Scientific Papers, UASVM Bucharest, Series A, Vol. LIV, 2011, ISSN 1222-5339

MODEL FOR PREDICTING THE FLOWERING STAGE AND HONEY POTENTIAL YIELD OF SUNFLOWER AND RAPESEED CROPS

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Keywords: *sunflower, rapeseed, prognosis model, flowering stage, honey potential yield*

Abstract

This paper describes a model for predicting the dates of the beginning and end of flowering stage and the honey potential yield of sunflower (Helianthus annuus L.) and rapeseed (Brassica napus L. ssp. oleifera) crops. The prognosis of flowering stage is based on "thermal time" (TT) measured in "growing degrees-day" (GDD), determined by the daily biologically active temperature that is related to "base temperature" (species parameter) and "corrected" average daily temperature. The prognosis parameters (crop stage TT thresholds and honey potential yield) are specific to each variety, maturity class (four classes for each species) and climatic type of crop year (four types). The (re-) calibration of the prognosis parameters is performed by averaging the crop historical data that are accumulated during model use ("self-improving" model). Four calibration methods of different accuracy are used for that, depending on available data. The prognosis of meteorological data is performed based on the historical data of the years of the given climatic type estimated by user for the prognosis year. The prognoses of the flowering stage and honey potential yield are based on the calibrated parameters, estimated meteorological data for the prognosis year, and sowing data specified by user. Some results concerning model calibration and validation are also presented in the paper.

INTRODUCTION

Prognosis of flowering stage and honey yield of crops is important for beekeepers aiming at scheduling in time and space the emplacement of their beehives to flowered fields.

This paper describes a model for predicting the dates of the beginning and end of flowering stage and the honey potential yield of sunflower (*Helianthus annuus L.*) and rapeseed (*Brassica napus* L. ssp. *oleifera*) crops. The prognosis principles, method and algorithms presented for sunflower in a previous paper [7] are improved and applied also to rapeseed crops. Some results concerning model calibration and validation are also presented in this paper.

MODEL DESCRIPTION

The method used to estimate the plant development is based on "thermal time" (**TT**) measured in "growing degrees-day" (GDD, °**C-d**) [6, 7]. Plants require a specific amount of heat to develop from one point in their life-cycle to another and, in the same time, development occurs if air temperature exceeds a minimum limit, named "base temperature" ($\mathbf{T_b}$). The daily biologically active temperature ($\mathbf{T_{BA}}$) is a measure of the daily plant development based on the heat used and is usually calculated as the difference between the average daily air temperature and T_b. There is an optimum average daily temperature for plant development ($\mathbf{T_o}$) and an upper limit of developmental temperature ($\mathbf{T_u}$), above which the plant development drastically diminishes or stops. The T_b , T_o and T_u are specific for each species. The TT obtained by summing the T_{BA} of the days of a period gives an estimate of the heat accumulated by plant, respectively of the "amount" of plant development in that period. The TT that plants need for developing from a stage to another is specific to each species and each stage.

The following improved algorithm of the T_{BA} calculation is proposed:

$T_{BA} = 0$, if: $T_{max} \leq T_b$, or $T_{max} \geq T_u$,
$T_{BA} = ((T_{max} - T_b) / 2) * (T_{max} - T_b) / (T_{max} - T_{min})$, if: $T_{min} < T_b < T_{max} < T_u$,
$T_{BA} = (T_{max} + T_{min}) / 2 - T_b$, if: $T_{min} \geq T_b$ and $(T_{max} + T_{min}) / 2 < T_o$ and $T_{max} < T_u$,
$T_{BA} = T_o - T_b$, if: $T_{min} \geq T_b$ and $(T_{max} + T_{min}) / 2 \geq T_o$, and $T_{max} < T_u$.

where: T_{max} and T_{min} are daily maximum, respectively, minimum air temperatures (in the day period – between the hours 00:00 and 24:00).
T_b = 6.7 °C for sunflower [7], and 5 °C for rapeseed [3, 5, 6],
T_o = 20 °C for both sunflower and rapeseed [4, 5, 6],
T_u = 40 °C for sunflower [7], and 35 °C for rapeseed [6].

Because in Romania during the flowering stage of rapeseed and sunflower, usually, the maximum temperatures are not higher than 35 °C, respectively 40 °C, and the average temperature are not higher than 22 °C, respectively 27 °C, a correction of T_{BA} calculation for upper temperatures was not taken into consideration and a simplified formula was used for that.

Three thermal time thresholds for the interested crop stages are defined [7]: the TT that plants need for reaching the emergence from the sowing date ($\mathbf{TT_E}$), the TT that plants need for reaching the beginning of flowering stage from the emergence date ($\mathbf{TT_{FB}}$), and the TT that plants need for reaching the end of flowering stage from the beginning date of flowering stage ($\mathbf{TT_{FE}}$).

