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Author	Family Name	**Odyntsova**
	Particle	
	Given Name	**Valentyna**
	Prefix	
	Suffix	
	Role	
	Division	
	Organization	Melitopol Experimental Gardening Station named after M.F. Sidorenko at Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine
	Address	Melitopol, 72311, Ukraine
	Email	
Corresponding Author	Family Name	**Sushko**
	Particle	
	Given Name	**Serhii**
	Prefix	
	Suffix	
	Role	
	Division	
	Organization	Tavria State Agrotechnological University
	Address	B. Khmelnitsky ave. 18, Melitopol, 72310, Ukraine
	Email	sls447@gmail.com
	ORCID	http://orcid.org/0000-0002-2933-2573
Author	Family Name	**Bondarenko**
	Particle	
	Given Name	**Larysa**
	Prefix	
	Suffix	
	Role	
	Division	
	Organization	Tavria State Agrotechnological University
	Address	B. Khmelnitsky ave. 18, Melitopol, 72310, Ukraine
	Email	
	ORCID	http://orcid.org/0000-0001-5858-7375
Author	Family Name	**Scherbakova**
	Particle	

Given Name	**Nina**
Prefix	
Suffix	
Role	
Division	
Organization	Tavria State Agrotechnological University
Address	B. Khmelnitsky ave. 18, Melitopol, 72310, Ukraine
Email	
ORCID	http://orcid.org/0000-0003-2632-2641

Abstract	The study of the stages of morphogenesis in generative buds along with the quantitative accumulation of GDH made it possible to establish the influence of the interaction of two extreme environmental factors on the growth and development of the buds. The factors (minimum and maximum air temperatures) were considered as parameters for phenoclimatographic models. These indicators determined the elements of irrigation control. The control signal was transmitted to the actuators of the irrigation system. Incoming and outgoing information registration was provided. A functional and structural diagram of the irrigation system control unit has been developed. The positive experience of using of fine-dispersed sprinkler for evaporative cooling of the buds on the trees with the aim of delaying their development was outlined. That provided the indirect method of protecting plantings from spring frosts.
Keywords (separated by '-')	Phenoclimatographic models - Irrigation - Protecting plantings - Buds - Digital indicator - GDH accumulation

Application of Phenoclimatographic Models in Stone Fruits Protecting from Spring Frosts

Valentyna Odyntsova, Serhii Sushko, Larysa Bondarenko and Nina Scherbakova

1 Introduction

Providing the adaptation of stone fruits such as apricot, peach and cherry to the low air temperatures in winter and, especially, in the period after long thaws, as well as during spring frosts, it is necessary to take into account their biological characteristics of resistance to extreme temperature conditions for the climatic zone cultivation. When the stone fruit plantings are placed on the territory of the Southern Steppe of Ukraine, weather conditions of the winter–spring period can damage generative formations in varying degrees. The result depends on their anatomical, morphological and physiological features. In this regard, the study of the stone fruits needs to be heated during the period of biological rest and the beginning of intensive vegetation is a priority.

Rest is a necessary step in the life cycle of plants. To release biological rest, a number of fruit plants need the average daily air temperature in the range of 0–10 °C [1].

Due to the biological characteristics of stone fruits (short rest and early flowering), frequent spring frosts (once every 3–5 years) have a negative effect on the safety of generative buds. After blooming buds, during flowering, and especially during the formation of the ovary, their resistance to negative temperatures is almost completely lost. Spring frosts with an intensity of 1–3 °C below zero cause complete death or partial damage to the generative buds. That leads to significant crop losses.

To predict the date of completion of the period of biological dormancy in fruit crops, various methods have been developed: according to the date of intensive veg-

V. Odyntsova
Melitopol Experimental Gardening Station named after M.F. Sidorenko at Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine, Melitopol 72311, Ukraine

S. Sushko (✉) · L. Bondarenko · N. Scherbakova
Tavria State Agrotechnological University, B. Khmelnitsky ave. 18, Melitopol 72310, Ukraine
e-mail: sls447@gmail.com

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etation of apricots using the transition date of average daily air temperature through 15 °C to lower values in autumn [2]; by cooling apple [3], peach [4], nectarine [5] at temperatures below 7.2 °C; on the accumulation of dynamic portions [6] and others.

