TEMPERATURE CONDITIONS DURING THE DORMANCY PERIOD FOR SOME FRUIT CROPS GROWN IN BULGARIA

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Abstract

Orchard plantations are natural indicator for changing agrometeorological conditions. In all European regions, variations of temperatures have a cyclic character with a relatively regular change for the periods of active vegetation and dormancy. The years from the begging of this century has been characterized by an increased frequency of climatic anomalies and their amplitude. These anomalies affect the productivity orchards, which is directly dependent on agrometeorological conditions.

As a multiannual plants, fruit species in the temperate climate, need to accumulate a cultivar-specific quantity chilly units during the endodormancy, and heat units during ecodormancy for breaking of dormancy state and successive flowering during the spring. The knowledge of chilly and heat requirements is important in the selection of the appropriate species and cultivars for growing in a particular area. The buds remain dormant until they have accumulated sufficient chilly units (CU) during the cold season. When are accumulates enough chilly units, the buds are ready to grow in response to increase temperatures above biological minimum. If there have been enough CU's, the flower and leaf buds develop normally.

The present study aimed to assess the thermal conditions during the dormancy stages of development of some stone fruit plants grown in Bulgaria during a 30 years period. There are analysed the conditions during the deep dormancy in the orchards and the permanent transition of the average daily temperature above 5°C. Chilling requirements for breaking dormancy and growing degree hours (GDH) requirements up to flowering were studied for some peach, cherry, and apricot cultivars, located in the regions for industrial producing of these plants. Phenological and hourly temperature observations for 30 years (1971-2010) were used to perform this study. The GDH were calculated as sum of temperatures above 5°C accumulated from the breaking of dormancy to the flowering. The heat requirements (HR) necessary for successful flowering are given. The results indicate that flowering time of orchards in the studied regions is influenced by GDH.

Keywords: *chilly units (CU), chilling requirements, chilling accumulations, heat requirement (HR), growing degree hours (GDH), phenology*

