



*Original Contribution*

**TRENDS IN THE BIOCHEMISTRY OF APPLES IMPACTED BY  
CLIMATE CHANGE**

**A. Sotirov\***

Department of Agrotechnology, Plant Protection and Economics, Institute of  
Agriculture-Kyustendil, Agricultural Academy, Sofa, Bulgaria

**ABSTRACT**

The aim of the study is to detect the changing trends of biochemical indicators in some of the most popular apple varieties as a result of climate factors. Their impact on the biochemical characteristics of apple fruits in the Kyustendil valley (Bulgaria) is followed for the period 2020–2025. Four standard apple varieties have been analyzed – Granny Smith, Golden Delicious, Red Delicious and Florina. The observed biochemical indicators are total dissolved sugars (Brix), electrical conductivity (EC), acidity (pH), redox potential (Eh), vitamin C, dissolved salts and solids (Salts and TDS). The results manifest a distinct trend towards an increase in temperatures and a decrease in precipitation, leading to an increase in Brix, EC, TDS, Salts, and vitamin C in all varieties, as well as a disruption of the salt balance in drier years. Eh and pH remain unchanged. Correlation analysis reveals links between temperature stress and some biochemical responses of plants, which has potential implications for agricultural practice, the food industry, and adaptation to climate change

**Keywords:** climate change, apples, biochemistry, agroclimatic stress, sustainable agriculture

**INTRODUCTION**

The aim of the study is to determine the changes in biochemical indicators of some the most popular apple varieties as a result of climatic factors.

This study was initiated on the basis of a series of own climate observations in the Kyustendil valley (Bulgaria) for the period January 1, 2020 – September 30, 2025. The climate component includes measurements of precipitation and temperatures daily, monthly and annually over a 6-year period.

In order to trace the changes in the biochemistry of apples, harvests of six consecutive years of four "standard" varieties were studied: *Granny Smith* (green), *Golden Delicious* (yellow), *Red Delicious* (red) and *Florina* (mixed – green-yellow-red). The *Florina* variety in the Kyustendil region is presented in different shades, although the predominant color is red.

**\*Correspondence to:** *Institute of Agriculture-Kyustendil, Department of Agrotechnology, Plant Protection and Economics, Agricultural Academy, Sofa, Bulgaria, E-mail: a\_sotir@iz-kyustendil.org*

Apples (*Malus domestica*) are a traditional crop in the region because of the specific geological and geographical conditions: a mild transitional - Mediterranean climate and a subsoil horizon of old river deposits that act as reservoirs of water. The selected varieties are widespread both in Bulgaria and internationally, which facilitates the repeatability of the study and increases the applicability of the results in food science. In addition, these varieties are genetically and biochemically well characterized.

Within a six-year period, apples were examined both in the laboratories of processing workshops in Kyustendil (with supplies from the Institute of Agriculture - Kyustendil), as well as in the experimental fields and laboratories of the same institute.

**LITERATURE REVIEW**

Atkinson et al. [1] have proven that temperature and irrigation level significantly affect the development and quality of Cox's Orange Pippin and Queen Cox apples. Optimal water supply improves the yield and characteristics of fruits under different temperature regimes.

Calderón-Zavala, et al. [2] have found that the early development season of apple fruits and shoots is highly dependent on temperature, with higher temperatures accelerating growth, but can negatively affect the balance between fruit and vegetative development.

According to Wahid, et al. [3], plants use different physiological and molecular mechanisms to cope with heat stress, with adaptation and tolerance to high temperatures depending on complex interactions between these mechanisms.

Lobell & Gourdjji [4] have found that the significance of climate change is already having a significant impact on crop productivity globally, with some regions suffering from a decline in yields and others being able to benefit from the new conditions.

FAO (Food and Agriculture Organization, 2022) [5], is a document on adaptation strategies in fruit and horticulture to climate change. Adaptation to climate change in fruit growing is the creation of an integrated strategy, including the selection of sustainable varieties, improved agrotechnical practices and effective management of resources such as water and soil.

Hongxia Tao et al. [6] have established how water stress in Gala apples can provoke changes in fruit quality and sugar metabolism, leading to the accumulation of certain sugars used to manage palatability.

Sultan, et al. [7] have researched trends in biochemical, anatomical mechanisms, and molecular aspects in the enzymatic browning of apples.

## MATERIALS AND METHODS

The meteorological data was obtained from an automated meteorological system Meteobot® Pro, with software of the same name for Android and Windows systems. The system had a Wi-Fi internet connection with mobile devices. Data by regular non-automated meteorological station was also used.

To conduct the study, we applied the following digital instrumental methods. Digital refractometers were used to determine the total amount of dissolved sugars according to (Brix, %), the fructose content (Fru, %) and glucose content (Glu, %). To measure uric acid (UA, mmol/l) we relied on a digital instrument with electrochemical biosensor technology,

calibrated to very low values with a reference analyzer, traceable to the following standard reference materials and methods: NIST SRM 913 uric acid test standard, Uricasa/UV method.

Combined digital instruments were also used as conductivity meters-potentiometers to implement measurements for determination of total acidity (pH), redox potential (Eh, V), electrical conductivity EC (mS/cm), total dissolved solids TDS (ppm,%), total salt content (ppm,%), specific gravity (S.G.), and temperature (t°C) of the plant fluids. The devices can be automatically corrected, depending on the temperature of the solution and may transfer Bluetooth data to a computer.

Ascorbic acid was measured by semi-quantitative colorimetry with MQuant™ test strips with a range of 0-25-50-100-200-300-500-700-1000-2000 mg/l. Ascorbic acid reduces yellow molybdophosphoric acid to phosphomolybdenum blue. The concentration of ascorbic acid was taken semi-quantitatively by visually comparing the reaction zone of the test strip with the fields of the colour scale.

