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RESEARCHES REGARDING THE PROGNOSIS OF THE FLOWERING STAGE AND HONEY POTENTIAL YIELD OF SUNFLOWER CROPS

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Key words: sunflower, prognosis model, thermal time, flowering stage, honey yield, decision support, agroinformatics.

Abstract: The objective of this research was to develop a prognosis support system that provides users with predictions of the dates of the beginning and end of flowering stage and the honey potential yield of sunflower (*Helianthus annuus L.*) crops. It is emphasized that this prognosis is a "poor-structured" problem and it can be solved most advantageously by a tool of "decision support system" type. The prognosis method of the flowering stage is based on "thermal time" (TT) measured in "growing degree-days". The model of calculation of the daily biologically active temperature for TT summations uses a "base temperature" of 6.7 °C and a correction of the average daily temperature. Three TT thresholds are defined: (1) sowing – emergence, (2) emergence – beginning of flowering, and (3) beginning – end of flowering. These TT thresholds and the honey potential yield – the prognosis parameters – are specific to hybrids, maturity class of hybrids (four classes) and to climatic types of crop years (four types). The (re-) calibration of the prognosis parameters is performed by averaging the sunflower crops historical data that are accumulated during system use (in that way a "self-improving" system is obtained). Four estimation methods of different accuracies are used. 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.

INTRODUCTION

Sunflower (*Helianthus annuus L.*) is the main oil-producing crop in Romania and, at the same time, the most valuable melliferous plant, together with acacia and lime-tree. The beekeepers are interested in moving their beehives to the sunflower crops, in order to obtain a good honey yield, but at present there is a risk of moving beehives at random, without knowing the melliferous information on the sunflower crops, particularly in the case of hybrids less known from the melliferous point of view. The beekeepers would like to know the melliferous characteristics of the cultivated hybrids, i.e. the beginning of flowering, duration of flowering, nectar secretion and concentration in sugar (potential honey yield) et al.

The prediction of the flowering stage and honey yield of sunflower crops comes to fulfil these requirements of the beekeepers and it could be achieved by using a prognosis model implemented in computer software. Flowering date prediction helps beekeepers to plan bringing their beehives to the sunflower crops, respectively helps sunflower growers to find beekeepers who could improve the sunflower pollination. Honey yield prediction helps beekeepers to take advantage of using the most productive sunflower crops, i.e. the highly nectar secreting hybrids. Also, using the predictions, beekeepers will be able to plan and perform some works in the beehives in order to obtain the best honey production.

The objective of this research was to develop a computerized tool (system) that provides users with predictions of the dates of the beginning and end of flowering stage of sunflower crops (the period of intense gathering of nectar for bees) and the honey potential yield of sunflower crops.

PROGNOSIS METHOD

The growth and development of sunflower – particularly the passing from a developmental stage to other and the honey potential yield – are determined by an important number of complex factors and their complex interrelations. This makes the prognosis task to be a so-called "poor-structured problem" (characterised by complexity, incompleteness, uncertainties, fuzzy parameters etc.) and, consequently, it can be solved most advantageously by a computerized tool of "decision support system" type, which does not automatically yield solutions, but these are obtained by involving and under the control of user (Vlad, 2001). In the same time, a main requirement imposed to the prognosis system was easiness in use by farmers, i.e. the system was to request few and relatively easily obtained data, and also relatively not advanced knowledge for it use.

Following these requirements and conclusions, a hybrid approach resulted for the system development: use of simple and robust models, based on statistical data accumulated from farming practices and project experiments, as well as use of heuristic models based on both knowledge and experience of authors and those obtained from scientific literature.

A simple method used to estimate the plant development is based on "thermal time" (**TT**) measured in "growing degree-days" (**°C-d**) (Miller et al., 2001; NDAWN, 2008). 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 defined as the difference between the average daily air temperature and T_b. There is also an upper limit of plant developmental temperature ($\mathbf{T_{ul}}$), above which the plant development drastically diminishes or stops. The TT obtained by adding the T_{BA} of the days in a period gives an estimate of the heat accumulated by plant, respectively of the amount of plant development in that period. The TT's are specific to plant development from a stage to another, and also specific to different plants (species).

The TT method was the most used method for sunflower stage prediction (Doyle, 1975; Anderson et al., 1978; Villalobos & Ritchie, 1992; Miller et al., 2001; Rossi, 2002; Prairie Grains, 2008; NDAWN, 2008), including for sunflower crop simulation models (Villalobos et al., 1996; Barros, 1997), and the validation reports proved it to be accurate enough (Doyle, 1975; Rossi, 2002; Aiken, 2005). More complex models were not taken into consideration in this project because they require too complex data inputs.