Based on the experience of our many years of research [7, 8] and modern foreign researchers [9, 10], it has been found that the phenoclimatographic models developed by American scientists at University of Utah provide a fairly accurate forecast for the date of the onset of the deep dormancy end and the beginning of flowering. These original models are created on the basis of information on changes in temperature environmental conditions. To determine the date of deep dormancy completion, they proposed the chill unit (CU) model [11], and the dates of the onset of the phenological phases for the generative buds' development until the beginning of flowering are the accumulation of growing degree hour (GDH) with the application of the ASYMCUR model [12, 13]. It should be noted that these models are closely related. The basis of their development is on hourly maximum and minimum air temperatures. The date when the marginal accumulation of CU occurs is the starting point for the onset of GDH accumulation. It is necessary for the further development of the buds until the beginning of flowering. The boundary values of the chill units (CU) required for the completion of dormancy and the growing degree hours (GDHs), the accumulation of which is necessary for the plant to start flowering, vary depending on the crop and variety. When calculating the limit constant values of CU and GDH, not only the values of maximum and minimum air temperatures are used, but also data on the occurrence of the phenological phases for stone fruit development.

In conditions of irrigated gardening, an indirect method of protection is the most effective and reasonable when fine sprinkling is applied. The principle of the method is to wet the trees with irrigation water, followed by cooling of the buds due to evaporation of water from their surface (evaporative cooling of the buds). This leads to the flowering phase of fruit crops delaying for a later date, so that the generative buds in the least development-resistant phase do not fall under the influence of critical temperatures.

2 The Basic Part of the Study

Experimental data of phenophase onset of flowering trees were obtained in plantings of apricot varieties (*Prunus armeniaca L.*) Melitopol'skiy Luchistyy, peach (*Prunus persica* (*L.*) *Batsch*) *Ivan Tupitsyn* and cherries (*Prunus avium L.*) *Krupnoplodnaia*, which are placed on the experimental site of the Melitopol Experimental Horticulture Station named after M.F. Sidorenko IS NAAN in the city of Melitopol (46°50/N, 35°22/E). The height above sea level is 33 m. The climate is continental.

To calculate the constant boundary values of CU and GDH, we used the maximum and minimum air temperatures obtained at the meteorological station in Melitopol, located in close proximity to the plantations of the studied varieties of stone fruit. In the calculations, the perennial data (for at least ten years) of the phenophase of the onset of flowering of apricot, peach and sweet cherry in the garden were also used. These daily maximum and minimum temperatures were converted to hourly, synthesizing air temperature values as it was described in [14].

When using phenoclimatographic models, the following conditions should be taken into account: For accumulating one unit of CU per hour, the optimum temperature is 6 °C. At temperatures different from the optimum, the cooling process is less efficient. At temperatures below 1.4 °C and above 12.5 °C, CU accumulation does not occur, and temperatures above 16 °C introduce a negative effect to the accumulation process. One GDH unit is calculated as one hour at a temperature 1 °C higher than the baseline, equal to 4.5 °C for most fruit crops. At temperatures lower than the baseline, the growth and development of trees do not occur. The air temperature of 25 °C is the optimum when the greatest accumulation of GDH occurs (per one hour about 20.5 °C accumulates), and the temperature of 36 °C is critical, because there is a weak development of trees or its complete absence when the temperature is higher.

Predicting the release date of the studied crops from deep dormancy as reaching the CU limit value for each variety was calculated by summing up its hourly values for each day, starting from the date with a negative CU value, which is observed in autumn and corresponds to the period of the growing season end. The accumulation of GDH to the corresponding limit value is performed immediately after the maximum accumulation of CU values, up to the predicted start date of flowering for each stone fruit.

The total water content in the generative buds was determined in grams per gram of dry matter by drying the buds' samples at a temperature of 105 °C [15]. Mathematical processing of experimental data was provided through the methods of correlation and regression analysis [16]. To obtain analytical expressions for the velocity and acceleration of the process of hydration of the buds with the corresponding GDH value, the first and second derivatives of the functions obtained were calculated [17].

Anatomical and morphological changes of generative buds were studied according to the methodological guidelines [18].