INTRODUCTION

Like other fruit trees from the temperate climatic zone, such as apricot, and peach require adequate winter chill before they can produce economically significant yields. Chilling is the base of appearance of endodormancy, the transition to ecodormancy, and the resumption of growth in the spring (Saure, 2011). Dormancy for perennial fruit tree species is a phase during the annual cycle where buds remain inactive. To describe the two primary dormant phases during winter (Lang et al.,1987) proposed two stages: endo-dormancy and ecodo-dormancy. Endodormancy is defined as an inactive state of meristems and organs able to growth in which growth does not resume even under favorable conditions until this state is changed by environmental signals (Rohde et al., 2007, Considine et al., 2016;). Upon exposure to low temperatures during the cold season, plants progress from endo-dormancy to the next phase-eco-dormancy-when growth is restricted only by unfavorable climatic conditions, this event is called pass to dormancy (Allona et al., 2008; Yu et al., 2020). The pass to dormancy from endo-dormancy requires exposure to low temperatures termed chilling requirement (CR), which is expressed in chilling units (CU) and reflects the sum of plant exposure at temperatures lower than temperature of biological minimum, most commonly in the range of 0 to 7 °C. The apparent green tissues observed at least in 50% of buds were considered as an indicator of completion of dormancy for each cultivar, which was defined as the "end of dormancy" (Bayazit et al., 2012). The chilling requirement varies depending on genotype and regional climate (Considine et al., 2016). Effects of insufficient exposure to low temperatures have already been reported for apricot by Fadón et al., 2020; Rumul et al., 2018; Razvi et al., 2011; Viti et. al., 2010; Valentini et. al., 2004, and works for peach by Drogoudi et al., 2023; Fadón et al., 2020; Razvi et al., 2011. According to Viti et. al., 2010, the low adaptation capacity of some cultivars might be related to the necessity of adequate fulfillment of chilling requirements. Irregular dormancy may cause disturbance in flowering and hence significantly impact subsequent growth phases. Warm winter temperatures might cause late dormancy pass and consequently to late buds burst (Sunley et al., 2006). The chilling requirement is thus a major determinant of where a certain species or cultivar can be grown. Peach and apricot are sensitive to temperature, with cultivars showing considerable variation in chilling requirements (Fadón et al., 2020; Razvi et al., 2011). Available estimates of chilling requirements have been difficult to compare, due to differences in the response of studied cultivars to different climates, the use of unreliable chill calculation models, or variations in the methodology used to determine the orchard's agroclimatic needs. Insufficient chill exposure may result in short, prolonged, and delayed bloom and low yield (Li et al., 2016; Rumul et al., 2018). Prolonged winter chill accumulation, in contrast, may reduce the heat requirement in spring (Ruiz et al., 2007; Razvi et al., 2011). Viti et. al., (2010) are calculate the chilling and heat requirement of different apricot cultivars, for breaking dormancy and for flowering, as trough Utah and the Dynamic model, so and under the field conditions. Valentini et. al., (2004) are determine the chilling and heat requirements of peaches and apricots trees with different temperature models in northwest Italy. Razvi et al., (2011) found that in Iran the chilling requirements (CR) ranged between 746 to 868 CU for peach and 652-826 CU for apricot. The heat requirements (HR) for peaches and apricot ranged between 4099 and 4543 GDH and 2987 to 65 GDH respectively. According to (Fadon, 2020; Ruml, 2018) for some apricot cultivars, the range of chilling requirements is between 621-1600 CU- in Italy, between 631-1683 in Spain, and between 834-1122 in Serbia. Heat requirements (HR) ranged between 2114-5800 in Spain, between 1611- 4680 in Italy, and between 2938-3469 in Serbia. (Drogoudi et al., 2023) estimated the dates of the rest of completion and flowering and correlated them with observed flowering dates for 14 peach cultivars that were evaluated in 11 locations across Europe (Greece, France, Spain, Italy, and Romania). They determine that dormancy release happened earliest in Bucharest and Cuneo, sites where heat accumulation had a strong influence on the regulation of flowering time. The greatest risk of damage (Georgieva and Kazandjiev, 2013) is established in Northeastern Bulgaria and the North-Western region. They established that during winter dormancy are two areas in which more than 50% of the period temperatures remain below - 15°C for more than three days in the Central part of the Danubian Plain and the Central part of the Thracian lowland. Analysis of cases with temperatures below -15°C, compared with the availability and snow cover depth shows that the largest percentage of days with snow cover less than 10 cm in Razgrad (48%), lowest in Buzovets (14%) and between 2-16% of cases there is no snow cover.

The aims of the present research are to assess the thermal conditions in the dormancy period of the development of apricot and peach and determine the chilly and heat requirements for the flowering of 11 apricots and 9 peach locations with industrial production in Bulgaria.

MATERIAL AND METHODS

Materials

Apricot (*Prunus armeniaca L.*) and peach (*Persica vulgaris Mill.*) orchard trees are traditional in Bulgaria. The optimum results for their growth are got only in separate regions, where the agrometeorological conditions are most suitable for their growth and development. The data for this investigation were collected from agrometeorological archives, and database of the National Institute of Hydrology and Meteorology (NIMH), and also from the ERA5-Land dataset. Long-term 2002-2010 daily and hourly meteorological data were used. There were used hourly temperature data are taken from the ERA5-Land dataset between beginning of November and end of March. To characterize the chilly requirements during the winter period are taken hourly values of air temperature for the period

1st November - 31st March from the mentioned abovementioned period. The dates of the phenological development for apricot, and peach trees during the period of 2002-2010 are presented for 13 meteorological stations situated near the industrial apricot and peach plants. Used stations are grouped by the similarity of agrometeorological conditions. The dates of permanent transition of average daily temperature and average dates occurrence of phenological stages are present as time series of days starting date 1st January, i.e. in Julian days. For the day of mass appearance of a given phenological stage is accepted the first day after registration of mass arrival of these stages i.e. when it is observed on more than 75 % of the trees. According to the climatic zoning of Bulgaria (Sabev and Stanev, 1959), the regions for growing cherry orchards include areas from two climatic zones and four sub-regions. The stations of investigation are located in Moderately continental sub-region including the Northern climate region of the Danube plain - Oryahovo, Ruse, and Silistra, the middle climatic region of the Danube plain - Razgrad, Isperih. The eastern part of Dobrudja - Dobrich. The transitional continental sub-region included the Climatic region of Eastern Central Bulgaria - Sliven, Yambol, and Plovdiv, Kyustendil climatic region include Kyustendil areas, Sandanski and Petrich's valley includes the southwestern part of Bulgaria, fig. 1. The continental Mediterranean region includes the Black Sea climate sub-region - Suvorovo. As this is the beginning of our dormancy study and due to the lack of field observations, we assume that the date of the end of deep dormancy occurred when a certain number of CU has accumulated use literature data (Razvi et al., 2011). This value of CU is 750 for apricot and 810 for peaches

