Challenges and Difficulties of Imposing and Monitoring Crop Water Stress in Field Trials

Camilo L. T. Andrade[1], Reinaldo L. Gomide[2], Paulo E. P. Albuquerque[2], Tales A. Amaral[3], Cristiano M. R. Silva[4]

Introduction

Crop water stress is a complex process involving interactions between plant and environment. Characterizing stress in terms of onset, intensity, duration and damage caused to the crop is very important but difficult and can be made easier by using crop growth simulation models like ECOTROP (Sultan et al., 2005), as shown by Heinemann et al. (2007).

Crops grown during the first harvest season in Central Brazil might experiment dry spells (Assad e Castro, 1991) with duration varying from days to weeks (Wolf, 1975). Plants are, usually, subjected to stress at pre-flowering or flowering stage. For crops planted during the second harvest season ("safrinha"), water stress normally occurs at post-flowering or at the end of the cycle and can last longer.

A systematic study of water stress effects on crops has been commonly done by running two simultaneous experiments: one fully irrigated and one with water shortage. Admissible stress level varies with species and may also vary with genotypes. Stress application is imposed by cutting irrigation out for a certain period of time. Plant canopy symptoms, like leaf rolling or senescence are observed and compared to control plants. Stress effect is evaluated by estimating yield reduction. This is a very subjective methodology that requires a lot of practice. Simulation models or even simple spreadsheets (Albuquerque and Andrade, 2000), requiring basic information on soil, crop and climate, can be used to manage irrigation and estimate stress level. The best way of controlling the stress is by using a combination of methods, including some sort of soil, weather and plant monitoring. However, simple indirect approach, based on soil-water potential or soil-water content monitoring, are usually utilized. A description of available methods to monitor soil-water status is found in Andrade et al. (2007). Practical field application of that kind of approach is not simple, though.

The objective of this paper was to address some of the difficulties encountered during field trials carrying out in Brazil.

Materials and Methods

Data from maize and sorghum field trials, carried out in Sete Lagoas, MG, Brazil, were used as a case study. Stressed and non-stressed field experiments were planted in such a way that crops would be fully developed at the beginning of the dry season. Sorghum were sowed on February 27th, 2007 and maize on March 3rd. A spreadsheet (Albuquerque and Andrade, 2000) was used to manage irrigation and to define when to stop irrigation, considering that for maize, stress would be desirable at pre-flowering and for sorghum, just after flowering. After a period of stress, irrigation was re-started in maize crop, while for sorghum stress was maintained until physiological maturity. Maize and sorghum soil-water and yield data, of both fully irrigated and stressed trials, were acquired.

Results and Discussion

The first difficulty faced was to find information on genotypes cycle length when grown at that season, in addition to reliable field-based soil-water data, both required by the monitoring spreadsheet. By using approximate values and considering a forecasted daily evapotranspiration, one could estimate the day for stopping irrigation. Re-watering for maize was difficult to define since there was no information regarding soil-water reduction and stress level reached.

For maize, the last irrigation was applied 43 days after planting (dap) and a 76 mm rainfall occurred at 47 dap (Figure 1A). One can notice that possibly the crop started to suffer some stress at about 66 dap, when the soil-water dropped under 50% of available water. This indicates that stress occurred later than the desirable pre-flowering stage. Stress intensity seemed to have been adequate, as grain yield reduction for the six genotypes, varied from 47.3 to 75.3%.

For sorghum (Figure 1B), last irrigation was applied on 51dap and a 76 mm rainfall occurred on 54 dap. Crop started to suffer some stress by 100 dap, i.e. too late. Stress effects were diminished

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[1] Irrigation Eng. Researcher, Embrapa Maize and Sorghum, P.O. Box 151, 35701-970 – Sete Lagoas, MG, Brazil, camilo@cnpms.embrapa.br
[2] Irrigation Eng. Researcher, Embrapa Maize and Sorghum, P.O. Box 151, 35701-970 – Sete Lagoas, MG, Brazil
[3] Biologist, MSc, Fapemig Fellowship
[4] Information System, BSc, CNPq-PIBIC Fellowship

by the 76 mm rainfall. Yield reduction varied from 2.8 to 15.7%, confirming that stress onset, duration and intensity was not enough to cause significant damage to sorghum crop.