3 Results and Discussion

Application of phenoclimatographic models and the statistical method of the smallest deviations [14] allowed to establish the limiting values of the CU index, which are necessary to be accumulated by apricot, peach and sweet cherry in order to release the period of deep dormancy. The limiting values for the GDH index have been defined as well. The accumulation of the GDH index is necessary to start flowering. It has been established that in order to release the period of biological rest *Melitopolskii Luchistyi* apricot needs to accumulate 940 °C CU, *Ivan Tupitsyn* peach requires 1200 and *Krupnoplodnaia* sweet cherry needs 1350 °C CU. To start flowering, the stone fruit crops of these varieties will need to be accumulated, respectively, at 3725 °C GDH, 4866 °C and 4839 °C GDH. A smaller value of the CU for apricot indicates an earlier period of its release from dormancy, which is consistent with the data of researchers [19] and indicates a weaker degree of frost resistance of this crop compared to peach or cherries. At the same time, the limiting value of GDH for apricot indicates the earlier terms of its flowering. After all, from these cultures, sweet cherry comes out of rest. However, in terms of the accumulation of GDH, the size of peach and cherry is almost the same. In most cases, that is confirmed by the timing of flowering of these crops in the garden.

Having determined the limiting values of phenoclimatographic indices, as a result of summing up their values for each day to the limiting values corresponding to 100% of CU and 100% of GDH, the dates for exiting the period of deep dormancy and the beginning of flowering for each culture of the corresponding variety for specific research years were predicted. A comparison of the estimated forecast dates of the onset of flowering and the actual dates of observations of the phenophase of the onset of flowering in the garden is presented in the table. The predicted dates of apricot emergence from dormancy do not contradict the findings of scientific studies about Melitopol conditions, where apricots leave dormancy in December to the second half of February depending on weather conditions and the varieties belonging to the ecologic and geographic group [20]. The later dates of dormancy breaking for peach and cherry are also consistent with their pomological characteristics on the basis of increased winter hardiness and cold resistance [21, 22]. Obtained by calculating the date of commencement of apricot flowering also does not contradict the fact that it blooms in earlier calendar periods than peach and cherry.

The results of validation of phenoclimatographic models by comparing the calculated and observed dates of the onset of flowering of apricot, peach, cherry in the field showed fairly high prediction accuracy (see Table 1). The discrepancy between the estimated and the actual dates of the start of flowering of stone fruit crops does not exceed three days. That, in turn, indicates the adequacy and representativeness of the phenoclimatographic models used in the climatic conditions of the Southern Steppe of Ukraine. It must be noted that the authors create models indicate that they are closely related. We also statistically proved that there is a functional nonlinear relationship between the values of accumulation of CU and GDH at $R^2 = 0.96$, $P = 0.01$.

Studies on the use and evaluation of phenoclimatographic models conducted in the climatic conditions of Iran [9], the mountainous region of Italy [10], Spain [23] and Japan [24] do not reject the possibility of their use and confirm rather high accuracy of prediction of the time needed for rest breaking and development of buds for fruit crops before flowering in comparison with other predictive models.

Over the years of research, we have established that the duration of deep dormancy (from beginning to completion) for apricot was 66 days on average, 93 days for peaches and 112 days for cherries. The period of accumulation to the GDH limit value, that is, the period after the dormancy breaking before the onset of flowering, was, on average, 114 days for apricot, 95 days for peach and 77 days for sweet cherries. It must be highlighted that the accumulation period of CU with the corresponding lower air temperatures is longer for sweet cherry rather than for apricot and peach. It means that the process of cooling generative buds for stone fruits in the autumn–winter period is more significant in their development regulation as well

Table 1 Comparison of calculated and actual dates of the onset of flowering for apricot, peach and cherry

Crop, variety	Test year	Estimated date of biological rest breaking	Date of flowering		The difference between the dates of flowering, days
			Forecast	Actual	
Melitopolskii Luchistyi apricot	2010	25.12.09	18.04	18.04	0
	2011	07.12.10	23.04	22.04	+1
	2012	13.12.11	16.04	17.04	–1
	2013	22.01.13	15.04	13.04	+2
	2014	22.12.13	10.04	07.04	+3
	2015	30.12.14	17.04	17.04	0
Ivan Tupitsyn peach	2010	05.02.10	24.04	22.04	+2
	2011	28.12.10	27.04	28.04	–1
	2012	31.12.11	20.04	23.04	–3
	2013	10.02.13	21.04	19.04	+2
	2014	12.01.14	17.04	17.04	0
	2015	28.01.15	24.04	21.04	+3
Krupnoplodnaia cherry	2010	16.02.10	24.04	22.04	+2
	2011	06.02.11	28.04	28.04	0
	2012	08.01.12	20.04	22.04	–2
	2013	21.02.13	21.04	22.04	–1
	2014	10.02.14	17.04	18.04	–1
	2015	04.02.15	26.04	25.04	+1

as degree of frost resistance control comparing to the need of plants for a thermal resource after dormancy breaking.