The fruit juices were obtained by pressing with a single-shaft press in a laboratory and shaft-belt press in fruit processing plant, unpasteurized, without additives, at a pressure of 2.5 atm., temperature 20°C in a regular air environment. At least 5 measurements of the technological parameters of each individual apple variety were made.

**Tables 2, 3, and 4** show how statistics was performed. Summary statistics (**Table 2**), Correlation matrix (Pearson) (**Table 3**), Coefficients of determination (Pearson) (**Table 4**). Statistical processing was done by a method described by Lumivero [8] with Excell and XLSTAT PRO [9].

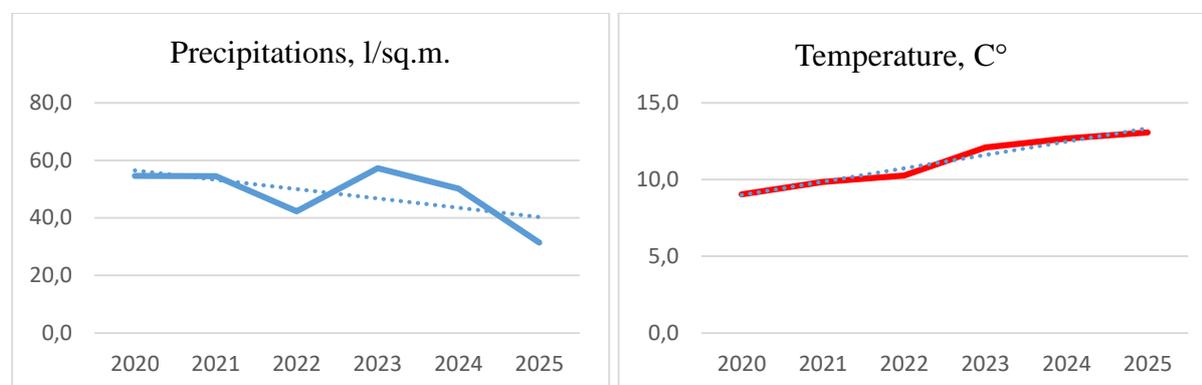
All measurements have been carried out in accordance with the requirements of Directive 2001/112/EC on fruit juices and related products and references to other regulations.

## RESULTS AND DISCUSSION

**Climate change:** As can be seen from **Figure 1**, the average precipitation for the period from January 1, 2020 to September 30, 2025, after the last harvest, showed a cyclical pattern, increasing or decreasing each year, but in general the trend marked a strong decrease in precipitation by almost 50% from the maximum to the minimum of the period studied. However, it should be noted that the decrease in

precipitation between the minimum in 2022 and the maximum in 2023 was about a third, and by the time of the last harvest, the decrease in precipitation was almost 50% (Table 1). What is not seen in the figure is that rainfall becomes more and more uneven each year, and long very dry periods alternate with rare, short periods of

very intense rainfall, bordering on disasters. The diagram for temperature shows the strong increase in average temperatures from 9°C in 2020 to 13.6°C in 2025 or an average of 0.76°C per year for the period (Table 1). The temperature increases constantly without cyclicity.



**Figure 1.** Average precipitations ( $l/m^2$ ) and temperature ( $^{\circ}C$ ), during the studied period. Data for 2025 is until harvesting at the end of September.

**Table 1.** Precipitations  $l/m^2$  and temperature of the air  $^{\circ}C$  and some biochemical indices of the apples by varieties (standards).

Year	2020	2021	2022	2023	2024	2025
Precipitations, $l/sq.m.$	54,6	54,5	42,3	57,3	50,2	28,0
Temperature, $^{\circ}C$	9,0	9,8	10,3	12,1	12,7	13,6
<b>Brix, %</b>						
Granny Smith	13,31	15,10	12,50	17,60	16,10	15,00
Golden Delicious	11,50	18,70	14,10	13,10	17,40	17,10
Red Delicious	11,60	19,00	12,50	16,10	19,90	14,50
Florina	11,70	13,40	13,50	15,00	20,00	17,50
<b>pH</b>						
Granny Smith	3,14	2,97	3,20	3,05	3,86	2,89
Golden Delicious	2,92	3,60	3,50	2,87	3,50	3,21
Red Delicious	2,91	3,78	3,82	3,35	3,73	3,54
Florina	3,05	3,80	3,20	3,50	3,56	3,11
<b>EC, <math>mS/cm</math></b>						
Granny Smith	1,82	1,80	3,20	3,07	2,24	3,23
Golden Delicious	1,81	1,59	3,50	1,67	1,81	1,98
Red Delicious	1,86	0,60	3,82	1,96	2,30	2,10
Florina	0,84	1,62	3,20	1,75	1,22	2,16
<b>TDS, <math>g/l</math></b>						
Granny Smith	1,22	1,22	1,30	1,54	1,12	1,62
Golden Delicious	1,21	1,08	1,32	0,84	0,91	1,98
Red Delicious	1,24	0,41	1,32	0,99	1,15	1,06
Florina	0,56	1,09	1,04	0,80	0,61	1,06
<b>Salt, <math>g/l</math></b>						
Granny Smith	0,92	0,91	0,97	1,56	1,01	1,64
Golden Delicious	0,91	0,80	1,00	0,84	1,30	0,99

