MIMYCS.MOISTURE, A PROCESS-BASED MODEL OF MOISTURE CONTENT IN DEVELOPING MAIZE KERNELS

MIMYCS.MOISTURE, UN MODELLO DI SIMULAZIONE BASATO SU PROCESSI DELL'UMIDITÀ DELLA GRANELLA DI MAIS DURANTE LA MATURAZIONE

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Abstract
The model MIMYCS.Moisture was developed for simulating maize kernel moisture during their development and dry-down.

Keywords: maize kernel moisture, process-based model, developmental moisture, dry-down moisture.
Parole chiave: umidità della granella di mais, modello basato sui processi, umidità di sviluppo, umidità durante il dry-down.

Introduction

Maize grain moisture content during maturation and post-maturity dry-down is a very important factor influencing harvest and post-harvest management, and the technological and safety quality of maize grain. Development of maize kernels in the field can be partitioned into three phases: I) lag phase, II) grain filling and maturation drying, III) and post-maturity dry-down. The lag phase is a period of active cell division and differentiation. Following the lag phase is a period of rapid dry matter accumulation resulting from the deposition of seed reserves. After seeds reach the 'physiological maturity' (maximum dry matter accumulation) they enter a quiescent state. At this point there is no more exchange of fluids between the plant and the kernel but only between the kernel and the atmosphere and moisture loss occurs primarily by evaporative loss from the kernel itself (Brooking, 1990).
An improved understanding and the modelling of the process of moisture loss during kernel development would allow: (I) to assess risks regarding weather factors that may impede harvest timing, (II) to evaluate the costs associated with an increased need for mechanical drying, (III) a better understanding of maize development during the field phase and the relationships with insect pests and diseases development.
The model MIMYCS.Moisture was developed for simulating maize kernel moisture during their development and dry-down.

Matherials and Methods

The MIMYCS.Moisture model integrates the crop model CropSyst for the simulation of the phenological development of maize. The moisture content and the length of the lag phase between different maize genotypes is considered constant and they were fixed respectively at 85% and 170 degree-days from flowering (Jones and Kiniry, 1986; Gambín *et al.*, 2007). The rate of moisture loss during grain filling (i.e. developmental moisture) was considered proportional to moisture content itself and modeled as an exponential decay process.

$$M(t) = M_0 e^{-at}$$

where M(t) is moisture (%) at time t (degree-days – DD) and M_0 is moisture (%) at the end of the lag phase.

The rate of moisture loss during dry-down was modeled according to the findings of Henderson and Perry (1966) who reported that the declining water content of grains is inversely proportional to the water to be removed, given by the difference between the actual moisture and the equilibrium moisture content:

$$\frac{dM}{dt} = -k(M - M_e)$$

where M is the water content at time t (% dry basis), M_e is the equilibrium water content (% dry basis), and k is a proportionality constant. M_e was calculated according to the Henderson's equation (1952):

$$1 - RH = e^{-c(T+k)Me^{n}}$$

where RH is the air relative humidity (expressed as a proportion), T is air temperature (°C), and c, k, n are constants valued according to Thompson (1968).
MIMYCS.Moisture was calibrated using data collected from northern Italy in a maize hybrid comparative field. The experimental field was set up in northern Italy, in the province of Treviso, close to Montebelluna (45°46' N, 12° 02') from 2003 to 2011. Collected data were about phenological development, appearance of black layer (physiological maturity) and moisture content of kernels. MIMYCS.Moisture is composed of discrete model software units of fine granularity. The modelling solution presented in this work is composed by the components MIMYCS.Moisture, CropSyst (Stockle et al., 2003), AirTemperature (Donatelli *et al.*, 2010), and EvapoTranspiration (Donatelli *et al.*, 2006) (Fig. 1). MIMYCS.Moisture is composed of four main model software components. *DevelopmentalMoisture* simulates moisture loss during the developmental phase. *DryDownMoisture* simulates kernel moisture during dry-down. *EquilibriumMoistureContent* calculates the equilibrium moisture content needed by the strategy *DryDownMoisture* to calculate dry-down moisture. Inputs required by the MIMYCS.Moisture component are: degree-days from flowering, hourly air temperature (°C), hourly relative humidity (%). Degree-days from flowering are *CropSyst* output. Hourly air temperature is an output of the *AirTemperature* component. Hourly relative humidity is an output of the *EvapoTranspira-*

