DEVELOPING A MODEL OF DROUGHT OCCURRENCE BY INTRODUCING A NETWORK OF AUTOMATIC WEATHER STATIONS

Jevtić S., Mičić N., Đurić Gordana, Cerović R.
Agricultural Research Institute “Serbia”,
Fruit and Grape Research Centre Čačak, Yugoslavia

Abstract

The paper presents basic concept and preliminary results in the development of the model for analysis of climatic parameters used for prediction drought occurrence in plums. Čačak area has been covered by the network of automatic weather stations connected with the central computer in the meteorological centre. The computer has formed a base of meteorological parameters and calculated the function of the course for each stage of organ and tissue differentiation defined by the algorithm of the organogenesis cycle.

Key words: model, drought occurrence, automatic weather stations

Introduction

The development of highly-intensive technologies in crop growing implies the defining of various cultural practices that can control the processes of their growth and development. This approach is of particular importance for perennial plants, with several competitive processes occurring simultaneously in the trees: the development of different types of growth, differentiation of generative buds and fruit development, etc. (Severini et al. 1990). It is also relevant to the understanding of processes in physiological and imposed dormancy underlying the studies on resistance to low temperatures (Koshelev 1990). This approach is based upon an integrated study of all developmental stages and processes of organ and tissue differentiation by observing them on an algorithm basis under defined ecological conditions (Mičić et al. 1996; Jevtić et al. 1996). The application of any cultural practice can be thus observed as a treatment of the current stage of differentiation, but also as its direct effect on the further processes of plant development. By precisely locating the application of a certain treatment to the current course of differentiation, and then by clearly defining its response in the organogenesis cycle, a basis is obtained for developing software to assess the onset of the expected developmental stage determining certain functions of the development of the target organs in plant production (Mičić and Đurić 1994).
Figure 1. - Graphical presentation of the formation of bases of meteorological indices by the developmental stages defined by the algorithm of organogenesis cycle

The aim of this paper is to present the basic concept and the preliminary results in the development of a model for the analysis of climatic parameters as a basis for modelling the occurrence and effects of differing ecophysiological processes in cultivated plants.

**Basic hypotheses in model definition**

Automatic weather stations, measuring 14 meteorological parameters at 2-minute intervals and transmitting them by radio to a central computer of the meteorological centre, have been set up at 4 locations in an intensive-production Čačak area. The measurements in each station cover the space ranging from 0.5 m below the ground level to 2 m above the ground level. On the basis of the data collected, the computer forms a base of climatic parameters, not a temporally continuing one, but separately for each developmental stage of the plants observed (Figure 1).

Developmental stages were defined on an algorithm basis as a structural relationship in the sequence of the onset of stages, assuming it as a fixed form, whereas the moment of the occurrence and the duration of the phenomenon are genotype-specific and vary with the changes in ecological conditions. The programme for each defined step in the algorithm forms a distinct base, which is defined by the time of the start and end, i.e. the length of the duration (days, hours, etc.). The start and the end of each step in the experimental stage are defined by the response of the observer, and, after the formation of database, by the response of the user, or automatically on the basis of the boundary values of the model function or the base of climatic parameters.

Meteorological parameters thus fed to the computer, and the formed bases of meteorological parameters by the defined developmental stages in the algorithm of the organogenesis cycle, represent a basis for modelling different ecophysiological processes in agricultural crops.
Analysis of the basic hypotheses of the model

The basis of the model functioning is a computer programme receiving daily meteorological data, calculating from them for each developmental stage the trends of the type: \( y = a + bx + cx^2 + dx^3 \), and then, by means of the trend function, calculating mean accumulation or the sum of the effects of the same parameter, either as the total sum of the effects, or as the sum of effects beyond a certain constant which represents a boundary value or a biological threshold of the developmental stage observed. For the sum of mean daily temperatures exceeding + 5°C, the model operates according to the following formula (1):

\[
\Sigma t^0C = \int_{t_1}^{t_2} f(x)dx - A(t_t-t_s)
\]

(1)

\( t_1 \) = the transit time \( f(x) \) of the trend of mean daily temperatures beyond the limiting constant temperature \((y = 5^\circ C)\).
\( t_2 \) = the time of the onset of the observed phenophase;
\( A \) = constant temperature (temperature threshold of the developmental stage defined by any criterion) \( t = 5^\circ C \).

The efficiency and precision of the model defined in this way was tested by making available to the computer the base of mean daily temperatures, absolute maximum

![Graph 1982](image1)

![Graph 1989](image2)

Figure 2. - Flowering time (C) of plum, depending on climatic conditions, occurs at an interval of variation exceeding 30 days. The average temperature sum above 5°C (the shaded area) required for the onset of the folowing phenophase, amounts to 145°C with an error of ± 4.83°C.
and absolute minimum temperatures for the developmental stages up to the end of the flowering phenophase in plum cv. Požegača over the 1981-1983 and 1987-1990 seasons (Figure 2). The data were obtained from the weather station belonging to the Fruit and Grape Research Centre in Čačak.

It can be seen from the graph that over the period observed the flowering phenophase occurred at an interval of variation of 33 days (on 1 April, 1989 and 2 May, 1982).