Red Delicious	0,94	0,30	1,09	0,99	1,15	1,07
Florina	0,41	0,82	0,78	0,88	0,61	1,07
<b>Ratio Brix/pH</b>						
Granny Smith	4,24	5,08	3,91	5,77	4,17	5,19
Golden Delicious	3,94	5,19	4,03	4,56	5,52	5,33
Red Delicious	3,99	4,90	3,27	4,1	5,34	4,10
Florina	3,84	3,26	4,22	4,29	5,62	5,63
<b>Ratio Salt/TDS</b>						
Granny Smith	0,75	0,74	0,75	1,01	1,00	1,01
Golden Delicious	0,75	0,74	0,75	1,00	1,00	0,99
Red Delicious	0,76	0,73	0,83	1,00	1,00	1,00
Florina	0,73	0,75	0,75	1,10	1,00	1,01
<b>Vitamin C, mg/l</b>						
Granny Smith	50,00	50,00	50,00	50,00	125,00	75,00
Golden Delicious	50,00	50,00	50,00	50,00	100,00	75,00
Red Delicious	50,00	50,00	50,00	50,00	100,00	150,00
Florina	50,00	50,00	50,00	50,00	300,00	150,00

**Table 2.** Summary statistics for studied apple variety *Granny Smith*.

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
Brix, %	5	0	5	17,200	19,300	18,567	1,061
Fru (%)	5	0	5	17,600	19,900	18,833	1,183
GLU, mmol/l	5	0	5	33,300	33,300	33,300	0,000
EC, mS/cm	5	0	5	1,547	1,712	1,666	0,061
TDS, %	5	0	5	0,078	0,086	0,081	0,004
Salt, %	5	0	5	0,078	0,086	0,081	0,004
Acidity, pH	5	0	5	3,420	3,720	3,613	0,126
Redox, Eh, V	5	0	5	0,197	0,231	0,223	0,013
Specific Gravity S.G.	5	0	5	1,001	1,001	1,001	0,000
Juice yield, %	5	0	5	28,000	41,000	36,167	6,432
Vit.C, mg/l	5	0	5	0,125	0,175	0,158	0,020

**Table 3.** Correlation matrix (Pearson) for studied apple variety *Granny Smith*.

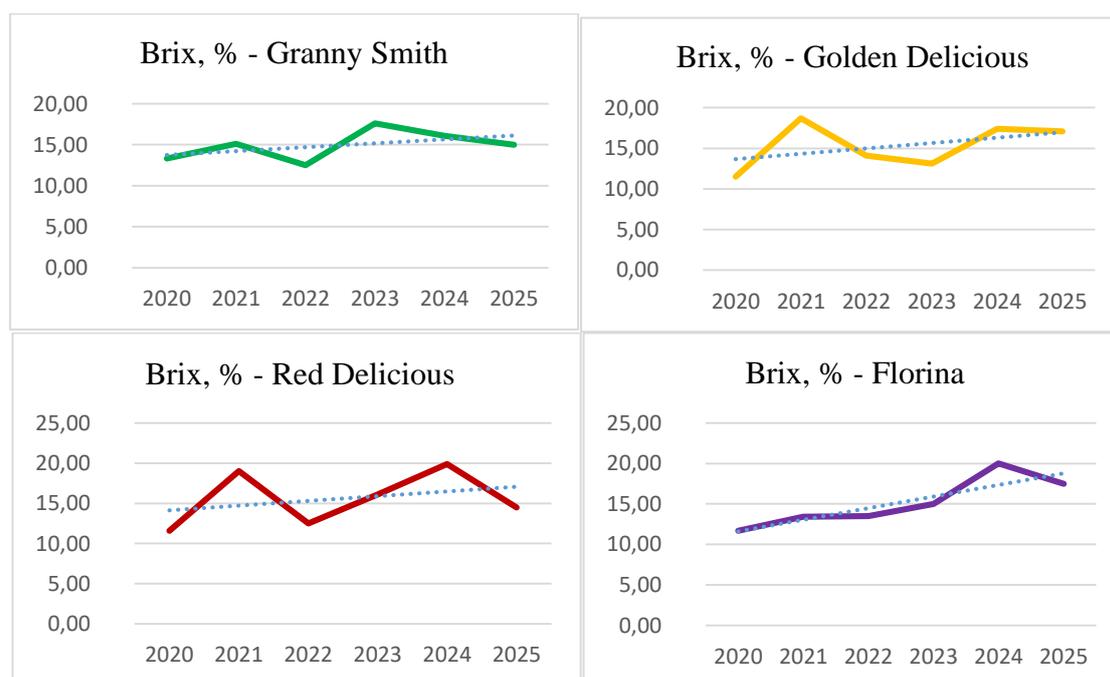
Variables	Brix, %	Fru (%)	EC, mS/cm	TDS, %	Salt, %	Acidity, pH	Redox, Eh, V	Juice yield, %	Vit.C, mg/l
Brix, %	<b>1</b>	0,849	-0,530	-0,990	-0,993	0,455	-0,025	0,994	0,385
Fru (%)	0,849	<b>1</b>	-0,002	-0,767	-0,781	0,857	0,508	0,901	0,815
EC, mS/cm	-0,530	-0,002	<b>1</b>	0,643	0,626	0,513	0,861	-0,435	0,579
TDS, %	-0,990	-0,767	0,643	<b>1</b>	1,000	-0,327	0,163	-0,969	-0,253
Salt, %	-0,993	-0,781	0,626	1,000	<b>1</b>	-0,348	0,142	-0,975	-0,274
Acidity, pH	0,455	0,857	0,513	-0,327	-0,348	<b>1</b>	0,879	0,549	0,997
Redox, Eh, V	-0,025	0,508	0,861	0,163	0,142	0,879	<b>1</b>	0,084	0,913
Juice yield, %	0,994	0,901	-0,435	-0,969	-0,975	0,549	0,084	<b>1</b>	0,482
Vit.C, mg/l	0,385	0,815	0,579	-0,253	-0,274	0,997	0,913	0,482	<b>1</b>