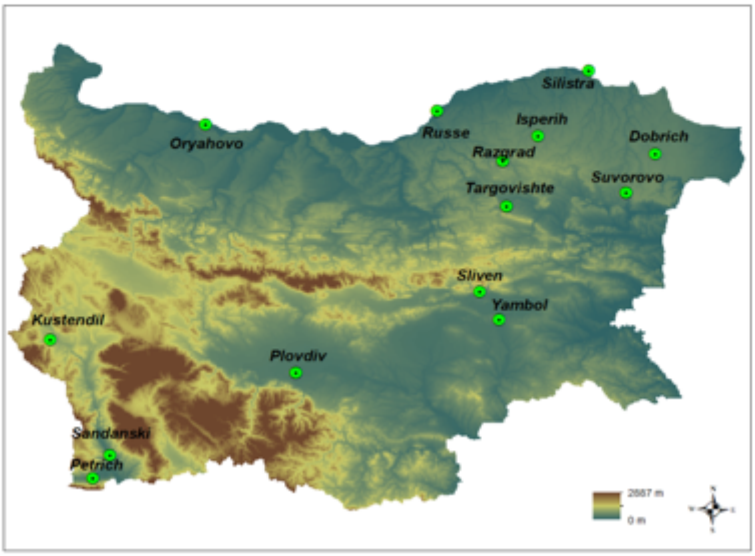

Fig. 1. Stations situation on the territory of the country

Methods

All-time series was tested for homogeneity and controlled statistical parameters by applying standard procedures from the package "Statistica".

Chilling requirement calculation

Used hourly temperature data are taken from the ERA5-Land dataset. ERA5-Land is a reanalysis dataset providing a consistent view of the evolution of land variables over several decades at an enhanced resolution compared to ERA5. Native resolution is 9 km which parameters 0.1° x 0.1°. ERA5-Land has been produced by replaying the land component of the ECMWF ERA5 climate reanalysis. Reanalysis combines model data with observations from across the world into a globally complete and consistent dataset using the laws of physics. The temperature of the air at 2m above the surface of land, sea, or in-land waters 2m temperature is calculated by interpolating between the lowest model level and the Earth's surface, taking account of the atmospheric conditions.

The Utah model (Richardson et al., 1974) was used to measure the accumulation of chilling requirements (CR).

Utah Model

The Utah model is based on the quantification of Chilling Units (CU) and establishes different ranges of temperatures with different contributions to dormancy completion. This model was developed under cold winter conditions. A chilling unit corresponds to one chill unit hour under temperatures between 2.5-9.1°C, a range that is considered the most effective temperature on dormancy completion. Other ranges of temperatures are considered to have half (1.5-2.4°C and 9.2-12.4°C), null (<1.4°C and 12.5-15.9°C), or negative for temperatures above 16°C contribution to dormancy (Richardson et al., 1974). In this model chilling requirements were estimated in Chill units (CU), giving to each hour the value in function of the rate for each temperature range (< 1.4°C=0 CU; 1.5 to 2.4°C =0.5 CU; 2.5 to 9.1°C =1CU; 9.2 to 12.4ºC=0.5 CU; 12.5 to 15.9ºC=0 CU; from 16 to 18ºC = - 0,5 CU and for the values > 18ºC = -1. The annual quantity is accumulated for the period December - March, in the winter preceding the fruiting, because this period includes the dormancy period. The Utah model is used particularly in cold areas of temperate zones (Dennis, 2003).

Heat requirement calculation

According to the recommendation of Anderson et. al., 1986, heat requirements have been calculated as growing degree hours (GDH) and accumulated from the breaking of dormancy to the flowering period using a base temperature of 5°C. A GDH are defined as number hours with a temperature above the base temperature of 5 °C. It is accepted the regale according to which if existing temperatures are equal or above 25°C they are assumed to be equal to 25°C and correspond to 20.5 GDH as the largest 1-hour accumulation.

