THE EFFECT OF CLIMATE CHANGE ON THERMAL BIOCLIMATE INDICES IN THE IASI REGION

EFECTUL SCHIMBĂRILOR CLIMATICE ASUPRA INDICILOR BIOCLIMATICI TERMICI ÎN REGIUNEA IAŞI

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Abstract. *The influence of environmental factors on plant growth and development is a well-known fact, and in agrometeorology, bioclimatic indices are used to quantify this influence. In recent years, plant growth technologies have been manipulating these factors to ensure the optimal conditions needed to improve agricultural production. In greenhouses, these factors can be controlled to ensure optimal growing conditions, but in the field, plants will be influenced by their variation. In order to understand how bioclimatic indicesvary as a result of climate change, we propose the evaluation of the most important thermal index in horticulture, namely the growing degree days index. The analysis of the air growing degree days is important to be able to calculate the state of vegetation in which the plant is, but also to estimate the period when it passes from one growing stage to another. Global warming has as a consequence the increase of the heat accumulated by the plant in a season, which is calculated as the number of temperature degrees accumulated during the vegetation period (from April 1st to September 30th). In the present study, we evaluated how this indicator has changed in Iasi in the last 6 decades. The results show a significant increase in the accumulated temperature degrees during growing seasonwhich requires an agroclimatological study on future plant varieties that will be grown in the coming years.*

Keywords: bioclimatic indices, growing degree days, agrometeorology, global warming

Rezumat. *Influența factorilor de mediu asupra creşterii şi dezvoltării plantelor este un lucru foarte cunoscut, iar, în agrometeorologie, pentru a cuantifica această influență se folosesc indici bioclimatici. În ultimii ani, tehnologiile de creştere a plantelor manipulează aceşti factori pentru a asigura condițiile optime necesare pentru a îmbunătăți producția agricolă. În sere, aceşti factori pot fi controlați pentru a asigura condiții optime de creştere, însă, în aer liber, plantele vor fi influențate de variația acestora. Pentru a înțelege cum se modifică indicii bioclimatici ca urmare a schimbărilor climatice, propunem evaluarea celui mai important indice termic din horticultură, şi anume, indicele de sumare a temperaturii. Analiza indicelui de sumare a temperaturii aerului este importantă pentru a calcula starea de vegetație în care se află planta, dar şi pentru a estima perioada în care aceasta trece dintr-o fenofază în alta. Încălzirea globală are ca şi consecință creşterea căldurii acumulate de plantă*

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într-un sezon, care se calculează ca numărul de grade de temperatură acumulate în perioada de vegetație (de la 1 aprilie la 30 septembrie). În prezentul studiu, am evaluat cum s-a modificat în Iaşi acest indicator în ultimele 6 decenii. Rezultatele arată o creştere semnificativă a gradelor de temperatură acumulate în sezonul de vegetație ceea ce impune un studiu agroclimatologic asupra viitoarelor soiuri de plante cultivate în următorii ani.
Cuvinte cheie: indici bioclimatici, sumarea temperaturii, agrometeorologie, încălzire globală

INTRODUCTION

In this study, the thermal climate change was analysed by using data recordedat the Iasi meteorological station, from 1961 to 2020, in order to understand how it influences the growth and development of plants.This assessment is based on the calculation of the most important thermal bioclimatic index for agriculture, named the growing degree day (GDD).All the outdoor activities are closely related to weather conditions, especially the agricultural activities, from the establishment of a crop to its harvesting. The identification of this index is important for the planning of agrotechnical works, but also for the determination of the time when plants go from one growing state to another.

