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MODELLING THE CUMULATIVE EFFECTS OF MICROCLIMATE IN AN INTENSIVE APPLE ORCHARD BASED ON MICROMETEOROLOGICAL MEASUREMENTS

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Abstract

The study of specific microclimate in apple fruit orchards is very important, thus micrometeorological measurements give valuable information on how the plants will react on different weather changes. Modelling the variations of environmental factors in apple orchard, specialist can give directions on critical periods and points when is an urgent demand of technological intervention (irrigation and other orchard management). In the plant-air interaction system critical parameters such as air maximum and minimum temperature, relative humidity, rainfall directly influences the crop physiological responses. A series of micrometeorological parameters were evaluated in an intensive apple orchard in Northern Transylvania, Bistrita fruit region from Romania with the objective of defining the interactions between trees and the aerial environment. An important objective was the study of daily meteorological observations in the flowering period in spring with implications on floral development and specific summer drought periods.

Key words*: micrometeorology, environment, plant-air system, flowering, drought period.*

INTRODUCTION

Micrometeorology deals with measurements and observations in small scale and time, smaller than 1 km and occur at the bottom of the atmospheric layer close to the earth surface. It shows primary interactions of low exchange processes between plants, water, land atmosphere, radiant energy. Microclimatology and agrometeorology measurements thus give valuable information on plant-microclimate interaction. In fruit growing is essential the study of these parameters including air temperature (minimum, maximum), air relative humidity, rainfall, sunshine hours and solar irradiance, wind. Knowledge of these factors are crucial in plant protection (Cristian M.F., 2019), irrigation scheduling, water uptake, evapotranspiraton, breeding, physiology. The Intergovernmental Panel on Climate Change-IPCC Special Report on Global Warming showed an increase of 1.5°C in Europe, for Romania it is estimated an increase of 0.5-1.5°C also, for the period 2020-2029. Several researchers studied the effect of temperatures in tree phenology in Europe (Chmielewski, 2001, 2002, 2005), the negative influence of drought periods (Mateescu, 2012; Sandu, 2010) and the effect of water deficit (Paltineanu et al., 2008, 2011) in Romania. Objective of the present study was the accurate modelling of the main micrometeorological factors like average, minimum, maximum temperatures, relative humidity, rainfall and those impact in the last three years (2017-2019) in an intensive apple orchard in Bistrita fruit region, Northern Transylvania, Romania.

MATERIALS AND METHODS

The micrometeorological observations were effectuated at FRDS Bistrita, in an intensive apple orchard planted with Romanian bred - cultivars Auriu de Bistrita, Aura, Generos grafted on M26 and M9 rootstock. Main micrometeorological parameters were registered by Adcon Telemetry weather station. The orchard was planted on a clay-loamy site, well drained, with specific thermal and rainfall conditions. The microclimatological data acquisition was effectuated at 2.0 m height, experimental period was the last 3 years (2017-2019). Data were registered every 15 minutes, downloaded, respectively analysed by MS Office Excel package.

RESULTS AND DISCUSSIONS

The aim of the study was the presentation of daily, monthly and yearly fluctuations of main micrometeorological parameters, these factors being characteristic to local conditions of Bistrita fruit production region from Northern Transylvania, Romania, which influenced the physiology of apple orchards between 2017-2019. Global climatological parameters showed, that the yearly average values had a clear increasing tendency (Fig. 1), when average values of the experimental years (10.8°C) were compared with the 9.6°C multiannual reference temperature (1993-2019). The calculated difference temperature was 1.2°C (Table 1) in agreement with the IPCC modelling for Europe and implicitly for Romania.