Other difficulties faced during data collection campaign were the strong labor demand associated with inappropriate equipments and instruments. Soil water content was monitored by gravimetric method, that is time consuming and labor intensive. Soil spatial variability was a problem requiring replicated samples to be collected. After cutting the irrigation, it was difficult to auger soil and soil layers could be mixed up. The volume of plant samples to be processed for leaf area and dry matter, considering all genotypes and replications of the two experiments (stressed and irrigated) and for the two crops was enormous, demanding lots of labor and large lab ovens.

Conclusions and Recommendations

The methodology to impose and control water stress in field trials needs to be refined; more research is needed to access the effects of different stress levels (onset, duration and intensity) into crops growth and yield; plant and soil indicators of water stress have to be better defined and correlated to crop growth and yield reduction; some sort of automated data collection is required to improve data quality and reduce labor involved with soil and plant sampling.

Research on genotypes rooting system development, specially considering water or multiple stresses, is strongly recommended.

References

ALBUQUERQUE, P. E. P., ANDRADE, C. L. T. Uso de Planilha Eletrônica para a Programacão da Irrigação na Cultura do Milho. Circular Técnica. Sete Lagoas:Embrapa, 2000.

ANDRADE, C.L.T.; BORGES JÚNIOR, J.C.F.; COUTO, L. Características físico–hídricas e dinâmica de água no solo. In: ALBUQUERQUE, P.E.P.; DURÃES, F.O.M. (eds). Uso e manejo de irrigação. Brasília: Embrapa Informação Tecnológica, cap. 2, 2007. (no prelo)

ASSAD, E. D.; CASTRO, L. H. R. Análise freqüêncial da pluviosidade para a estação de sete lagoas, MG. Pesquisa Agropecuária Brasileira, Brasília, DF, v. 26, n. 3, p. 397-402, mar. 1991.

HEINEMANN, A. B.; ANDRADE, C. L. T.; GOMIDE, R. L.; ALBUQUERQUE, P. E. P.; SILVA, S. C. Determinação de padrões de estresse hídrico para a cultura do milho na safra e safrinha no estado de Goiás. Congresso Brasileiro de Agrometeorologia, 15. Aracajú, 2007. Anais…

SULTAN, B.; BARON, C.; DINGKUHN, M.; JANICOT, S. Agricultural impacts of large-scale variability of the West African monsoon. Agricultural and Forest Meteorology, Amsterdam, v.128, p.93-110, 2005.

WOLF, J. M. Water constraints to corn production in central Brazil. 1975. 199 f. Thesis (Ph.D) - Cornell University, Ithaca.

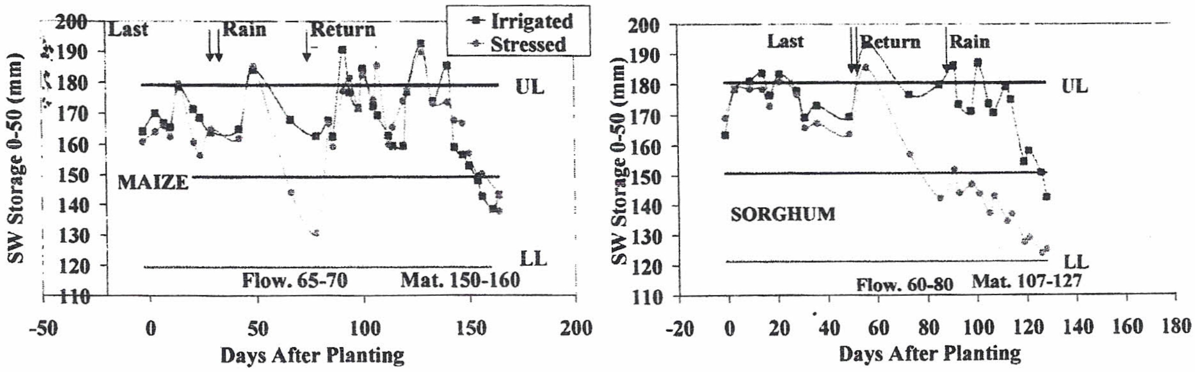

Figure 01 – Soil-water storage along maize (left) and sorghum (right) crop cycle and field-determined upper and lower limits of available water.