RESULTS AND DISCUSSION

Estimation of Chilly requirements

Chilling accumulations were calculated by use the Utah model from 1st November to during 31st March at the 13 meteorological stations in which are situated 11 apricots plantations and 9 peaches plantations with the similarity of agrometeorological conditions during of 9 consecutive years and are presented on figures 2-3. There is shown an example of estimation of the endodormancy breaking date.

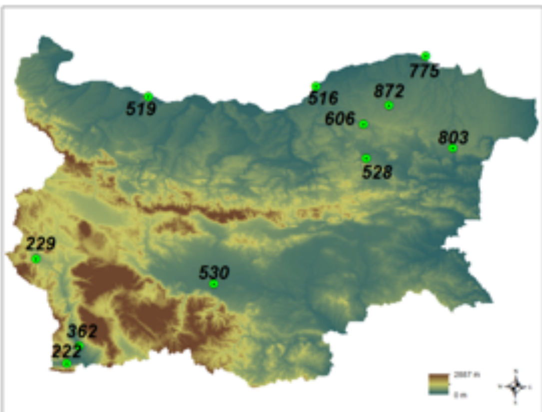

Fig. 2. Chilling requirements for breaking of dormancy for the Apricot trees (*Prunus armeniaca* L.)

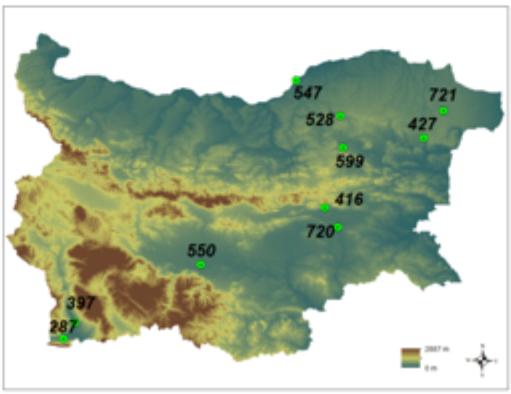

Fig. 3. Chilling requirements for breaking of dormancy for the Peach trees (*Persica vulgaris* Mill.)

In our climate conditions, the Utah model is a recommendable, because it was developed for colder areas of temperate zones. We are aware that the best way to assess the starting date of the chill accumulation is the date when orchards reach 50% of leaf fall (Alonso et. al., 2005). This approach used in our study allowed a significant improvement of final results as compared to the other studies, which randomly fix the beginning of CR accumulation on 1 November (Ruiz et al., 2007). Richardson's model better explained the good agronomic performance of peach, and apricot in growing areas featured with cold winter temperatures. Also, the model shows the sufficiency of the chilling requirements of a wide range, which are evaluated in the present work. Chilling requirements for apricot cultivars, the results ranged between 1494 CU for Kyustendil, fig. 2. The range of chilling requirements for the peach cultivars was between 1530 CU and 1845 CU, Fig. 3. The average date of dormancy breaking for apricot, and peach cultivars was found, figures 4-5.

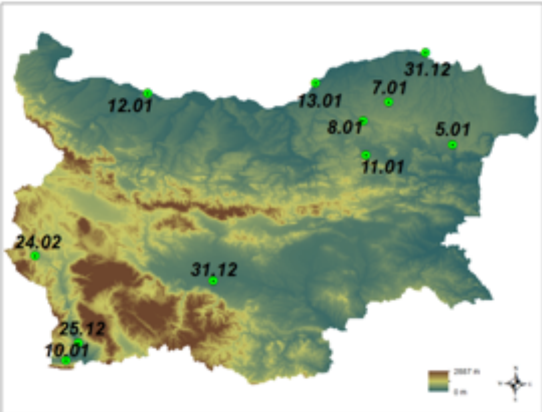

Fig. 4. Average dates of dormancy break for the apricot trees (*Prunus armeniaca* L.)

