CERES-Sorghum: a new formulation of the water stress criteria on leaf expansion (SWDF2) based on leaf water potential.

Sandro Luis Petter MEDEIROS[1], Ghislain GOSSE[2], Michel CHARTIER[2]

SUMMARY

CERES-Sorghum model use one stress factor that reduce leaf expansion (SWDF2) in under water stress conditions The water stress factor is calculated when daily root water uptake is less than potential transpiration. But, the SWDF2 is not mechanist because it do not take into account firstly, the relation between soil water content and soil water potential and secondly, short term water deficits such as midday deficits. The new formulation suggested by JEGU (1994) for lucerne crop relies upon two relationship: a) a relationship between soil water content and soil potential; b) a relationship that describes diurnal trends of leaf water potential according to soil and atmosphere water status. The introductions of functions suggested by JEGU (1994) improve leaf area simulations in CERES-Sorghum model because new model is more mechanistic.

Key words: CERES-Sorghum, water stress, leaf expansion.

INTRODUCTION

Many simulations models describing leaf growth and development of a sorghum crop exist in the scientific literature. In the present study, we have used the CERES-Sorghum model (RITCHIE & ALAGARSWAMY, 1989). In this productivity model, the leaf area development routine is used in two conditions : a) under potential conditions, ie without water stress (the water stress criteria SWDF2=1), which represents the maximum leaf area expansion and b) under actual conditions including water stress (SWDF2 <1). The SWDF2 depends on the water status of the crop, it's based on a relation between potential daily root water uptake and potential transpiration.

The leaf area development routine, under potential conditions SWDF2=1, was recently modified by INRA-Bioclimatologie (SOONTORNCHAINAKSAENG, 1995; JEGU, 1994) in order to improve leaf area simulations. Our objective is to introduce water stress effect, SWDF2<1, in this new leaf area submodel. This new water stress criteria will rely upon leaf water potential and its relationship with soil water status.

[1]Universidade Federal de Santa Maria - CCR - Depto de Fitotecnia. 97.105.900 - Santa Maria, RS - Brasil.
e-mail: sandro@ccr.ufsm.br
[2]INRA - Unité de Bioclimatologie. 78.850 - Thiverval -Grignon - France

BACKGROUND OF THIS NEW FORMULATION.

The new formulation relies upon the two following relationships :

a) a relationship between the global soil water potential, ψ_s and the soil water content data existing in CERES-Sorghum. ψ_s may be calculated using the functions suggested by DRIESSEN (1986), where soil texture is needed but other equations can be find in agronomic literature.

b) a relationship which describes nycthemeral evolution of the leaf water potential ψ_f according to soil and atmosphere water status. This relationship is based upon a model proposed by DERACHE & LE GUEN (1984) for a lucerne crop which considers that:

i) during night ψ_f is equal to the predawn water potential which is well correlated with the soil water potential ψ_b :

so, at night $\psi_f = \psi_b$ (1)

$\psi_b = 0{,}53 * \psi_s + 0{,}13$ (1bis)

Eq(1bis) was proposed by STRICEVIC (1991) and this equation is one exemple and other relationships are existing,

ii) the diurnal trend of ψ_f has a sinusoidal shape with the following characteristics: at sunrise and sunset $\psi_f = \psi_b$, and finally, the maximum (ψ_{max}) is reached at noon (Fig.1) and the value of this maximum may be given by the following relationship:

ψ_{max}= (RET-2,01)/0,68 (2)

Eq(3) by TARANTINO et al (1994).

where, ψ_s=soil water potential (MPa), RET= Relative Evapotranspiration Rate (Actual ET/ Potential ET).

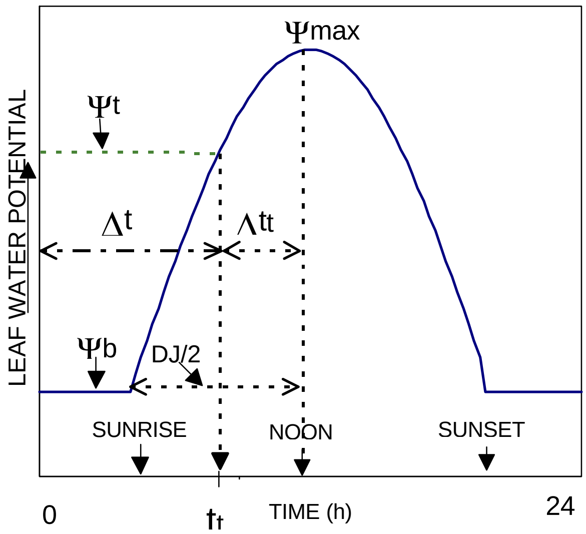
The diurnal trend of ψ_f (Fig 1) is described by equation (3)

$\psi_f = (\psi_{max} - \psi_b) * \sin((\pi/DJ) * t) + \psi_b$ (3)

where, ψ_{max}=Maximum leaf water potential (MPa), ψ_b=Predawn leaf water potential (MPa), DJ=Daylength (h), t=Step time (h).

The step time is equal to 0,1 h from 0 at sunrise to DJ at sunset. For facilities, the absolute values of ψ_f are considered in these calculations.