Plants grow and develop due to various environmental factors such as: temperature, light, air humidity, soil, etc. The most used factor for assessing the stage of developmentis temperature, due to the fact that it is directly responsible for the physiological activity of plants. Therefore, the evaluation of the amount of heat accumulated during the growing season is crucial, given that plants do not grow at any temperature.The various physiological activities in plants take place within certain temperature limits. The temperature at which the plant begins its physiological activity is called *biologically low threshold* (T_{LT}) or base temperature (T_{base}).The maximum threshold is given by its ceiling temperature, which is called the *biologic high threshold* (T_{HL}),above which all physiological activities stagnate(Bodale, 2021a,b).The values of these thresholds depend on each species and variety of the plant. For example, wheat is a relatively adapted plant at low temperatures for which the base temperature is 4°C, but most plants have a higher base temperature, for cherries being 9°C, and for corn and vines being 10°C (Irimia, 2012; Istrate, 2014).

The summation of temperatures for a vegetation period is necessary to:

- estimate the time it takes for the plant to reach eachgrowing stage. Thus, one can accurately estimate the growth progress of a crop in relation to air temperature and humidity.
- identify when certain diseases may develop in order to plan the application of phytosanitary treatments.
- compare the exact periods of crop development in different years or locations.

Because the assimilation – dissimilation ratio of plants is closely related to heat and depends on the physiological stage, it can be calculated the amount of accumulated heat needed for the plant to go from one growing stage to another one.

The GDD thermal agrometeorological index is the most important index that quantifies the influence of climatic factors on the stages of plant growth and development.This index also takes into account the fact that the growth rate of many crops and pests decreases to zero if the temperature exceeds a certain point (maximum biological temperature).For example, the maximum temperature up to which tomatoes carry out physiological activities is 28°C; corn, soybeans, sunflowers or vines carry out activities up to 30°C, and wheat up to 32°C (Irimia, 2012; Istrate, 2014).

Farm managers often use the calendar to set the schedule for agricultural works. From a meteorological point of view, the calendar days are not similar every year, which will make the same plants to have different growing stages, especially in the early stage of growth.

Research has shown that the use of GDD provides a more accurate physiological estimation than calendar days. The ability to predict the growth stage of a crop, in relation to the life cycles of insects and weeds, facilitates better management of farms (Battel, 2021).

MATERIAL AND METHOD

The air temperature was measured on the meteorological platform at a height of 2 meters above the grassed soil, in the meteorological shelter according to the international meteorological standards (Wylie and Lalas,1992;WMO, 2008). In the context of global warming, it is necessary to check whether this index is influenced by the changes in air temperature recorded in Iasi.In order to illustrate how global warming influences this index, we calculated GDD for the last 6 decades in the meteorological station fromIasi, starting with1st of January 1961 until31stof December 2020.

In order to calculate thebiologically effective degree days (BEDD), the average daily temperature was assessed (ECA&D, 2013).It is considered that if the average temperature is equal to or below the base temperature for a crop or pest of interest, then the GDD value is zero. If the average temperature is higher than the base temperature, then GDD is equal to the average temperature minus the base temperature. If the minimum temperature of the day is below the base value of the crop or pests, the base temperature is used during the calculations.

The heat accumulated by plants during the growing season (the growing season of most plants starts on April 1stand lastsuntil September 30th) is determined in relation to the daily temperature (T_{day}), which can be calculated as the average between maximum (T_{max}) and minimum (T_{min}) temperature:

$$T_{day} = \frac{T_{max} + T_{min}}{2}$$

For species that depend on both biological thresholds, BEDD is used by summing the degrees between the two limits, if the minimum temperature is higher than the biological minimum threshold ($T_{min}>T_{LT}$)and the maximum temperature does not exceed ceiling ($T_{max}<T_{HT}$):

$$BEDD = \sum_{April\ 1st}^{Sept\ 30th} min\left[max\left[(T_{day} - T_{LT}), 0\right], D\right]$$

where *D* is the difference between the two thresholds $D = (T_{HT} - T_{LT})$ (Bodale, 2021a).

A more rigorous application of this relationship involves the inclusion of two correction terms. The first correction term takes into account the length of the day of each month, and the second term is the angle between the solar radiation and the ground. These summation indices of temperature degrees are expressed in Celsius degrees (Istrate, 2014).

In the present study, we considered as a minimum threshold the temperature of 9°C (T_{base}), and as a maximum ceilingthe temperature of 30°C, because most plants grow between the two thresholds.