Most of the works use TT thresholds not variety specific. Experiments carried out in Southern Romania with 24 sunflower hybrids [2, 7] showed significant differences both between the measured TT thresholds of different sunflower hybrids and between the TT thresholds of the same hybrids measured in different years types from meteorological point of view (2006: normal, 2007: excessive droughty). Lower variation was observed in the same maturity class (**MC**). Doyle (1975), Miller et al. (2001) and Rossi (2002), cited by [7], also reported MC-specific TT thresholds. Consequently, the prognosis model uses different TT thresholds for different climatic types of years (**CT**) for each sunflower/rapeseed variety [7]. In the case of lack of data, the three TT thresholds are estimated by averaging the data regarding the varieties of the same MC, respectively regarding the years of adjacent CT's. The model uses four MC's of sunflower varieties and four MC's of rapeseed varieties (early, semi-early, semi-late, and late), and four CT's of years (excessive droughty, droughty, normal, and wet).

The honey potential yield of crops [1, 4] (determined by the nectar secretion of flowers and the sugar concentration of nectar) is influenced mostly by variety biological characteristics and meteorological conditions (especially air temperature). Experiments carried out in Southern Romania with 33 sunflower hybrids under different meteorological conditions of the period 2002-2007 emphasised these conclusions [1, 4]. Consequently, the prognosis of honey potential yield is based on the statistically-determined honey potential yield (**HPY**) for each sunflower/rapeseed variety for each of the four year CT's [7]. The same, in the case of lack of data, the HPY is estimated by averaging the data regarding the varieties of the same MC, respectively regarding the years of adjacent CT's.

The prognosis model consists of three main submodels (phases):

(i) Submodel for calibration of prognosis parameters (TT thresholds and HPY's)

Historical measured/observed data are assumed to be recorded and stored: data on crops (year, geographical area, variety, date of sowing, date of emergence, date of beginning of flowering, date of end of flowering, and honey yield) and meteorological data on geographical areas (year, year CT, daily T_{max} and T_{min}). From these data the "measured" values of the TT thresholds and HPY are calculated for each historical crop. For each variety, a set of prognosis parameters (the three TT thresholds and the HPY) is estimated for each of the four year CT's, by averaging appropriate historical measured values.

Four estimation methods can be used [7]. In the decreasing order of accuracy (corresponding to the historical data availability), they are: (1) averages on the cases of the given variety and the given year CT, (2) averages on the cases of the given variety and the adjacent year CT's with the given year CT, (3) averages on the cases of the varieties of the same MC with the given variety, and the given year CT, and (4) averages on the cases of the varieties of the same MC with the given variety, and the adjacent year CT's with the given year CT.

(ii) Submodel for prognosis of meteorological data

The daily T_{max} and T_{min} for the prognosis year are estimated by averaging the historical meteorological data regarding the requested geographical area and the years of the same year CT as that of the prognosis year, which is estimated by user (or obtained from meteorological services estimates).

(iii) Submodel for prognosis of flowering stage and honey potential yield

The dates of emergence, beginning of flowering and end of flowering are predicted by matching the estimated TT's to the corresponding TT thresholds calibrated for the given variety, plant stage and the year CT of the prognosis year, supposed to be estimated by user. The estimated TT for a plant stage is the summation of the T_{BA} calculated day by day from predicted T_{max} and T_{min} , beginning with the day after the previous plant stage. The sowing dates are supposed to be estimated by user.

During the crop year, the crop development and the meteorological evolution up to the moment of prognosis request can be recorded and the prognosis for the remained period of the crop year is improved by using actual data instead of predicted data.

The predicted honey potential yield is assumed to be the calibrated parameter HPY for the given variety and the year CT of the prognosis year (estimated by user).

MODEL CALIBRATION AND VALIDATION

Experiments carried out on three years (2006, 2007 and 2008) in the Experimental Farm Moara Domnească (15 km NE of Bucharest, Romania) with 24 hybrids of sunflower (each of the four MC's was represented) provided measured/observed crop data [1, 2, 4, 7]. Local meteorological equipment provided data for the experimental years. Other historical meteorological data (1961-2005) were obtained from a near meteorological station.

The three experimental years were meteorologically different: 2006 - normal, 2007 - excessive droughty and 2008 - normal to droughty.

Experimental data from the years 2006 and 2007 were used to calibrate the model. The prognosis provided by the model for the year 2008 was compared with the measured data and proved to be good enough:

Figure 1 shows the predicted daily biologically active temperatures (T_{BA}) for sunflower crops in comparison with those calculated from the measured daily temperatures, beginning with the 12 April, in the experimental location.

Figure 2 shows the predicted thermal time (TT) for sunflower crops comparatively with that calculated from the measured daily temperatures. After a thermal time of 700 °C-d, corresponding to a time of 65 days (12 April – 15 June), the cumulated deviations are about of 50 °C-d (6.7%), respectively 3.5 days (5.4 %).

