P. C., Durães, F. O. M. 2000. Dry bean evapotranspiration rates estimated by Penman-Monteith equation in ventilated greenhouse *In: 24th Conference on Agricultural and Forest Meteorology*, Davis, California, USA. p.18-21.

Smith, M., Segeren, A., Pereira, L.S., Perrier, A. and Allen, R. 1991. *Report on the expert consultation on procedures for revision of FAO guidelines for prediction of crop water requirements.* Rome: FAO, 45p.