The model shows that it took 37.28 ± 3.17 days from the moment of the trend function transit above 5°C to the start of flowering, i.e. that an average sum of mean daily temperatures exceeding 5°C, required for the onset of flowering, amounts to 145.68±4.83°C, with the coefficient of variation of 10.48%. It can be concluded, therefore, that the model defined in this way can provide a reliable estimate of the onset of the phenophases observed.

**Model for monitoring drought occurrence**

The studies conducted over the past period clearly indicate the existence of a close connection between the adverse effect of drought on bud formation and the process of differentiation occurring in stress conditions. Thus the drought spells during the season that are of lesser intensity and shorter duration, if they occur at certain developmental stages, i.e. the process of organ and tissue differentiation, may lead to more severe disturbances in the organogenesis cycle than the more severe drought spells of longer duration occurring after the transition to the further processes of differentiation (Mićić et al. 1996). The assessment of the less severe drought on the bud differentiation processes is therefore of great importance since its adverse consequences are not visible until the start of the next season.

To analyse reliably drought effects on the processes of bud differentiation in fruit crops, within the programme for monitoring climatic parameters by the developmental stages and processes of organ and tissue differentiation according to the defined algorithm, a model was developed for monitoring drought index, in this case the de Martone’s monthly drought index (Vlahinić and Hakl 1989) (2), as well as the drought index by the developmental stages, which is a modification of the former (3):

\[ I_{\text{monthly}} = 12q / t + 10 \]  \hspace{1cm} (2)

* (q = monthly amount of precipitation; 
* (t = mean monthly temperature.

\[ I_{\text{developmental stage}} = 12q(t_a - t_b) / t(t_a - t_b) + 10 \]  \hspace{1cm} (2)

q (ta - tb) = the amount of precipitation for the developmental stage observed; 
q (ta - tb) = mean monthly temperature of the developmental stage; ta = the moment of the onset of the developmental stage, to which the period of 15 days preceding it is added; tb = the moment of the completion of the developmental stage.

Also, the model defines the monitoring of stress temperatures, i.e. the average temperature accumulation above the trend of mean daily temperatures (4):
\[ \sum t^0 C = \int_{t_1}^{t_2} f_1(x)dx - \int_{t_1}^{t_2} f_2(x)dx \quad (4) \]

\( f_1(x) \) = trend of absolute maximum temperatures;
\( f_2(x) \) = trend of mean daily temperatures;
\( t_1 \) = the time of the onset of the developmental stage;
\( t_2 \) = the time of the completion of the developmental stage;

and the average accumulation of temperatures above a certain stress temperature (for example, if 30°C is taken as a limit):

\[ \sum t^0 C = \int_{t_1}^{t_2} f(x)dx - A(t_1 - t_2) \]

\( t_1 \) = the transit time \( f(x) \) of the trend of absolute maximum temperatures beyond the constant temperature (\( y = 30^\circ C \));
\( t_2 \) = the time of the onset of the observed phenophase;
\( A \) = constant temperature (a stress temperature for the developmental stage, defined by any criterium) \( t = 30^\circ C \).

The obtained accumulation of stress temperatures will be related to the amount of precipitation over the defined time period.

Namely, in the previous research we observed that a wide range between the trend of mean daily temperatures and the trend of absolute maximum temperatures in the period preceding flowering can result in some plum cultivars in the occurrence of temperature stress, which leads to a greater number of morphologically sterile flowers (Mićić 1992).

Thus defined model for monitoring the developmental stages in plum and apple in different zones covered by the network of automatic weather stations will enable us to define more precisely, after several seasons, the amplitude of the observed indices and their effects in the organogenesis cycle of these fruit crops. The boundary values defined in this way will then be added to the model, so that the programme will be able, on the basis of the course of the developmental stages in plant and meteorological parameters obtained via the network of weather stations, to warn the user against the dynamics of approaching the stress moment, stress effects and, finally, the measures for its prevention or alleviation. The precision of the model prediction increases with each successive growing season. Also, the occurrence of each undefined stress at new amplitudes of the observed indices will be be included as a new defined ecophysiological boundary in the cycle of developmental stages of plant.

The model presented in this paper was developed as a software package and is now in its second season of data collection and experimental processing (Figures 3 and 4).
Figure 3. - The screen for determining the course of differentiation of generative buds on some types of fruiting branches (June-August)

Figure 4. - The screen for determining the course of differentiation of generative buds during the period of microporogogenesis (March-April)
Conclusions

The paper presents the basis of a model for the analysis of climatic parameters used for predicting drought occurrence in plums in the area covered by the network of automatic weather stations. The computer has formed a base of meteorological parameters and calculated the function of the course for each stage and substage of organ and tissue differentiation defined by the algorithm of the organogenesis cycle. The obtained functions enable a precise assessment of the stress occurrence, as well as a thorough analysis of the conditions in which it occurred. Based on thus defined functions of meteorological parameters inducing drought, and on the average of several years’ functions, the model is becoming increasingly more precise in predicting the occurrence and effects of stress. In this way, the knowledge about various drought aspects can be more efficiently applied in intensifying agricultural production.

References