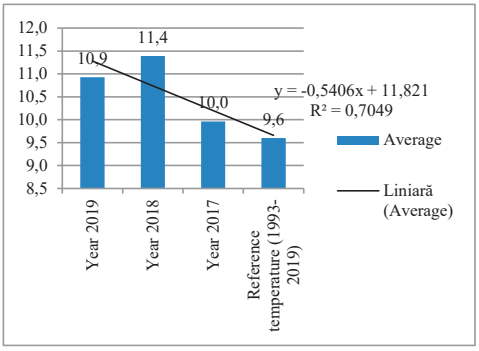

Figure 1. Average temperatures registered at micrometerological weather station FRDS Bistrita

Average minimum temperatures showed fluctuations in the last 3 years, the calculated difference was 1.3°C (Fig.2).

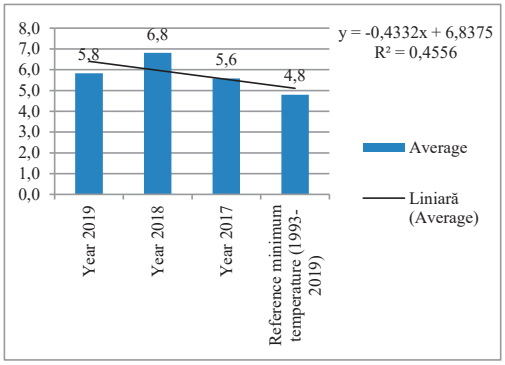

Figure 2. Average minimum temperatures registered at micrometerological weather station FRDS Bistrita

We can observe that the minimum temperatures in 2017 and 2019 had close values, excepting year 2018 which had a higher average minimum temperature value (6.8°C).

In the analysis of maximum temperatures (Fig. 3) it is shown a linear tendency of increasing of temperatures from 15.4°C to 17.1°C between 2017-2018, respectively from 15.4°C to 16.9°C in 2019. There are observed great fluctuations between the experimental years regarding the average maximum temperature parameter.

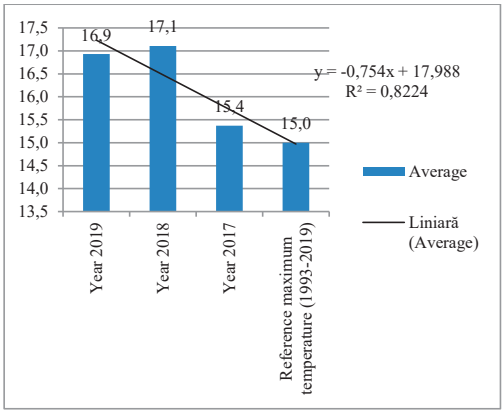

Figure 3. Average maximum temperatures registered at micrometerological weather station FRDS Bistrita

However, when analysing average maximum temperatures in the studied interval (1993-2019), one can observe in overall, that there are differences of 1.5°C.

Relative humidity fluctuations (Fig. 4) showed relatively close values, average being 73.9%.

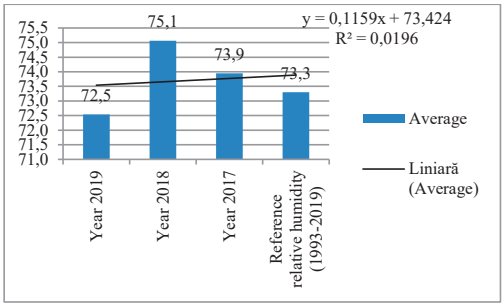

Figure 4. Relative humidity registered at micrometerological weather station FRDS Bistrita

Calculated relative humidity difference (Table 4) between reference relative humidity interval and the studied period was slight, namely 0.6%. One of the most important micrometeorological

factor is the rainfall for the life of a fruit tree. Measurements showed (Fig. 5) a decreased tendency of rainfall when compared with the multiannual reference interval (756.9 mm).