RESULTS AND DISCUSSIONS

To calculate BEDD, we used the data for the minimum, average and maximum daily temperatures measured in Iasi station between 1961-2020 (Tank*et al*, 2020). Based on these data, the average monthly temperatures were calculated, and then the annual ones, to understand how the phenomenon of global warming affects the climate in the Iasi region. From the results obtained, we can notice that in during the 6 decades, the air temperature has changed extremely. It experienced a period of cooling in the 70s, and after the 90s the air at the regional level it warmed up continuously (fig. 1).

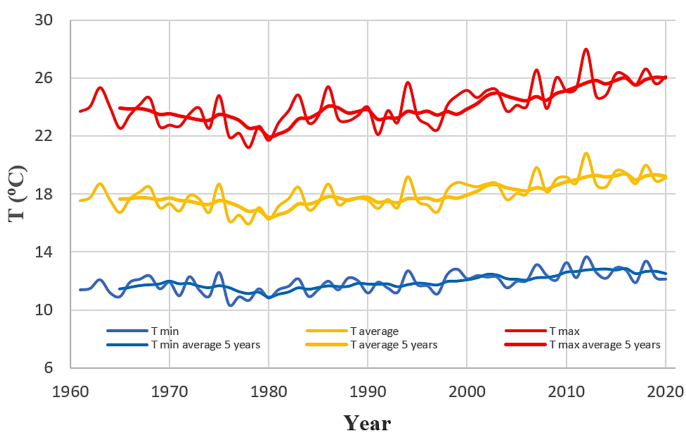

Fig. 1 Annually air temperature from 1961 to 2020 in Iasi

Based on the observation that air temperature has risen in the last decade compared to the 1970s, we proposed a study to assess how this change affects plants.In order to quantify the influence of climatic factors on plants, in climatology, bioclimatic indices are used. Bioclimatic indices play a crucial role in all branches of agriculture being essential for plant growth and development.

By calculating the sum of active and effective temperatures,it can be understood if the climate in a certain area is favourable to the growth and development of a certain plant variety and how it affects crops.

To calculate BEDD, the above formula was used for the data recorded in the Iasi meteorological station.

The accumulated heat of plants (GDD) has a real significance if it is calculated for the vegetative period, i.e., from April 1st to September 30th of each year of the analysed interval.The annual temperature oscillations (from fig. 1) also imply the annual variations of the BEDD bioclimatic index (fig. 2).In order to understand how global warming changes the analysed thermal index, the BEDD values were averaged for 5 consecutive years, which significantly reduces the fluctuations from year to year (fig. 2).This analysis shows a constant increase of BEDD from 1167 degrees in 1977, to 1854 degrees in 2012. The increase of the heat accumulated during the vegetation period by 787 degrees directly influences the vegetation of the plants.