PROGNOSIS SUPPORT SYSTEM

The T_b and T_{ul} are specific for each plant (species). For the T_b of sunflower, there have been used different values: 4 °C (Villalobos & Ritchie, 1992) - for sunflower leaf appearance; 6 °C (Mailhol et al., 1997); 6.5 °C (Barros, 1997); 6.7 °C (Prairie Grains, 2008; NDAWN, 2008) and 10 °C (Seiler, 1998) - for sunflower root growth. In this project it is used T_b = 6.7 °C as those (or closed to those) used for the same geographical latitude as that of Romania (43 - 49 °N; North of USA, France).

For the T_{ul} of sunflower the most works give/suggest the value of 40 °C (Villalobos et al., 1996; Seiler, 1998; Chimenti et al., 2001; Rondanini et al., 2003; Aiken, 2005). Prairie Grains (2008) uses the value of 30°C. At present, in this project T_{ul} is not taken into consideration because in Romania air temperatures above of 40°C have been extremely rare. At the same geographical latitude (Montana and North Dakota / USA), the T_{ul} also is not taken into consideration because of the same reason (Miller et al., 2001; NDAWN, 2008).

The following model of the T_{BA} calculation is implemented:

$$T_{BA} = (T_{max} + T_{min}) / 2 - T_b , \qquad \text{if: } T_{max} > T_{min} > T_b ,$$

$$T_{BA} = ((T_{max} - T_b) / 2) * (T_{max} - T_b) / (T_{max} - T_{min}) , \qquad \text{if: } T_{max} > T_b > T_{min} ,$$

$$T_{BA} = 0 , \qquad \text{if: } T_b > T_{max} > T_{min} ,$$

where: T_b = 6.7 °C ,
T_{max} and T_{min} are daily maximum, respectively, minimum air temperatures (in the day period – between the hours 00:00 and 24:00).

Three thermal time thresholds for the interested sunflower stages are defined: the TT needed by plants to reach the Emergence (75% of plants have emerged in the whole crop) from the sowing date (**TT_E**), the TT needed by plants to reach the Flowering stage Beginning (10% of plants heads are flowered in the whole crop) from the emergence date (**TT_{FB}**), and the TT needed by plants to reach the Flowering stage End (only 10% of plants heads are still flowered in the whole crop) from the flowering stage beginning date (**TT_{FE}**).

Most of the works use TT's not hybrid specific. Experiments carried out in Southern Romania with twenty four sunflower hybrids (Stefan et al., 2006; Ion V. et al., 2007) showed significant differences between the measured (observed) TT's of different sunflower hybrids and, also, between the TT's of the same hybrids measured (observed) in different years types from meteorological (climatic) point of view (2006: normal, 2007: excessive droughty) (Table 1). Consequently, it was decided that the system has to use sets of the three TT's experimentally determined for four Climatic Types of years (**CT**) for each hybrid. In the case of lack of data, the three TT's are to be estimated by averaging the data regarding hybrids of the same Maturity Class (**MC**), respectively regarding the years of adjacent CT's. Doyle (1975), Miller et al. (2001) and Rossi (2002) also reported MC-specific TT's. This project uses four MC's of sunflower hybrids (early, semi-early, semi-late, and late), and four CT's of years (excessive droughty, droughty, normal, and wet). In that way, the influences on sunflower development of other factors than air temperature (especially precipitations and photoperiod length) are acceptable-well taken into consideration.

Reports on methods for prognosis of honey yield of sunflower have not been found in literature. The honey potential yield (determined by the nectar secretion of flowers and the sugar concentration of nectar) is influenced mostly by hybrid biological characteristics and meteorological conditions (especially air temperature). Experiments carried out in Southern Romania with thirty three sunflower hybrids and under different meteorological conditions of the period 2002-2007 (Stefan et al., 2006; Ion Nicoleta et al., 2007) emphasised these conclusions (Table 1). Consequently, the prognosis of honey potential yield is based on the statistically-determined Honey Potential Yield (**HPY**) for each of the four CT's of years for each hybrid. The same, in the case of lack of data, the HPY is estimated by averaging the data regarding the hybrids of the same MC, respectively regarding the years of adjacent CT's.

The database of the system can store historical meteorological data (year, CT of year, daily T_{max} and T_{min}, geographical area) obtained from meteorological stations, and can record historical data on sunflower crops (year, geographical area, hybrid, dates of sowing, flowering

Table 1. Measured thermal time (TT) thresholds for some hybrids of different maturity class (MC) cultivated in Southern Romania in two years of different climatic types (2006: normal, 2007: excessive droughty).