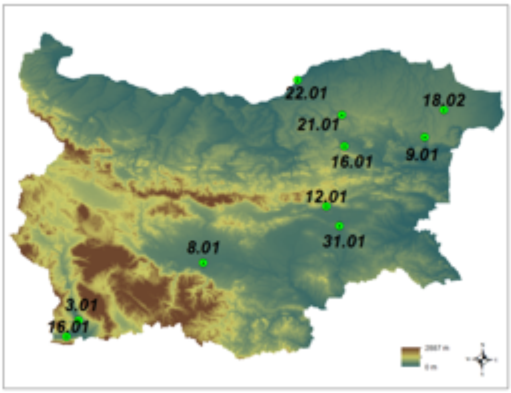

Fig. 5. Average dates of dormancy break for the peach trees (*Persica vulgaris* Mill.)

For apricot, the earliest date occurred is 25.XII in Sandanski, and the latest in Kyustendil on 24.II, in Ruse on 13.I, and 12.I in Oryahovo. For the peaches the earliest dates are in Petrich 03.I and Suvorovo 09.I, and latest in Yambol on 31.I and Dobrich on 18.II. Terms of flowering depend from the chilling requirements. The flowering dates of the evaluated cultivars are showed on figures 6-7.

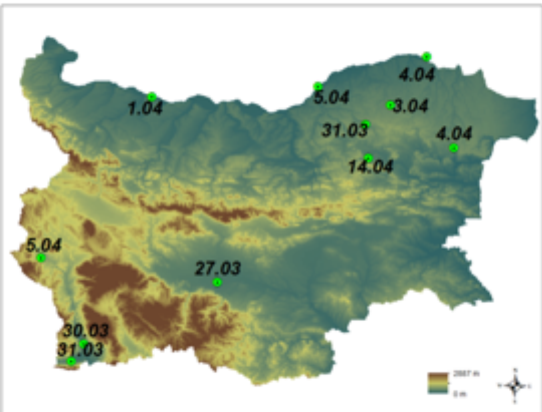

Fig. 6. Average dates of flowering for apricot trees (*Prunus armeniaca* L.)

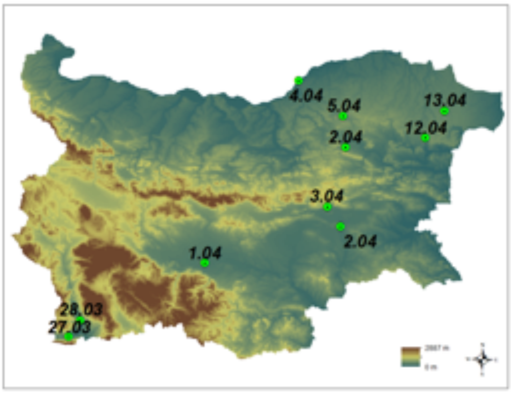

Fig. 7. Average dates of flowering for peach trees (*Persica vulgaris* Mill.)

Apricot cultivars with lower chilling requirements show an earlier flowering dates. The earliest flowering apricot cultivars are in Plovdiv which flowered on 27.III. The latest flowering cultivars are in Targovishte which have flower on 14 April. In the case of peach cultivars of Petrich and Sandanski was the first variety that reached full flowering on 27-28.III and followed by Plovdiv on the 1.IV and Yambol 2.IV. The latest flowering cultivars were in Suvorovo which flowered on 12.IV.

To estimate the temperature conditions during the winter months, we investigated the average number of days with an average daily temperature > 5 °C during these months. The number of days on which the air temperature in January, February, and March were above 5°C is shown on figures 8-9.