Fig 1. Diurnal trend in leaf water potential determines i) Δt=period for leaf expansion ($\psi_f \leq \psi_t$) and (ii) Δt_t=period without leaf expansion; ψ_{max}=Maximum leaf water potential (MPa), ψ_b=Predawn leaf water potential (MPa), ψ_t=threshold value of leaf water potential for expansion (MPa), DJ=Daylength (h)



In its diurnal variations, ψ_f, can reach values which affects plant growth processes. It's relatively easy to define threshold values for different growth processes and particularly leaf expansion, photosynthesis... Thus, leaf expansion is halted when ψ_f in equation (3) is equals to the threshold value of leaf water potential for expansion (ψ_t). The ψ_t is equal to 0,5 MPa.

So, we need to calculate the day time (tt) when ψ_f=ψ_t, for water stressed and irrigated conditions and when ψ_f is higher then ψ_t the leaf expansion rate is considered as equal zero (Fig. 1), and tt is calculated as follows (4):

$$tt = (\pi/DJ)*\arcsin[(\psi_t - \psi_b)/(\psi_{max} - \psi_b)] \qquad (4)$$

So, we can calculate the diurnal duration of the period when leaf expansion is possible (Δt) and when leaf expansion is stopped (Δtt), for stressed and well irrigated conditions (Fig. 1). They are calculated by equations (5) and (5bis):

$$\Delta t = 12 - \Delta tt \quad (5) \qquad \Delta tt = DJ/2 - tt \quad (5bis)$$

The coefficient for reduction in leaf expansion (SWDF2) is the ratio between leaf growth duration under potential (Δt_2) and stressed (Δt_1) conditions :

$$SWDF2 = \Delta t_1/\Delta t_2 \qquad (6)$$

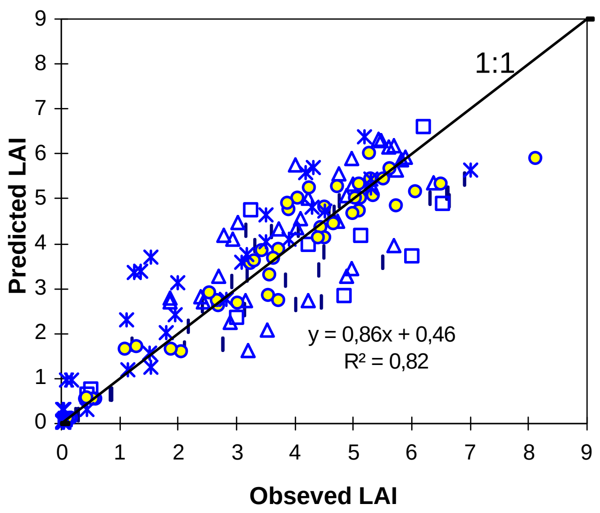
MODEL VALIDATIONS:

In order to Validate this water stress subroutine adapted to CERES-Sorghum, we have used data from different European partners of the European Sweet Sorghum Network (ESSON) supported by the European Commission (DGXII-AIR 00041).

CONCLUSION

The leaf area index was well predicted and precision was high (Fig. 2). These results shown that the model predicted well the dynamics of leaf expansion processes under water stress conditions.

Fig. 2. Performance of the new CERES-Sorghum model in simulation of leaf area index (LAI) in water stress conditions.



REFERENCES

DERACHE, P., LE GUEN, H. 1986. Valorisations industrielles de la luzerne: modelisation technico economique. Memoire de D.E.A. Ecole Superieure d`Agriculture d`Angers, INRA-Station de Bioclimatologie, centre de recherche Grignon-Massy-Paris.

DRIESSEN P.M. 1986. The water balance of soil. In : VAN KEULEN H. and WOLF J. (eds). Modelling of agricultural production : weather, soils and crops. Pudoc, Wageninger, The Netherlands. 410p.

JEGU, S. 1994. Modification d'un modèle dynamique de simulation de la productivité d'un couvert végétal (Ceres-Sorgho). Memoire de D.E.A., INRA. Ecole National Supérieure Agronomique de Rennes. 46 p.

RITCHIE, J.T., ALAGARSWAMY, G., 1989. Physiology of sorghum and pearl millet In: VIRMANI, S.M., TANDON, H.L.S., ALAGARSWAMY, G. (eds). Modeling the growth and development of sorghum and pearl millet. Research Bulletin no 12. 45p. ICRISAT, India.

SOONTORNCHAINAKSAENG, P. 1992.Effect de la température sur la mise en place des feuilles et l'élaboration de la matière sèche chez différents cultivars de sorgho. Mémoire de D.E.A., INRA-Station de Bioclimatologie, Centre de Recherches Grignon-Massy-Paris.32p.

STRICEVIC, R. 1991. Ecophysiological indicators of sweet sorghum water status as a criteria for irrigation scheduling. Master of Science in Irrigation. International Centre for Advanced Mediterranean Agronomic Studies. Bari - Italy.

TARANTINO, E., PERNIOLA, M., RIVELLI, A.R. 1994. Use of indicators of plant water status for irrigation scheduling. In: KATERJI, N., ITIER, B. 1995. Utilisation d'indicateurs de l'état hydrique des plantes pour la conduite de l'irrigation. Rapports finaux du Contrat N° 8001-CT91-0108(PL 900366).