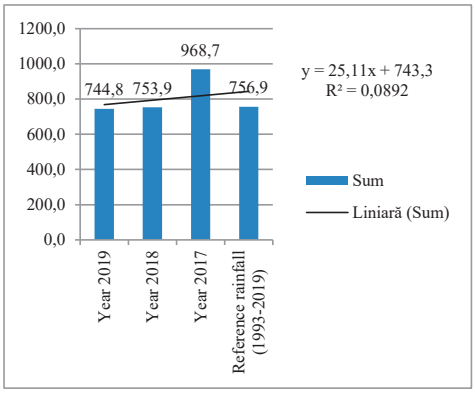

Figure 5. Rainfall registered at micrometerological weather station FRDS Bistrita

One can observe however, a great rainfall quantity in 2017 (968.7 mm) which decreased in time to 744.8 mm in 2019, thus influencing dramatically the apple orchard. The drought period in summer influenced negatively the yield, the fruits weight and diameter. Monthly average temperatures (Fig. 6) showed in 2018 a slight increase, during April-June, but in 2017 and 2019 were registered close values regarding thermal fluctuations.

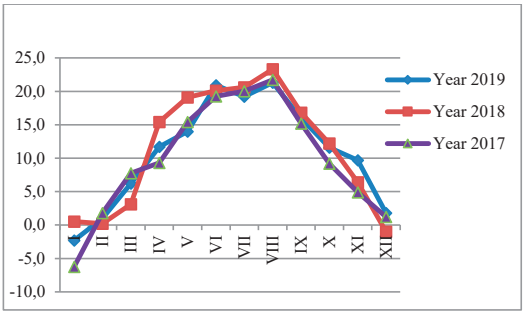

Figure 6. Average monthly temperatures registered at micrometerological weather station FRDS Bistrita

Monthly minimum temperatures (Fig. 7) showed also greater values during April-August in 2018, the graph showing clearly the increasing tendency.

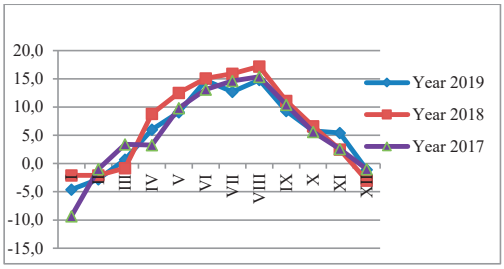

Figure 7. Average monthly minimum temperatures registered at micrometerological weather station FRDS Bistrita

The average monthly maximum temperatures (Fig. 8) in 2018 showed also a slight increase during April-June, being above the values from 2017-2018.

Figure 8. Average monthly maximum temperatures registered at micrometerological weather station FRDS Bistrita

Relative humidity fluctuations (Fig. 9) appeared in months April and May 2019, when compared with 2018-2017 period, showing higher values in the flowering period. Oppositely, during 2018, lower relative humidity values were registered in the same period, having a slight negative effect on the flowering of fruit trees.

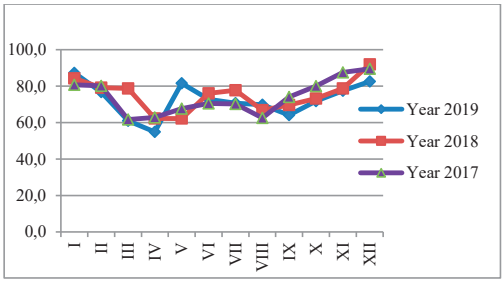

Figure 9. Average monthly relative humidity fluctuations registered at micrometerological weather station FRDS Bistrita

The registered rainfall (Fig. 10) showed also strong monthly variations, critical periods were June-July in 2019, causing drought in the most important physiological period of the year, namely the preparing of floral bud anthesis for the following year. The fruit growing during the same period (June-July) of summer was affected by the severe drought. Low rainfall values were registered also in September-October causing severe drought, falling of fruits before harvest and again a lesser yield.

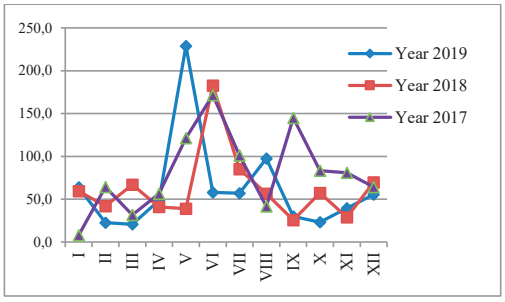

Figure 10. Average monthly rainfall fluctuations registered at micrometerological weather station FRDS Bistrita

Heavy rainfall occurred in May 2019, the soil was fully saturated with precipitations, hail event was also registered in July 2019.