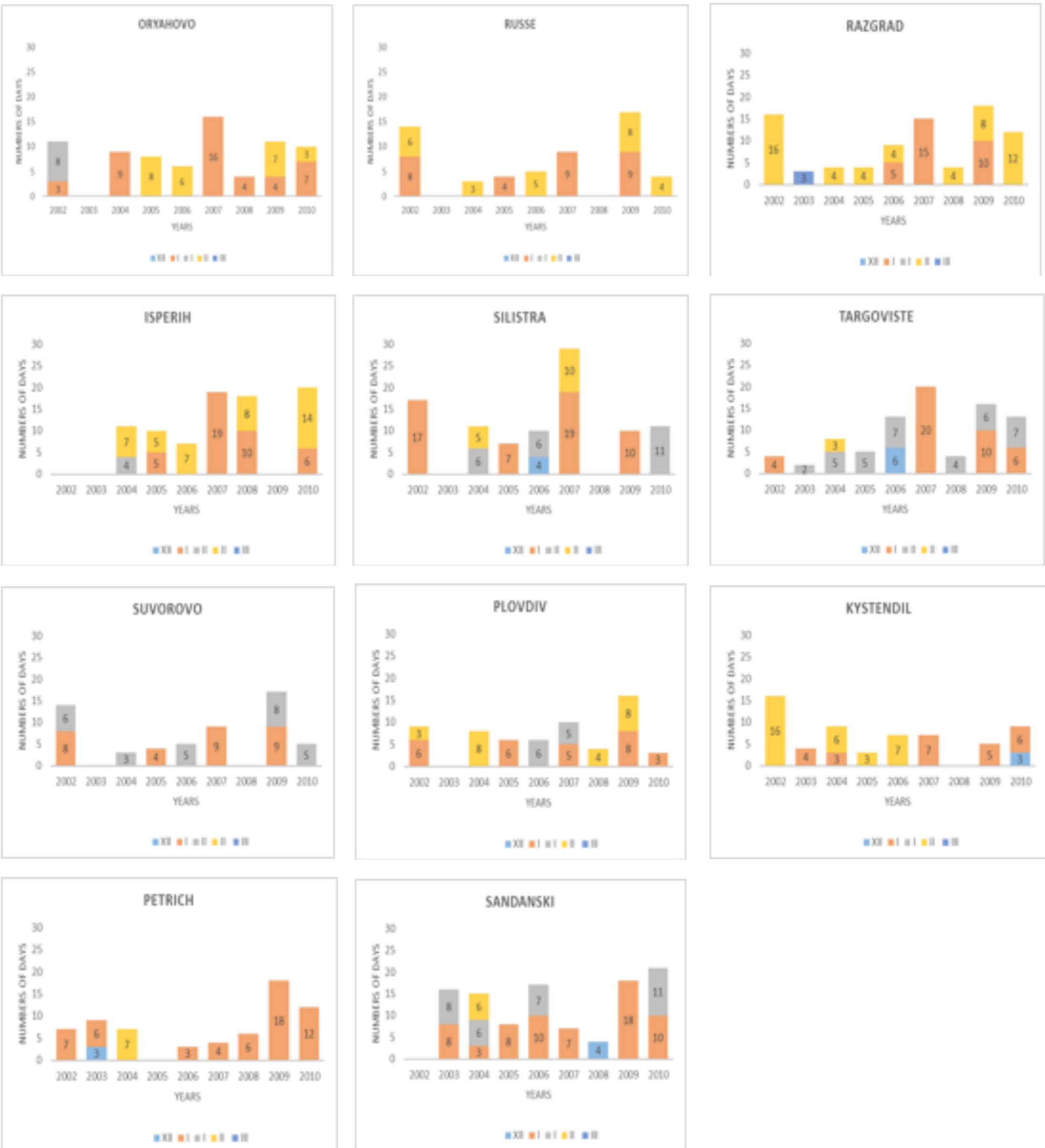

Fig. 8. Number of days with average daily temperature above 5°C across the cold months - December, January, February, and March for apricot trees (*Prunus armeniaca* L.)

Fig. 9. Number of days with average daily temperature above 5°C across the cold months - December, January, February, and March for peach trees (*Persica vulgaris* Mill.).

Analysis of data shows that during the winter months for apricot, the number of days with T> 5 °C the large for Targovishte 20, Isperich and Silistra 19. The smallest values are in Ruse 9, figure 8. For peach, the number of days with T> 5 °C is the biggest for Targovishte 20, Sliven 20, and Petrich and Sandanski 18. The smallest is in Suvorovo 7 and it is shown in figure 9. Investigation of the agrometeorological conditions during the ecodormancy of the apricot and peach plantations shows that in Bulgaria on average during the 7 of 9 years from the investigation period is observed warming during the period of forced dormancy. Usually, the number of warming is average 2 with a maximum duration of up to 20 days during the separate years. This increases the risk of early flowering species starting development outside the frost-free period and, accordingly, damage from late spring frosts. Due to the increase in winter temperatures, especially in January and February, the termination of deep dormancy and the entry of fruit crops into forced dormancy become particularly important. Georgieva, et al., 2022 established that for the period 1986-2015, the average monthly temperature increased in January by up to 1.9°C, February by up to 1.1 °C and March by 1.3 °C shifting the stable transition through 5°C to an earlier date, extending the period with a temperature higher than 5°C. Warming in the winter cause earlier development of fruit trees and the occurrence of frost during this period causes damage and yield loss.