**Table 4.** Coefficients of determination (Pearson) for studied apple variety Granny Smith.

Variables	Brix, %	Fru (%)	EC, mS/cm	TDS, %	Salt, %	Acidity, pH	Redox, Eh, V	Juice yield, %	Vit.C, mg/l
Brix, %	<b>1</b>	0,720	0,281	0,981	0,986	0,207	0,001	0,988	0,148
Fru (%)	0,720	<b>1</b>	0,000	0,588	0,610	0,735	0,258	0,812	0,664
EC, mS/cm	0,281	0,000	<b>1</b>	0,414	0,392	0,264	0,741	0,190	0,335
TDS, %	0,981	0,588	0,414	<b>1</b>	1,000	0,107	0,027	0,940	0,064
Salt, %	0,986	0,610	0,392	1,000	<b>1</b>	0,121	0,020	0,950	0,075
Acidity, pH	0,207	0,735	0,264	0,107	0,121	<b>1</b>	0,772	0,301	0,994
Redox, Eh, V	0,001	0,258	0,741	0,027	0,020	0,772	<b>1</b>	0,007	0,834
Juice yield, %	0,988	0,812	0,190	0,940	0,950	0,301	0,007	<b>1</b>	0,233
Vit.C, mg/l	0,148	0,664	0,335	0,064	0,075	0,994	0,834	0,233	<b>1</b>

**Trends in the biochemical changes of apples:** Figure 2 and Table 1 show an increase in the total amount of dissolved sugars according to Brix (%) in all standard apple varieties studied, with increasing trends in sugars being proportional to the increase of temperatures. Some varieties show a positive correlation with precipitation, such as Granny Smith and Red Delicious, yet the others do not show such an addiction as Golden Delicious and Florina. The increase in the total amount of dissolved sugars in different parts of plants in different species has been described by different authors, for example, [10] gives a description of colloidal-chemical changes that depend on the dose of

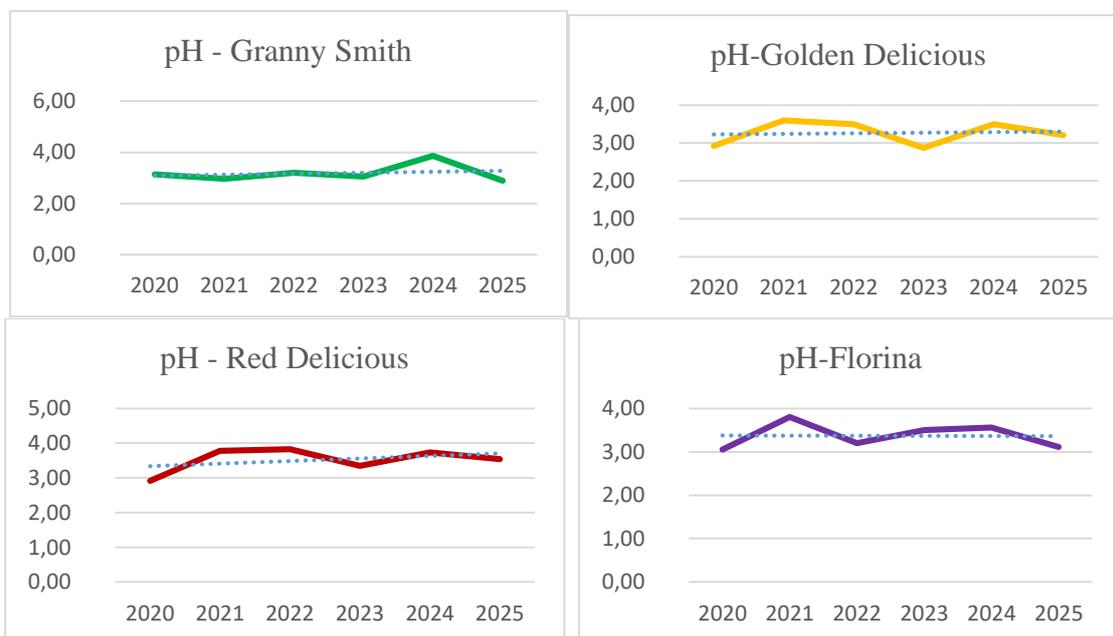
heat exposure. With a weaker thermal impact, the plant increases the intensity of life processes, as the growth and accumulation of dry matter and sugars is accelerated, the movement of the cytoplasm is detected, etc. With stronger or longer temperature impact, the metabolism of substances is disturbed. It ceases to accumulate dry matter and sugars. The movement of the cytoplasm slows down, and at an even higher temperature intensity, the plant reacts with irreversible changes in the structure of cells and metabolism. The cytoplasm vacuolizes and stratification of lipid compounds occurs [10].