This means that due to the early release of apricot from a period of deep dormancy, when the probability of thawing in the second half of winter remains quite high, as well as with early periods of flowering under conditions of possible spring frosts, weather conditions can be the main cause of generative sphere damage. In other words, when placing apricot plantations on the territory of the Southern Steppe of Ukraine, it is necessary to take into account its anatomical, morphological and physiological features. Peach and cherry blossom later, but during this period the probability of spring frosts remains high. Therefore, it is necessary to take into account the demands of these stone fruits for heat when placing plantings in this soil-climatic zone.

After the trees leave the state of biological dormancy, the rate of GDH accumulation can be judged on the intensity of growth processes occurring in the buds of stone fruits up to the beginning of blossom. The scientists [24] found that in the winter–spring period, the water regime of the buds is closely related to extreme (minimum and maximum) air temperatures. At this time, the total water content

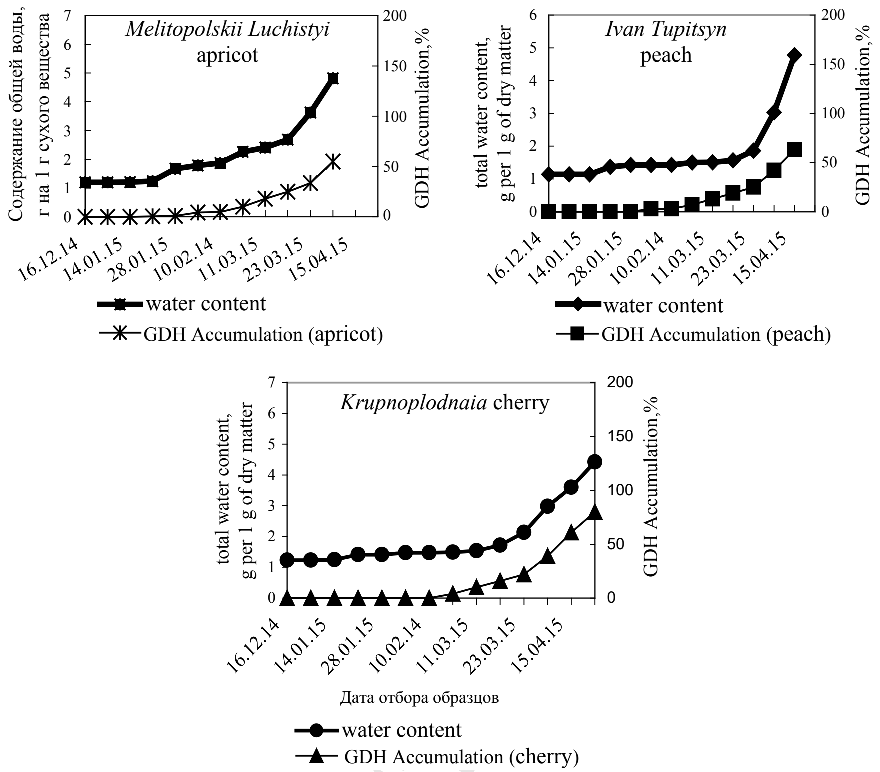

Fig. 1 Dynamics of total water content in generative formations and GDH accumulation in the winter–spring period 2014–2015

increases in the generative buds of stone fruits. The intensity depends on the varietal characteristics and specific environmental conditions [25]. Based on the fact that the main input parameters of phenoclimatographic models are hourly maximum and minimum air temperatures, it can be assumed that there is a correlation between the water content of the generative buds of apricot, peach, cherry and GDH.

According to the presented dynamics of the total water content of the buds of the stone fruit crops under study in the winter–spring period, the rate of development of the generative organs and the intensity of GDH accumulation can be traced (see Fig. 1). Using the example of experimental data for the winter–spring period 2014–2015, the nature of changes in the total water content in the generative buds of apricot, peach and sweet cherry together with the accumulation of GDH of each stone fruit was established. Analyzing graphically presented data of water content of tissues of generative buds and the rate of accumulation of GDH, it was determined that both processes in their development tend to increase.