The study of absolute minimum (Fig.11) temperature values showed low values in 2017 during winter (-19.1°C) and a severe decrease of temperatures in March 2018 (-14°C), April 2017 (-4.0°C). Absolute minimum temperatures showed a relative constancy in April-May 2019 registering temperatures just slightly above 0°C.

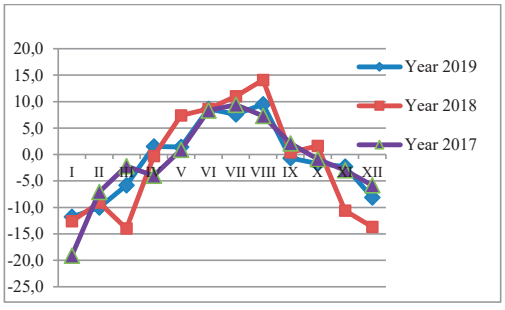

Figure 11. Absolute minimum temperatures registered at micrometerological weather station FRDS Bistrita

Absolute maximum values showed clearly higher values in 2018 during April-May and June (Fig. 12).

Figure 12. Absolute maximum temperatures registered at micrometerological weather station FRDS Bistrita

Analysing fig. 13 one can observe that in the most important period of flowering, generally lower maximum temperatures were observed in 2019 when compared with 2018, starting from 09 March until 12 May, the past year being colder in the sprig period.

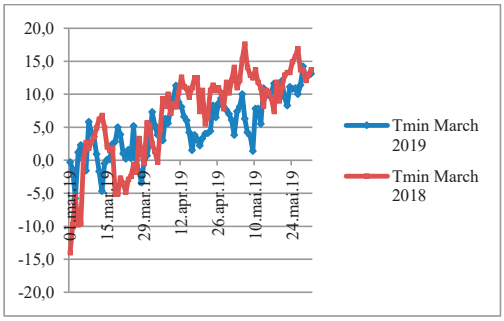

Figure 13. Daily minimum and maximum temperatures in May registered at micrometerological weather station FRDS Bistrita

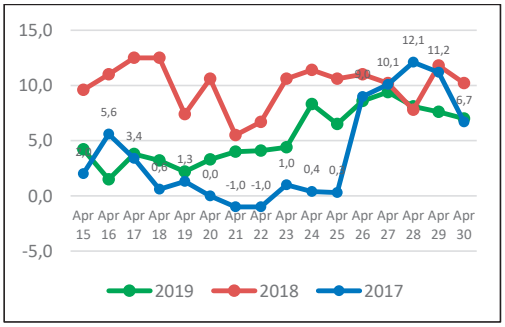

Figure 14. Micrometeorological conditions in the flowering period (April 2017-2019) at FRDS Bistrita

Focusing on the flowering period (Fig.14) of apple cultivars one can observe that climate conditions were not optimum in 2017 (18-25 April), several days the meteorological weather station registered very low values between -1.0 and 1.3°C. Thus floral development was affected (Table 1) in 2017, with negative implications on fruit quality and quantity. Flowering period was longer with 1-2 days in 2019 when compared with 2018 at Auriu de Bistrita cultivar (Table 1).

Studying the rainfall amount per month (Fig. 15) in the active vegetation period, we can observe that in August before harvesting the fruit yield in September, generally very low amount of precipitation was registered in 2017 and 2018, implications were crucial on fruit diameter, fruits were smaller and were not so crisp and turgescent (Table 1).

Fig. 16 shows the sum of rainfall in the active vegetation period, in 2018 were just 458.7 mm registered when compared with 2017 and 2019 period (523.7 mm in 2017 and 510.4 mm in 2019).