**Figure 2.** Average total sugar content by Brix (%) by apple varieties, during the study period 2020-2025.

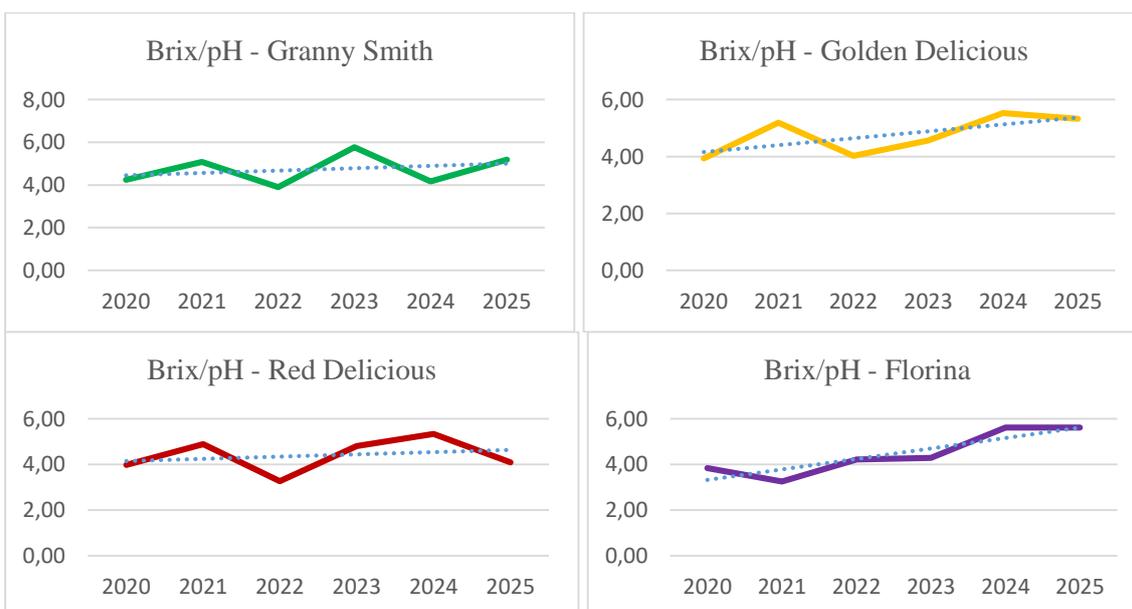
**Changing trends in the redox potential Eh (mV) of fruits:** No correlation has been established between the redox potential of apples of all varieties studied and precipitation or temperatures. The Eh values of apples vary in most cases between 100 and 400 mV, but most often it is around 300-400 mV. These values explain the high oxidation capacity of apples, i.e. they are very easily oxidized and destroyed in air. Their anti-oxidant capacity weakens, as well as their nutritional value.

**Changing trends in the pH acidity of apples:** In general, changes in the acidity of apples are not observed. There are separate measured pH values

in all varieties studied that correlate positively with temperature or precipitation, but the average content does not show any changing trend in the total (active) acidity, depending on precipitation (**Figure 3, Table 1**). The pH acidity remains relatively constant, but the increase in sugars leads to changes in the organoleptic properties of apples. The ratio of sugars/acids Ratio Brix/pH increases with rising temperatures, but there is also a positive correlation with precipitation, so this ratio gives the main sensations when eating apples. Apples become richer in flavour in terms of both sugars and acids (**Figure 4**), as scientist [11] identified Brix/pH=3.5-4.5 as most acceptable for direct consumption.



**Figure 3.** Average acidity pH by apple varieties, during the study period 2020-2025.



**Figure 4.** Average values of the ratio Brix/pH by apple varieties, during the study period 2020-2025.

**Trends in the evolution of the electrical conductivity (EC, mS/cm) of fruits:** The graph of the electrical conductivity of apples of the different varieties is approximately the same (Figure 5). It follows the cyclical precipitation. The trend is increasing, with the exception of Golden Delicious, which variety does not show a trend of EC changes. The presence of weak electrolytes, e.g. organic acids, which are part of the TDS or the presence of impurities,

precipitates, gases, etc. lead to the decaying of products due to anhydrous and waxy temperatures [12, 13]. This suggests that this apple variety is beginning to reach its maximum tolerance to warming and drought climate. As with the total amount of dissolved substances according to Brix, as well as in electrolytes, the tendency to increase their quantities is due to the higher temperatures (Figure 5, Table 1).

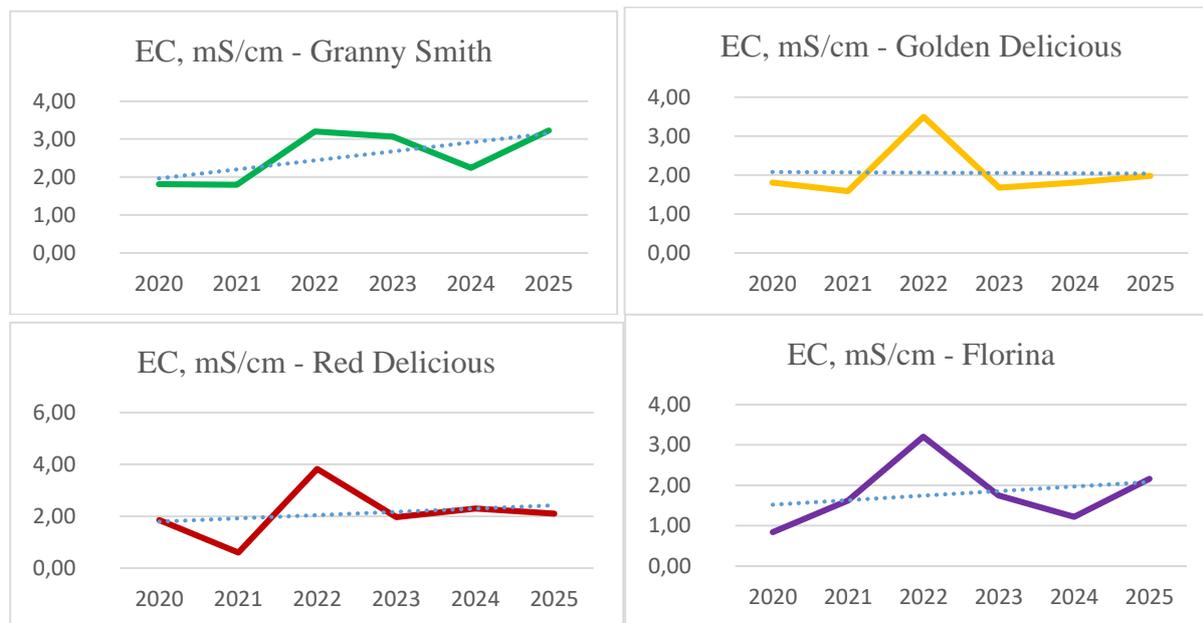


Figure 5. Average electroconductivity EC (mS/cm) by apple varieties, during the study period 2020-2025.