Maturity Class (MC)	*Hybrid*	*Crop Year*	*TT from Sowing to Emergence (TT_E, ℃-d)*	*TT from Emergence to:*		*TT from Fl.Beginn.to Fl.StageEnd (TT_{FE}, ℃-d)*	*Honey average Potential Yield (HPY, kg/ha)*
				Fl.Beginn. (TT_{FB}, ℃-d)	*Fl.Stage End (℃-d)*		
early	Alexandra	2006	**86**	**760**	985	**225**	**8.1**
		2007	**127**	**742**	1014	**272**	**12.4**
	Fleuret OR	2006	**86**	**726**	954	**228**	**10.3**
		2007	**118**	**738**	1051	**313**	**25.6**
	Mateol	2006	**94**	**736**	978	**242**	**10.3**
		2007	**127**	**762**	996	**234**	**16.6**
	Rigasol OR	2006	**77**	**753**	979	**226**	**8.9**
		2007	**127**	**683**	965	**282**	**10.9**
semi-early	Fly	2006	**77**	**797**	1031	**234**	**8.9**
		2007	**127**	**762**	996	**234**	**17.6**
	Kasol	2006	**86**	**760**	1020	**260**	**13.8**
		2007	**127**	**781**	1013	**232**	**18.0**
	Lindor	2006	**86**	**760**	1020	**260**	**9.2**
		2007	**127**	**742**	997	**255**	**23.3**
	Melody	2006	**77**	**786**	1012	**226**	**15.8**
		2007	**118**	**801**	1037	**236**	**33.3**
	NK Dolbi	2006	**77**	**770**	995	**225**	**14.2**
		2007	**127**	**762**	1013	**251**	**17.6**
	NK Ferti	2006	**67**	**780**	1005	**225**	**12.9**
		2007	**127**	**742**	1054	**312**	**16.9**
	Saxo	2006	**77**	**770**	995	**225**	**6.1**
		2007	**127**	**781**	1033	**252**	**11.3**
semi-late	Masai	2006	**86**	**787**	1039	**252**	**6.8**
		2007	**127**	**804**	1033	**229**	**15.4**
	Podium	2006	**77**	**770**	1030	**260**	**13.1**
		2007	**127**	**781**	1033	**252**	**12.1**
	Sanay	2006	**77**	**753**	1012	**259**	**13.0**
		2007	**127**	**762**	1117	**355**	**9.5**
	Sunko	2006	**77**	**770**	1030	**260**	**16.0**
		2007	**118**	**795**	1098	**303**	**29.9**
late	Delfi	2006					**11.4**
		2007	**127**	**762**	1135	**373**	**10.8**
	Jazzy	2006					**15.4**
		2007	**127**	**742**	1088	**346**	**12.8**
	NK Armoni	2006	**67**	**806**	1075	**269**	**13.5**
		2007	**127**	**781**	1073	**292**	**17.2**

beginning and flowering end, and HPY). From these data the measured/observed values of the three TT's are calculated for each sunflower crop.

The calibration/recalibration of the prognosis parameters of the system is performed for each hybrid by estimation of the three TT's and of the HPY for each of the four CT's of years, using the historical data. A recalibration can be performed each time new data are entered into the database. Thus the system 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.

Each prognosis parameter is calculated for each couple Hybrid-CT as an average of different historical values from database. Four estimation methods can be used. In the decreasing order of accuracy (corresponding to the historical data availability), they are: (1) averages on the cases of the given Hybrid and CT, (2) averages on the cases of the given Hybrid and the adjacent CT's, (3) averages on the cases of the hybrids of the same MC with the given Hybrid, and the given CT, and (4) averages on the cases of the hybrids of the same MC with the given Hybrid, and the adjacent CT's.

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 CT as that of the prognosis year, which is estimated by user (or obtained from meteorological services estimates). For the prognosis of the dates of emergence, flowering beginning and flowering end, the summations of the T_{BA}, calculated from predicted T_{max} and T_{min} , beginning with the day after sowing date, estimated by user – are related to the corresponding TT's calibrated for the given Hybrid and the CT of the prognosis year (estimated by user).

During the crop year, the user can update the database with data (events) achieved up to the moment of prognosis request and in this case 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 Hybrid and the CT of the prognosis year (estimated by user).

CONCLUSIONS

1. At present, there is a risk of moving beehives at random to the sunflower crops. Without knowing the melliferous information on the sunflower crops, beehives moving plans/schedules cannot be elaborated.