It has been established that in the winter period there is almost no increase in the total water content in the buds due to the fact that the trees have not released the state of deep dormancy yet. At this time, GDH accumulation is absent or does not exceed 1%. Then, in late winter to early spring, more intensive development of the buds begins, as evidenced by an increase in their water content and an increase in the rate of GDH. During the observation period, the total water content in the generative buds increased at different rates depending on the fruit species and weather conditions. At the beginning of the spring vegetation of stone fruit crops, more intensive growth of all indicators was observed. The highest degree of hydration of the reproductive formations of apricot, peach and cherry was noted before the trees blossom.

As a result of the regression analysis of multi-year data, a close nonlinear relationship was established between the indicator of generative buds' development in apricot, peach, cherry (by total water content), on the one hand, and the accumulation of GDH, on the other hand. Third-degree regression equations are obtained. Their reliability is confirmed by the coefficients of determination ($R^2 = 0.98$; 0.98; 0.95) that indicates the share of variations in the total water content in the buds of apricot, peach and cherry according to the action of the factor under study (GDH accumulation). The graphs (see Fig. 2a) clearly demonstrate the dependence of the water content in the generative buds of the studied crops on GDH accumulation.

The calculated first derivatives of the obtained functional dependencies, which characterized the intensity of generative formation development in apricot, peach and cherry at different air temperatures, were taken into account when determining GDH. It enabled to identify the patterns of this process (see Fig. 2b). A graphic representation of the values of the first derivatives showed that there were two stages of the growth rate (as for the total water content in the buds) in all stone fruits studied. The first was characterized as a stage with a slower pace of generative buds' development. Its duration lied in the range from 0 to 43% of GDH accumulation. In other words, at this stage, there was some inhibition of increasing the total water content up to the value of 43% GDH. The inflection points of the functions (the tops of the parabolas) correspond to the value of 43% GDH. After that, the second stage began. It had accelerated growth rate with a more rapid increase in the total water content in the generative formations of apricot, peach and cherry until the beginning of their blossom.

The calculations of the second derivatives characterized the rate of hydration of the generative buds of apricot, peach and cherry depending on the temperature conditions during the observation period. Graphs represent the nature of the change in acceleration (see Fig. 2c). The analysis of the presented graphs confirmed their general tendency that the point of intersection of the line in the acceleration function through the GDH axis, regardless of the stonecrops being studied, corresponded to 43% of the GDH.

That showed the possibility of predictions for the rate and acceleration of generative buds' development in winter and at the beginning of the growing season according to the phenoclimatographic indicator of GDH accumulation and the resulting functional dependencies.

Therefore, the water content in generative formations of apricot, peach and cherry increases with different intensities. It depends on the varietal characteristics and specific weather conditions (air temperature) during the winter–spring period of

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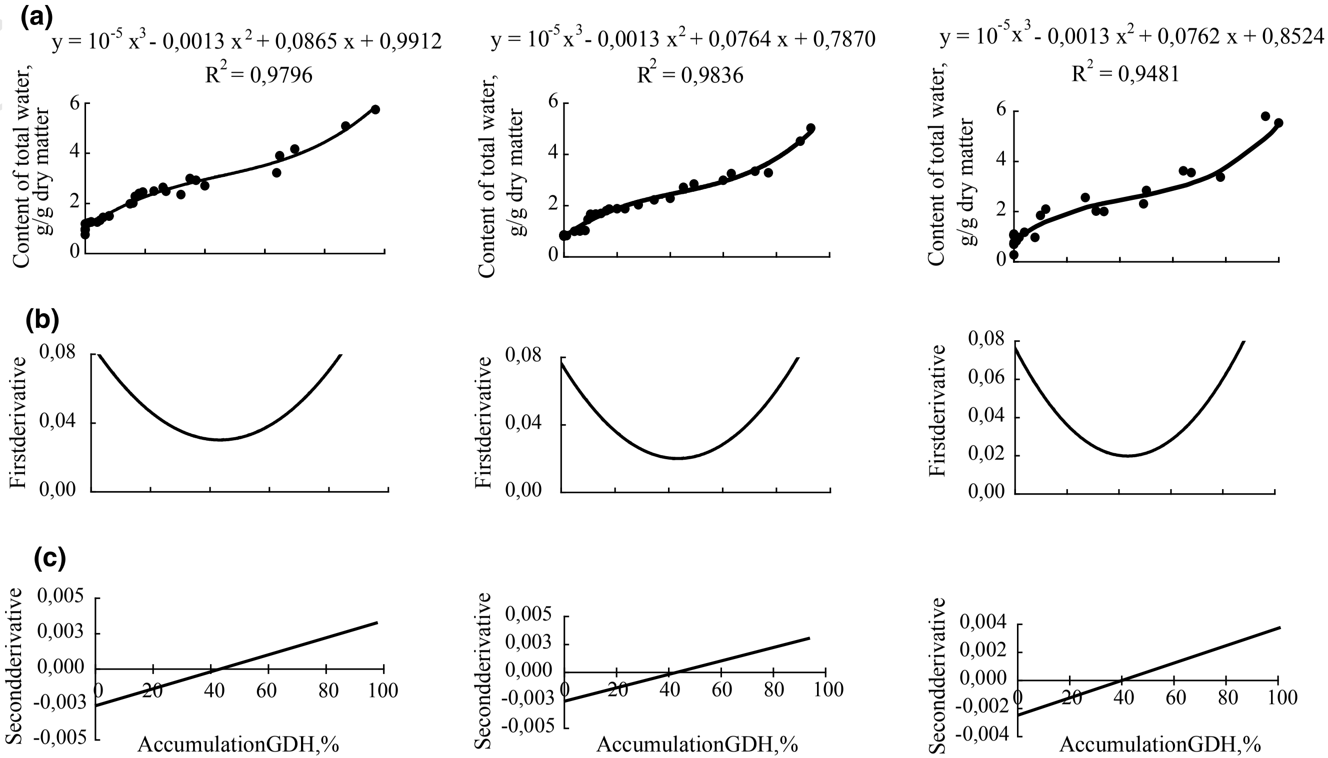