**Changing trends in the total amount of dissolved solids TDS (g/l):** The total amount of solids also rises with increasing temperatures. There is also a positive correlation with the amount of falling precipitation, but it is not always positive, as in the Golden Delicious and Red Delicious varieties. In pure water, the amount of salts and dissolved solids stays the same, but there is a certain amount of dissolved organic acids in

the plant fluids and the juices released from the fruit, and this equilibrium is disturbed [14]. An increase in the total amount of dissolved solids is a response of the plant to an increase in temperatures. The amount of released biologically active substances such as vitamins, auxins, toxins, amino acids, etc. increases. (Figure 6, Table 1) [10].

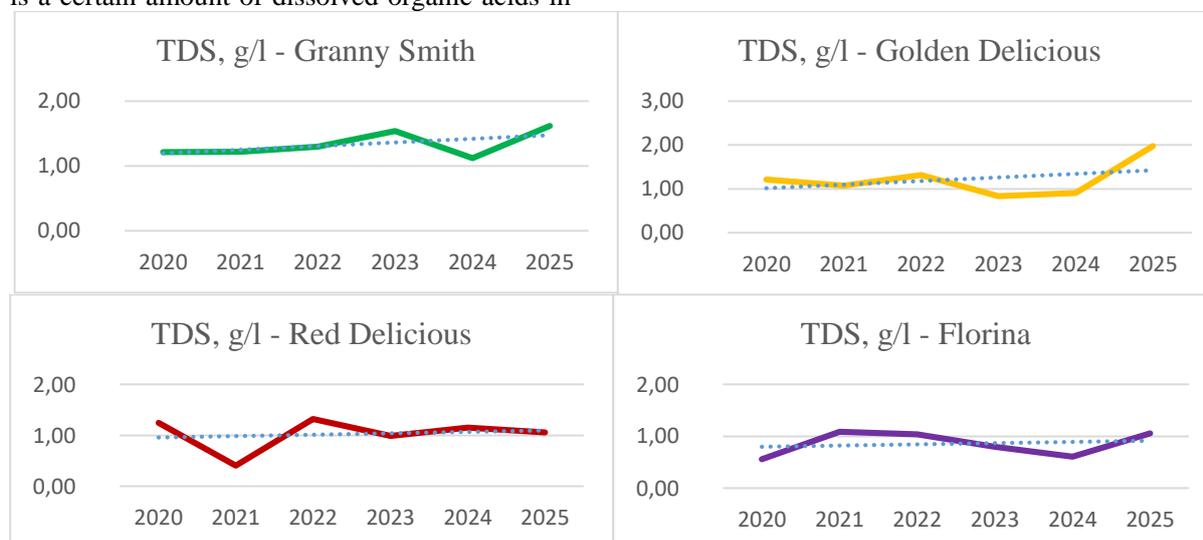
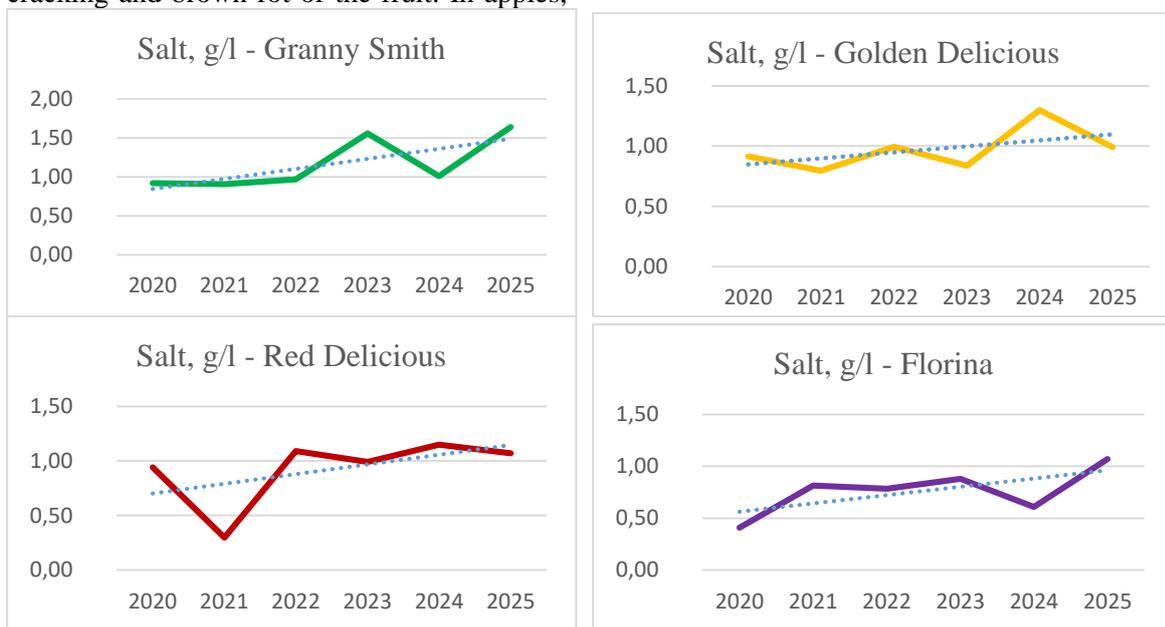