On the end of May and on June and July the measured temperatures were higher than in a normal year (as 2008 was supposed in the prognosis scenario) and, consequently, the predicted T_{BA} and TT was slightly underestimated for that period of the year 2008.

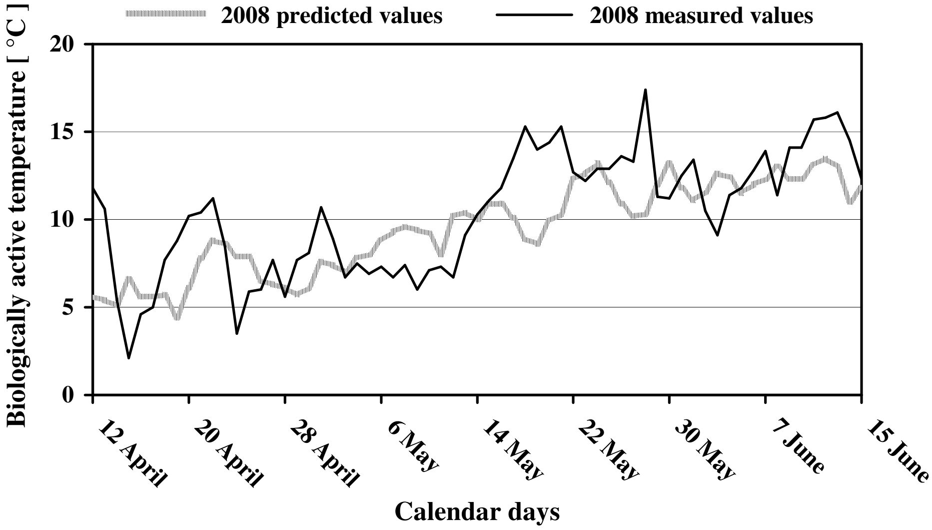

Fig. 1. Predicted daily biologically active temperatures (T_{BA}) for sunflower comparatively with those calculated from the measured daily temperatures (2008, Moara Domnească, 15 km NE of Bucharest, Romania)

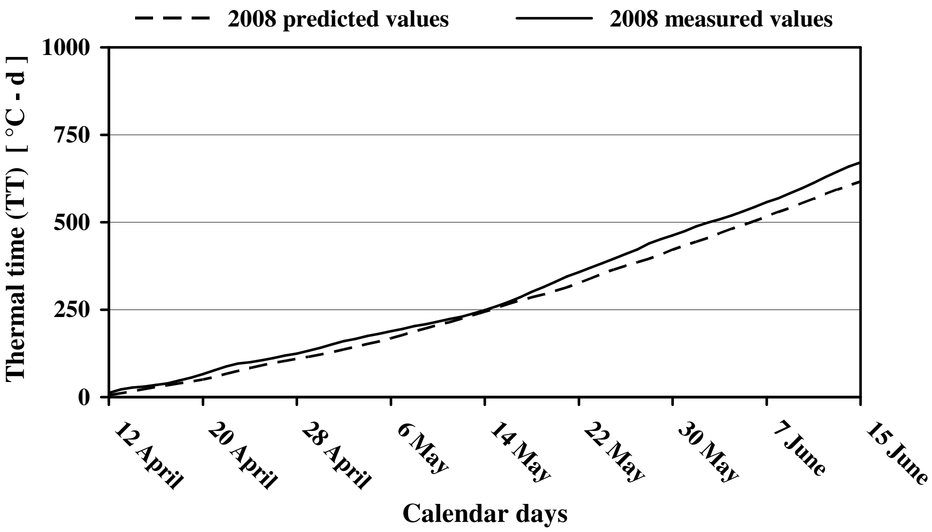

Fig. 2. Predicted thermal time (TT) for sunflower comparatively with that calculated from the measured daily temperatures (2008, Moara Domnească, 15 km NE of Bucharest, Romania)

CONCLUSIONS

1. Because TT calculation based on the standard definition of GDD is of low accuracy, a better algorithm is proposed. It can be further improved based on appropriate research.
2. Experiments carried out in Southern Romania with sunflower crops showed significant variability of TT thresholds for crop flowering stage and HPY's related to different hybrids and meteorological years. By using prognosis parameters specific to variety, MC's and year CT's, the influences on crop development of other factors than air temperature (especially precipitations and photoperiod length) are acceptable-well taken into consideration.
3. Four calibration methods of different accuracy are proposed, in order to completely use the available historical data.
4. Recalibration can be performed each time new historical data are available. Thus the model could be a "self-improving" one, because more is used more it could be enriched with new data, so the statistical support could be better and the estimates (prognosis parameters) could be more and more improved.

ACKNOWLEDGEMENTS

Research was supported by the Romanian Research Programs CEEX (Project MAFS, 2005-2008) and PN-II (Project STUPAS, 2008-2011).

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