Estimation of Heat Requirements (HR)

To estimate the conditions during the period of ecodormancy, the heat requirements (HR) were calculated as increasing degree hours (GDH) accumulated from the breaking of dormancy to flowering. For this calculation we accept a base temperature of 5°C. In our case, GDH for different apricot and peach cultivars was calculated for 9 consecutive years 2002-2010 for the period from the end of deep dormancy to flowering. Their values are ranged between 2351-3611 GDH for apricot and between 2216 - 3737 GDH for peaches and are presented in fig. 10-11. For apricot the highest hourly values (HR) are accumulated in Ruse 3611 HR followed by Silistra 3489 HR and Suvorovo 3337 HR. The lowest values are accumulated in Kyustendil 2089. For peach the highest hourly values (HR) are accumulated in Razgrad 3737 HR followed by Ruse 3657 HR and Dobrich 3457 HR. The lowest values are accumulated in Sliven 2216.

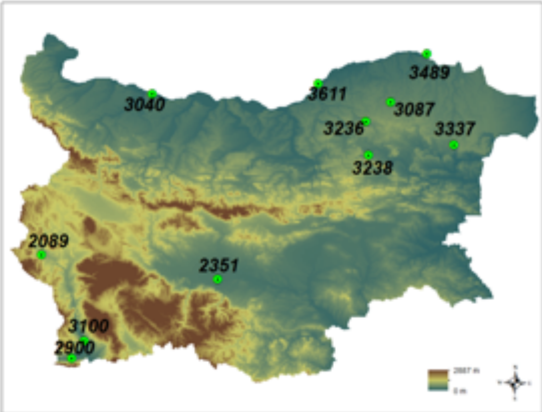

Fig. 10. Sums of temperatures above the base temperature of 5°C collected during the period from eco-dormancy to flowering for the apricot trees (*Prunus armeniaca* L.*)*

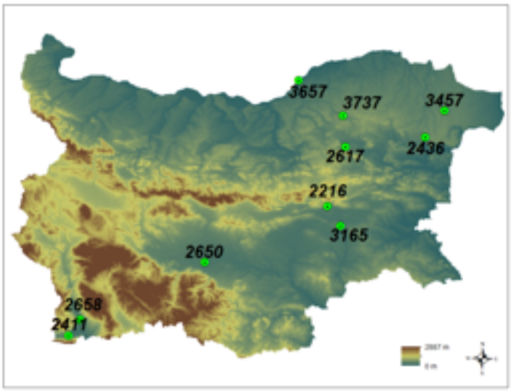

Fig. 11. Sum of temperatures above the base temperature of 5°C collected during the period from eco-dormancy to flowering for the peach trees (*Persica vulgaris* Mill.*)*

CONCLUSIONS

As a result of this investigation, we can confirm, that - Utah model is most appropriate for characterizing the dormancy conditions in Bulgaria. The agrometeorological conditions can be present from the next results: 1.The range of chilling requirements for the apricot cultivars, are 1494-1842 CU, and 1532-1848 CU for peach; 2. The average dates of dormancy breaking were found, which for apricots is around 16th January and for peaches around 18th January; 3. Heat requirements for dormancy were studied in 11 industrial apricot orchards and 9 peach orchards locations during the period 2002-2010. Their values range is 2900-3611 GDH for apricot, and 2216-3737 GDH for peaches accumulated from the breaking of dormancy to the flowering using a base temperature of 5°C; 4. This study on the agrometeorological conditions in Bulgaria during the ecodormancy of the apricot and peach plantations shows that during in the 7 out of 9 years of warming occurs during the period of forced dormancy. 5; Number of warming periods is 2-3 with a maximum sum of the duration to 30 days in different years and 6. This increases the risk of early flowering species starting development outside the frost-free period and, accordingly, damage from late spring frosts.

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