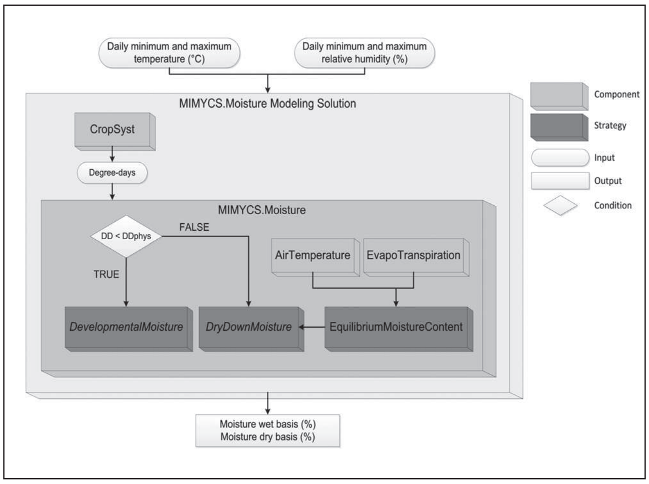

Fig. 1 - MIMYCS.Moisture modelling solution component diagram.
Fig. 1 - Diagramma delle componenti del modello.

tion component. Inputs to the modeling solution are: daily minimum and maximum temperature, and relative humidity. Outputs are: moisture dry basis (%), moisture wet basis (%).
The data source used to test MIMYCS.Moisture consisted of data collected from northern Italy in a maize hybrid comparative field. The experimental field was set up in northern Italy, in the province of Treviso, close to Montebelluna (45°46' N, 12° 02') from 2003 to 2011. Daily temperature and relative humidity data from 1 January of each year were taken from an electronic weather station placed close to the field.

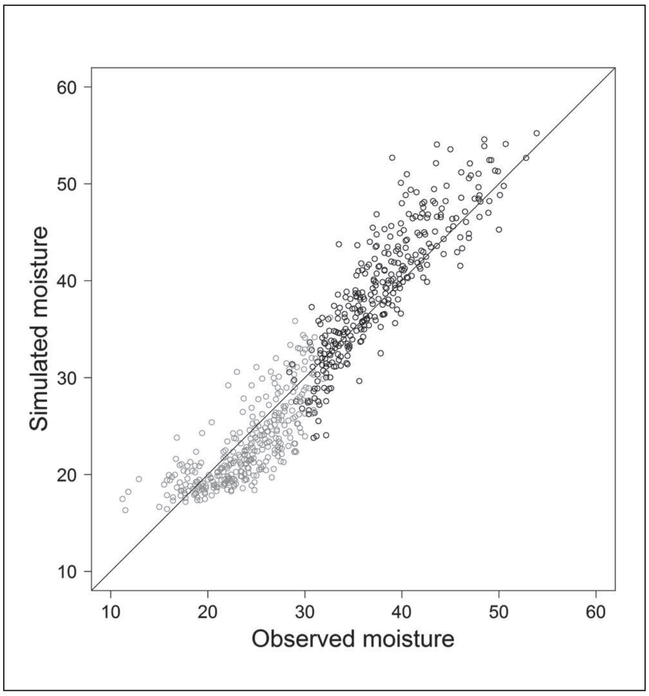

Fig. 2 - Simulated vs observed moisture content developing maize kernels of different maize hybrids. Black dots shows results related to developmental moisture. Grey dots show results related to dry-down moisture.
Fig. 2 - Dati di umidità della ganella di diverse varietà di mais, osservati VS simulati. I punti neri mostrano i risultati della umidità allo sviluppo, quelli grigi al dry-down.

Results and Discussion

The preliminary results of the MIMYCS.Moisture model using the dataset from northern Italy are shown in Fig. 2. Preliminary results showed that the model was accurate in the explored conditions, reproducing correctly the loss of moisture during maturation and dry-down. A pattern of moisture content deviating from the 1:1 line can be observed for the dry-down phase. This pattern is most probably related to the equilibrium moisture content equation used for this version of MIMYCS.Moisture. In fact, the Henderson's equation (1952) have been successfully used in the controlled conditions of dryers, and it could be not adequate to field conditions.

Conclusions

The model presented in this work is the preliminary version of the MIMYCS.Moisture model. Further analysis are needed in order to improve the model capability to estimate moisture content during the field phase of maize development.

Acknowledgments

This research was supported by a Marie Curie Intra European Fellowship within the 7th European Community Framework Programme. Project MIMYCS.

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