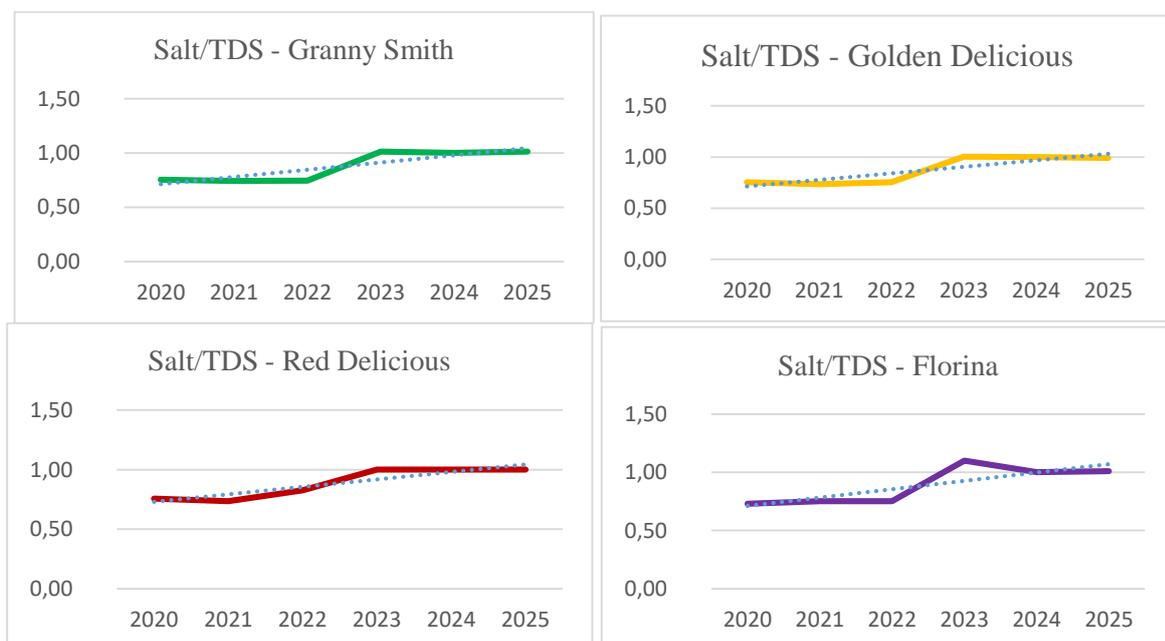
Figure 6. Average total dissolved solids TDS (g/l) by apple varieties, during the study period 2020-2025.

**Changing trends of salts (g/l).** Mineral salts are part of the dissolved solids in the plant fluids of apple fruits. **Figure 7** shows that, like the dissolved solids TDS and the other biochemical parameters studied at annual precipitation, which are in the norms, there is a positive correlation between the amount of precipitation and the salts. However, in dry years, such as 2024, 2025 and during an increase in temperatures, this TDS>Salt balance normal for plant fluids is disturbed and in almost all samples there is a predominance of Salt>TDS salts, i.e. the Salt/TDS>1 ratio (**Figure 8, Table 1**). This is especially true of cherries [15] leading to crop damages, expressed in massive cracking and brown rot of the fruit. In apples,

this phenomenon is also observed for the crop from 2024. The increased salt content disrupts the structure of cellular components, with chloroplasts, which are responsible for the adaptive response of plants to extreme impacts, reacting most strongly. Salts in plants can increase due to dehydration and increased temperature [10] but they can also be absorbed through the roots, as a result of soil salinization during extreme rainfall and the release of large amounts of salts, especially from clayey montmorillonite soils, followed by a period of drought and high temperatures. Thus, salts are deposited in the upper soil layer and cannot drain in depth [14].

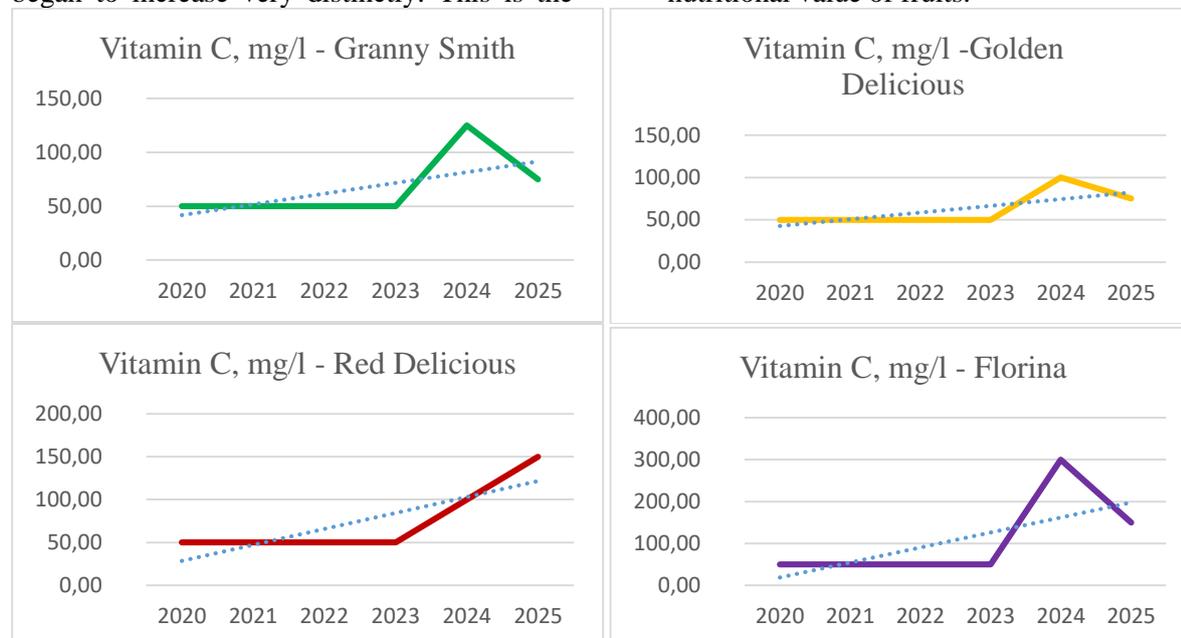


**Figure 7.** Average salt content Salt (g/l) by apple varieties, during the study period 2020-2025.



**Figure 8.** Average values of the ratio Salt/TDS by apple varieties, during the study period 2020-2025.

**Changing trends of vitamin C, mg/l (ascorbic acid) in apple fruit.** The measurement of vitamin C is semi-quantitative and the determined values are given in whole numbers. During the first 3 years of the study, the low values of vitamin C in apples, between 25 and 75 mg/l, were impressive, but in the next 3 years 2023-2025, the amount of vitamin C in apples began to increase very distinctly. This is the