Fig. 2 Dependence of water content in apricot (**A**) generative buds, peach (**B**), sweet cherry (**C**) on GDH changes (a) and graphs of their first (b) and second derivatives (c)

the year. As a result of the analysis of the obtained data, a general pattern of the relationship between the total amount of GDH and the level of water content of the generative buds was revealed. It was established that a significant increase in the intensity of the total water content occurred after 43% of GDH for all crops studied.

Studies of the anatomical and morphological features of the internal structure development in the anthers of apricot, peach and cherry blossoms showed that in the period from October to the end of January and the beginning of February, archesporial tissue was formed. That corresponded to a period of deep or biological rest. At this stage, generative buds had maximum resistance to negative air temperatures [26]. Application of phenoclimatographic model enabled to determine the date of biological rest breaking for studied crops. In 2014–2015, *Melitopolskii Luchistyi* apricot released from the state of biological rest on December 30, 2014, *Ivan Tupitsyn* peach on January 28, 2015, and sweet *Krupnoplodnaia* cherry on February 4, 2015 (see Table 1). These forecast dates were the starting point for the start of GDH accumulation. After the trees had left the state of biological rest, the generative buds were ready for their further development, but negative air temperatures hampered the onset of the subsequent stages of morphogenesis.

Therefore, the formation of maternal microspore cells proceeded somewhat slowly and lasted until the end of December for the apricot, until the end of January for the peach. For the cherries, this stage ended in early February. At the indicated time, GDH accumulation for all crops was up to 1%. The subsequent stage of reduction division with the formation of microspores was noted in apricot and peach on the first days of February, and in black cherry (at the beginning of the second decade of March). That led to a decrease in frost resistance of the buds. In this case, the accumulation of GDH was in the range from 5 to 10%. Subsequently, the tetrads decayed into microspores, forming separate pollen grains. When the stone fruit crops were passing that stage, they accumulated 11–42% of GDH. The weather conditions in the third decade of March to the second decade of April contributed to the further development of pollen. That period, there was a more active GDH accumulation, which reached 85% by the middle of April. By the time the generative buds dissolved in the pollen grains of all the studied crops, nuclear fission was observed with the formation of two-cell pollen with GDH of 90%. At that stage, frost resistance of generative formations was completely lost [26]. On apricot plantations, blossom was noted on April 17, 2015, peach—April 21, 2015, and sweet cherries—April 25, 2015.

Taking into account those results, we can conclude that the magnitude of the quantitative accumulation of GDH, along with the corresponding stages of the morphogenesis of generative buds (male gametophytes), gives an idea of the rate of their development from the moment they enter biological rest until buds open. It should be noted that more intensive accumulation of GDH occurred after achievement of that indicator of 42%, when microspore was formed in pollen grains and unicellular pollen began to form. The data obtained are consistent with the above material on a significant increase in the total water content in the buds after 43% GDH. As our studies have shown, accumulation of GDH for apricot, peach and cherry reached that magnitude during March. After that period, stable positive air temperatures were characteristics for the climatic zone.