2. The problem of prognosis of the sunflower flowering and honey potential yield is a poor-structured one and it can be solved most advantageously by a computerized tool of decision support system type, which implies the user to yield the solutions.

3. The prognosis method based on the TT's proved to be accurate enough and easy in use. It is useful to combine this method with heuristic models based on expert knowledge and experience. More complex models are difficult to be widely used because of the too complex data required.

4. The experiments carried out in Southern Romania showed significant variability of the sunflower stages TT's and honey potential yields by hybrids and climatic conditions. A good solution for this problem is to use TT's and honey yields parameters that are specific to hybrids, or at least to maturity classes of hybrids, and specific to climatic types of crop years.

5. It is advantageously to have a prognosis support system of self-improving type, that during its use records historical data (meteorological and on sunflower crops), which could be

used to recalibrate the prognosis parameters. Such a system could also implement different calibration methods and select the best one accordingly to data availability.

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BIBLIOGRAPHY

1. Aiken R. M., 2005, Applying Thermal Time Scales to Sunflower Development, Agronomy Journal, 97, p.746-754.
2. Anderson W. K., R. C. G. Smith, J. R. McWilliam, 1978, A systems approach to the adaptation of sunflower to new environments, 1. Phenology and development. Field Crops Research, v.1, pp.141-152.
3. Barros J.M.C.de, 1997, Quantitative analysis of selected land-use systems with sunflower. Doctoral thesis, Wageningen Agricultural University, 178 pp.
4. Chimenti C. A., A. J. Hall, M. Sol Lopez, 2001, Embryo-growth rate and duration in sunflower as affected by temperature. Field Crops Research, 69, pp.81-88.
5. Doyle A. D., 1975, Influence of temperature and daylength on phenology of sunflowers in the field. Australian Journal of Experimental Agriculture and Animal Husbandry, 15, pp.88-92.
6. Ion Nicoleta, V. Stefan, V. Ion, G. Fota, R. Coman, 2007, Results concerning the melliferous characteristics of the sunflower hybrids cultivated in Romania. Scientific Papers Zootechny and Biotechnologies, Timisoara, v.40 (2), pp.80-90.
7. Ion V., V. Stefan, Nicoleta Ion, 2007, Results on the flowering stage in the Romanian-grown sunflower hybrids. Scientific Papers Zootechny and Biotechnologies, Timisoara, v.40 (2), pp.91-100.
8. Mailhol J. C., A. A. Olufayo, P. Ruelle, 1997, Sorghum and sunflower evapotranspiration and yield from simulated leaf area index. Agricultural Water Management, 35, pp.167-182.
9. Miller P., W. Lanier, S. Brandt., 2001, Using growing degree days to predict plant stages. Field Crops, Montana State University, Extension Service, July 2001, E-5, 8 pp.
10. NDAWN, 2008, Sunflower development and growing degree days. North Dakota Agricultural Weather Network. http://ndawn.ndsu.nodak.edu/, 5 p.
11. Prairie Grains, 2008, Crop Development. Sunflower Development, Growing Degree Days. Prairie Grains, Issue 93, Summer 2008 (Crop Production), 10 p.
12. Rondanini D., Roxana Savin, A. J. Hall, 2003, Dynamics of fruit growth and oil quality of sunflower (Helianthus annuus L.) exposed to brief intervals of high temperature during grain filling. Field Crop Research, 83, pp.79-90.
13. Rossi V., 2002, Simulation of sunflower growth stages in relation to susceptibility towards D.helianthi. http://www.agr.unipi.it/diaporthe/deter3a.htm, 7 p.
14. Seiler G. J., 1998, Influence of temperature on primary and lateral root growth of sunflower seedlings. Environmental and Experimental Botany, 40, pp.135-146.
15. Stefan V., V. Ion, Nicoleta Ion, V. Vlad, 2006, Study of some foreign sunflower hybrids under conditions of the year 2006. Research of excelence,AMCSIT/CEEX,Ed.Printech,Brasov, v.1, L2-24, 11pp, (in Romanian).
16. Villalobos F. J., J. T. Ritchie, 1992, The effect of temperature on leaf emergence rates of sunflower genotypes. Field Crops Research, v.29, iss.1, March 1992, pp.37-46.
17. Villalobos F. J., A. J. Hall, J. T. Ritchie, F. Orgaz, 1996, OILCROP-SUN: A development, growth and yield model of the sunflower crop. Agronomy Journal, v.88, iss.3, May-June 1996, pp.403-415.
18. Vlad V., 2001, Contributions to decision support systems for evaluation and use of agricultural land. Doctoral thesis, University of Agronomic Sciences and Veterinary Medicine, Bucharest, 332 p, (in Romanian).