Table. 1 Flowering and floral development of some experimental cultivars during 2017-2019 at SCDP Bistrita

Cultivar/ Rootstock	Flowering period (start date) BBCH 57	Flowering period (end date) BCH 69	Floral development	Fruit diameter (mm)
Auriu de Bistrita-2019	18.04.19	02.05.19	Abundant flowering	92
Auriu de Bistrita-2018	16.04.18	30.04.18	abundant flowering	84
Auriu de Bistrita-2017	17.04.17	01.05.17	slightly affected	95
Aura-2019	18.04.19	02.05.19	Abundant flowering	84
Aura-2018	16.04.18	30.04.18	Abundant flowering	78
Aura-2017	17.04.17	01.05.17	slightly affected	82
Generos-2019	19.04.19	03.05.19	Abundant flowering	83
Generos-2018	17.04.19	01.05.19	Abundant flowering	82
Generos-2017	18.04.17	02.05.17	slightly affected	79

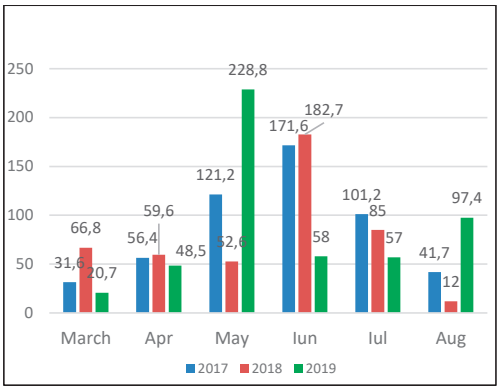

Figure 15. Rainfall in the active vegetation period during 2017-2019 at FRDS Bistrita

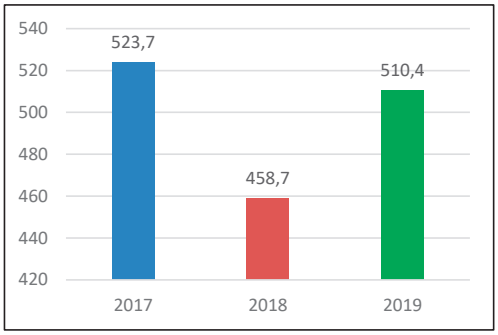

Figure 16. Sum of rainfall in the active vegetation period during 2017-2019

CONCLUSIONS

Investigations were effectuated in Northern Transylvania, Bistrita fruit region at Fruit Research and Development Station Bistrita during 2017-2019. Temperature (average, minimum, maximum, absolut minimum, absolut maximum), relative humidity, rainfall were registered in an intensive apple orchard at 2.0 m height.

The micrometeorological parameters together, cumulatively influenced the physiology of apple orchard, causing different variations in yield, diameter of fruits, weight of the fruits. The research showed an overall tendency of average temperature increasing in the last 3 years (+1,2℃) when compared with the multiannual reference interval, according to IPCC simulation. We confirm that the IPCC modelling was correct, indeed the temperature increasing is real and shows a linear tendency, also at the maximum temperatures (+1.5℃).

Low minimum temperatures were observed in the flowering period in 2017, thus yield was affected by meteorological conditions. Temperatures fluctuated between -1.0 and 1.3°C in the flowering period in April, floral development was affected, thus pistils and anthers of flowers. In the colder flowering period bees also have not searched the flowers for pollination. This process begun again just after 26.04.2017 when temperatures increased above 12°C and meteorological conditions were better. At the other hand rainfall measurements showed low precipitation level in June and July in the study period, especially in 2018 and 2019, when drought conducted to curling of leaves and the trees suffered of water deficit. Fruit diameter was greatly affected in 2018, the low amount of precipitation in August conducted to smaller fruits due to lack of water, fruits were not crisp thus quality of apples were affected also. Thus, researches show the urgent necessity of irrigation in fruit orchards in the summer period also in Northern Transylvania, Romania.

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