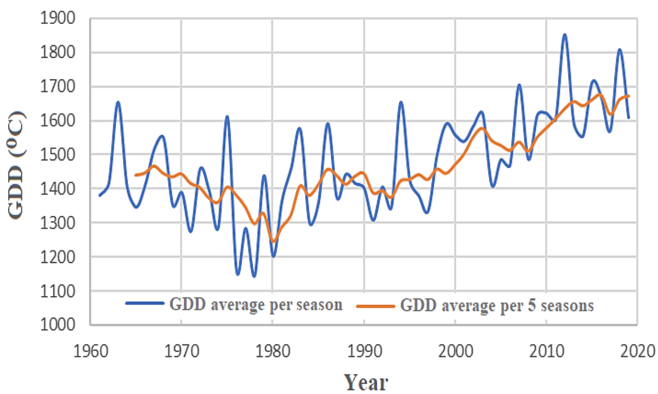

Fig. 2 Annually GDD from 1961 to 2020 in Iasi

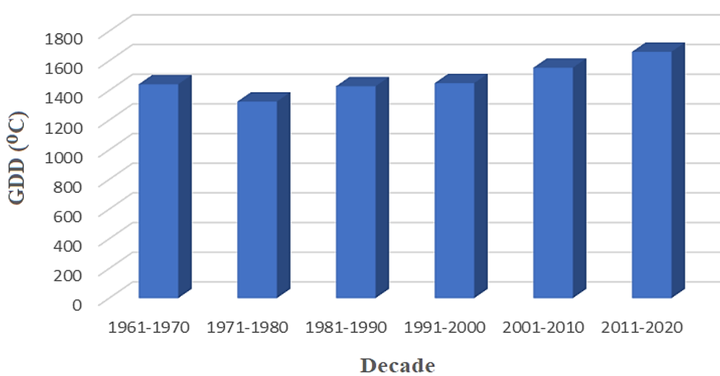

Fig. 3 BEDD annual average for every decade,measured at the Iasi meteorological station

The analysis of the evolution of average BEDD index by decades, from 1961 to 2020, which is the heat that can be accumulated by plants, shows an increase of 335 degrees (fig. 3) in the last decade as compared to the coldest decade of the analysed period (1971-1980). This increase in the number of BEDD requires an analysis of the plant varieties that will be grown in the coming years in Iasi region.

Climate change involves not only higher temperatures, but also extreme weather events and increased sea levels.In agriculture, climate change is responsible for changing the vegetation period, exacerbating the phenomena of late spring frosts, reducing periods of precipitation, and increasing their intensity. These phenomena lead to changes in ecosystems that directly influence flora and fauna.

CONCLUSIONS

1. The global warming has involved an increase of air temperature, in Iasi, in the last 6 decades. The average value in 2020 is with 1.8°C higher than in 1980. In the analysed period, the annually accumulated heat varied with 787 degrees which implies a direct influence on the cultivated plants.

2. The accumulated heat by plant in vegetation season (from $1^{st}$of April to $30^{th}$of September) steadily increased after 1980. The average value for 5 consecutive years increased from 1246°C/season in 1980 to 1673°C/season in 2020.

3. The results are useful to estimate the growing stage of cultivated plants, but also to choose the properly cultivars which are adapted to the local climatic conditions.

REFERENCES

1. **Battel B.,2017** – *Understanding growing degree-days*.Michigan State University Extension.
2. **Bodale I.**, **2021a** – *Manual de practică. Specializarea Horticultură, vol. 1, cap. 3.* Agrometeorologie, coordonator L. M. Irimia. Ed.“Ion Ionescu de la Brad”, Iasi.
3. **Bodale I., 2021b** – *Măsurarea şi prelucrarea datelor meteorologice*. Ed.“Ion Ionescu de la Brad”, Iasi.
4. **Irimia L. M., 2012**– *Biologia, ecologia şi fiziologia viței de vie*. Ed.„Ion Ionescu de la Brad”, Iasi.
5. **Istrate M., 2014** – *Pomologie*.Ed.„Ion Ionescu de la Brad”, Iasi.
6. **Tank A. K., Wijngaard J. B., Konnen G.P., Bohm R., Demaree G., Gocheva A., MiletaM.,Pashiardis S., Hejkrlik L., Kern-Hansen C., Heino R., *et al*, 2002** - *Daily dataset of 20th-century surface air temperature and precipitation series for the European Climate Assessment*.International Journal of Climatology, 22(12), p. 1441-1453.
7. **Wylie R. G., Lalas T.,1992** – *Measurement of temperature and humidity: specification, construction, properties and use of the WMO reference psychrometer*, WMO - No. 759, Technical Note, World Meteorological Organization, Geneva, Switzerland.
8. ***** 2008** – *Guide to Meteorological Instruments and Methods of Observation, volume I – Measurement of Meteorological Variables*, no. 8. World Meteorological Organization (WMO), Geneva, Switzerland.
9. ***** 2013** – *Indices Dictionary: Algorithm Theoretical Basis Document (ATBD)*. European Climate Assessment & Dataset (ECA&D), Royal Netherlands Meteorological Institute.