That entails more intensive development of the generative organs of stone fruits. In such favorable weather conditions, the only exception is the probability of spring frosts and, as a consequence, the possibility of generative sphere damage for apricot, peach and cherry. In this regard, the largest accumulation of GDH can predict the physiological state of wintering and vegetative plants in extreme weather conditions and predict the magnitude of their potential productivity.

The establishment of the above-mentioned regularities made it possible to develop algorithms and devices for their implementation into controlling the system of fine sprinkling.

The main control functions are defined by local arithmetic logic procedures, which can be represented as follows:

$$U_{n,m} = \begin{cases} U_1, & \text{if } Y_1 < \text{con } X_{n,m} \le Y_2; \\ U_2, & \text{if } Y_2 < \text{con } X_{n,m} \le Y_3; \\ \dots & \dots \ \dots \ \dots \ \dots \ \dots \ \dots \\ U_L, & \text{if } Y_{L-1} < \text{con } X_{n,m} \le Y_L. \end{cases}$$

where

- X is the matrix of the internal conditions of the control algorithm,
- Y is the matrix of input signals from measuring sensors,
- U is the matrix of output signals to the executing devices of the irrigation system.

On the basis of the obtained CU limit values, the date of dormancy breaking was determined, and according to GDH, the dates of flowering for a particular year were predicted as well. According to the data obtained, the period of exposure of the plants to fine sprinkling was established, in other words, the onset and completion of evaporative cooling with the help of combined irrigation systems (with simultaneous activation of the above-crown and subcrown parts of the system). It has been established that evaporative cooling of the buds should begin on those dates when the accumulation of GDH reaches 30% of the maximum amount required to start flowering and end at 100%. Observations on the morphogenesis of apricot buds showed that at the time of switching on the irrigation system they were at the stage of 'microspore' development. When the system was turned off, it was 'pollen formation.'

In order to save irrigation water and the greatest effect of cooling the buds, it was determined to sprinkle during the daytime at an ambient temperature of ≥7 °C.

According to the indications of temperature changes in the generative buds of apricot and peach, the mode of operation of the irrigation system (irrigation pause) was determined. The duration of watering corresponded to the time when the buds of the trees were completely wetted with irrigation water. It amounted two minutes. The duration of the pause depended on the time of complete evaporation of water from the surface of the buds and ranged from 5 to 30 min depending on the influence of weather conditions of each particular day on the temperature of the buds. Automatic control of temperature changes in the generative buds was performed by means of a sensor (differential copper–constantan thermocouple with a self-recording potentiometer