**Figure 9.** Average content of Ascorbic Acid (Vitamin C) (mg/l) by apple varieties, during the study period 2020-2025.

It must be said that the increase in the observed biochemical indicators is a response to the climatic stress of plants. Up to a certain point this has a positive effect on both plants and the food products obtained from them, but damage and irreversible negative effects can be triggered by the extreme conditions.

## CONCLUSION

In the present study, we have demonstrated that under the conditions of climate change (higher temperatures and decrease/unevenness of precipitation), apple fruits react with a pronounced change in key biochemical indicators. Although some of the reactions (increase in sugars, salts, vitamin C) can improve the organoleptic and nutritional properties of fruits under moderate conditions, in extreme cases adverse effects, such as cellular damage and loss of resistance occur. An increase in other indicators such as electrolytes – salts and dissolved solids lead to damage to fruits and reach the maximum tolerance of plants to heat and drought.

These results are applicable both for selection and agricultural technology, as well as for

response of plants to adverse climate change, and in terms of the increase in the quantities of biochemical indicators considered so far, this is good news. Against the background of an increase in the content of sugars and salts, the increase in the amount of vitamin C in addition to increasing the resistance of plants, their antioxidant ability, immunity, also increases the nutritional value of fruits.

forecasting the quality of apple production under future climatic scenarios. We therefore recommend:

1. Use of statistical analyses (regression models, correlation analyses) to validate correlations between climatic and biochemical indicators.
2. Conducting experiments under controlled conditions (greenhouse) to distinguish the effect of temperature, light and water.
3. Incorporating more varieties and genotypic variability to find resistant lines.
4. Development of agrotechnical measures (shading, watering, selection of harvest dates) to mitigate the negative effects of climate change.

## REFERENCES

1. Atkinson, C., L. Taylor, J. Taylor, A. Lucas, Temperature and irrigation effects on the cropping, development and quality of 'Cox's Orange Pippin' and 'Queen Cox' apples. *Scientia Horticulturae - SCI HORT-AMSTERDAM*. 75. 59-81. 10.1016/S0304-4238(98)00117-4, (1998).
2. Calderón-Zavala, G., A.N. Lakso, R.M. Piccioni, Temperature effects on fruit and

- shoot growth in the apple (*Malus domestica*) early in the season. *Acta Hortic.* 636, 447-453, DOI: 10.17660/ActaHortic.2004.636.54, (2004).
3. Wahid, S., M. Gelani, M. Ashraf, R. Foolad, Heat tolerance in plants: An overview, *Environmental and Experimental Botany*, Volume 61, Issue 3, Pages 199-223, ISSN 0098-8472, (2007). <https://doi.org/10.1016/j.envexpbot.2007.05.011>.
  4. Lobell, D.B., S.M. Gourdjji, The influence of climate change on global crop productivity. *Plant Physiology*, 160(4), 1686–1697, (2012).
  5. FAO (Food and Agriculture Organization), Climate change and horticulture: Adaptation strategies, (2022). <https://www.fao.org/>
  6. Hongxia Tao, Hanqing Sun, Yufei Wang, Xin Wang, Yanping Guo, Effects of water stress on quality and sugar metabolism in ‘Gala’ apple fruit, *Horticultural Plant Journal*, Volume 9, Issue 1, Pages 60-72, ISSN 2468-0141, <https://doi.org/10.1016/j.hpj.2022.03.008>, (2023).
  7. Sultan, M.Z., K.A. Farouk, M.M. Elbagoury, E.M. Yahia, Trends in biochemical, anatomical mechanisms and molecular aspects in enzymatic browning of apples: a review. *Eur Food Res Technol* 251, 3305–3326 (2025). <https://doi.org/10.1007/s00217-025-04824-9>
  8. Lumovero, XLSTAT, Statistical and data analysis solution, (2025), <https://www.xlstat.com/en>
  9. XLSTAT – PRO, User’s guide. Addinsoft, New York, USA, Version 7.5, p. 1-104, (2025).
  10. Stancheva, Y. Ecological Foundations of Agriculture. PenSoft, Sofia-Moscow, 346 p., (2000).
  11. Sotirov, A., N., Glavev, D. Sotirov, S. Dimitrova, N. Pistalov, V., Sotirov, K. Sotirov, Agro-ecological and technological quality of some apples. *Journal WSEAS Transactions on Environment and Development* 17:56-65. ISSN: 1790-5079 (2021).
  12. Zhang, W., X. Chen, Y. Wang, L. Wu, Y. Hu. Experimental and Modeling of Conductivity for Electrolyte Solution Systems, *ACS Omega* 2020 5 (35), 22465-22474, DOI: 10.1021/acsomega.0c03013, (2020).
  13. Robinson, R.A., R. H. Stokes, Electrolyte Solutions. Second Revised Edition. Courier Corporation, 509 p., (2002).
  14. Ganev, S., Contemporary Soil Chemistry, Science and Art, Sofia, 372 p. (1990).
  15. Sotirov, A., A. Stoeva, Critical amounts of precipitation, causing damages to sweet cherry fruits. *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development*, Vol. 24, Issue 4, 2024, 759-766. ISSN 2284-7995, ISSN Online 2285-3952, (2024).