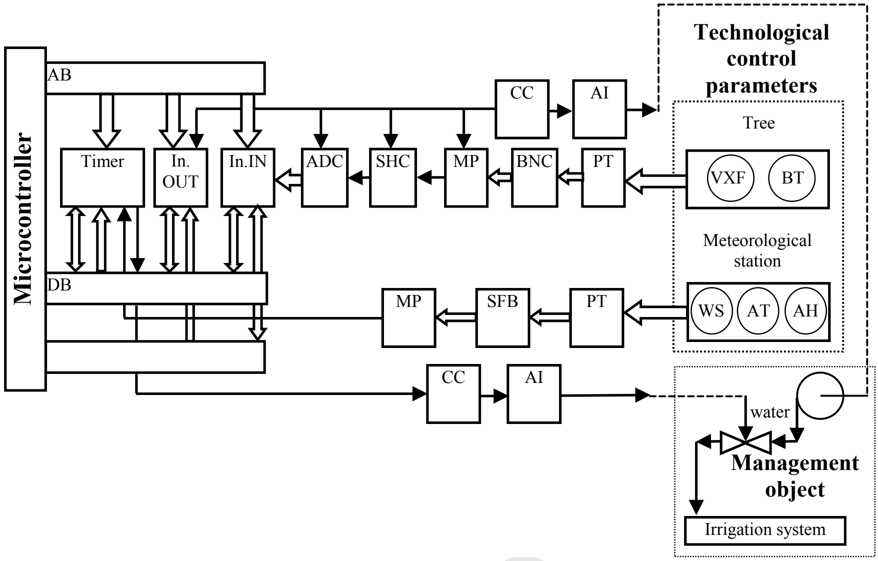

Fig. 3 Functional block diagram of the irrigation control device: In.IN is an input interface; In.OUT is an output interface; PC is a primary converter interface; BNP is a normalizing converter block; MP is a multiplexer; SHC is sample and hold circuit; ADC is an analog-to-digital converter; DB is a data bus; AB is an address bus; CC is a control circuit; AI is an actuator interface; SFB is a signal formation block; Timer is a timer; VXF is a sensor of xylem flow velocity; BT is a sensor of a bud/leaf temperature; WS is a wind speed sensor; AT is an air temperature sensor; AH is an air humidity sensor

output). It was established that watering should resume when the temperature difference on the sensitive sensor elements reaches 2.8 °C. This principle was taken as the basis for the development of a bud cooling sensor, which consisted of four dry and four permanently wetted differential copper–constantan thermocouples, imitating dry and moistened surfaces of buds.

For the full automation of plant irrigation management, a special device has been developed. According to the established physiological parameters, the device provided such technological elements of irrigation control as ‘start,’ ‘restore,’ ‘irrigation duration’ signals and established the ‘irrigation—pause’ mode. The control system provided the automatic collection of information from the plant objects and meteorological changes in the environment as well as transmission of a control signal to the executive mechanisms of the irrigation system and the recording of incoming and outgoing information.

The functional–structural diagram of the irrigation control device is shown in Fig. 3.

The diagram provides the connection of the control object with the microcontroller data bus (MC) using the interface circuits of «In.IN». The technological parameters of the object (temperature and humidity, xylem flow velocity, etc.) in the interfaces of the primary transducers (PTs) are converted into electrical signals (constant voltage or frequency). After passing through the block of normalizing converters «BNP», which provides a standard signal level, the monitored parameters are fed to a multiplexer (MP), which switches one of the input signals to a single output. Switching is provided by supplying a digital code through the output interface (In.OUT.). The channel that has been switched is fed to the sample and hold circuit (SHC) and then to the analog-to-digital converter (ADC), the output of which forms a digital code proportional to the value of the monitored parameter. Then, the digital code can be read into the MP via the input interface (In.IN) and the system data bus (SDB). The digital code, which is read, is subjected to further digital processing in the MC for the irrigation control algorithms that were developed earlier. When the indication of the measurement result was necessary, the resulting information could be presented on a digital indicator through In.OUT. When, according to the results of calculations, it was necessary to give a signal to the control object (pump and electromagnetic valves of the irrigation system), In.OUT could be used to transmit the control signal through the control circuit (CC) and the interface of the actuator interface (AI) to turn on or off the pump or valve.

The design of the control circuit significantly depends on the type of the actuator [27]. The actuators, in our case, were contactless relay devices. To control them it was enough to send a signal to the input, which accepted only two states: low or high. The control circuit in that case had to perform the functions of a power amplifier operating in key mode. In the case when the monitored parameter was converted to a frequency, the procedure for introducing it into the processor was greatly simplified and after being formed in the signal formation block (SFB) and switching in the MC, it reduced to supplying a timer to the input. All other transformations associated with the calculation of the monitored parameter value were provided by the control program. In that case, the timer could also be used to form a control signal in a CC.

4 Conclusions

The obtained results showed that in the conditions of the Southern Steppe of Ukraine, it was possible to use phenoclimatographic models with a fairly high accuracy of forecasting the dates of the onset of blossom for apricot, peach and cherry. Phenoclimatographic model, which was based on the use of hourly maximum and minimum air temperatures, allowed to take into account the needs of stone fruits in certain temperature conditions necessary for their development and growth in the autumn–winter–spring period with various changes in weather conditions of a particular year.

According to the phenoclimatographic indicator of GDH accumulation and the resulting functional dependence, it was possible to predict the rate of physiological development of generative formations of stone fruits at different stages of morphogenesis in winter after trees break their biological rest and at the beginning of vegetation, i.e., during blossom.

The irrigation control device, which implements the specified diagram, could be connected to a wide range of sensors, as well as various types of standard actuators. Setting various matrices of the internal conditions of the control algorithm and changing the matrix of input signals from the sensors enabled easy and flexible adjustment of the output signal matrix to the executing devices of the irrigation system. That was the settings of the specified irrigation mode.

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