# CRITICAL AMOUNTS OF PRECIPITATION CAUSING DAMAGES TO SWEET CHERRY FRUITS QUALITY AND HARVEST IN KYUSTENDIL ORCHARD OF THE AGRICULTURAL INSTITUTE, BULGARIA

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***Abstract***

*Present study concerns one of the basic causes for cracking of sweet cherry fruits as a result of increased rainfall, and this amount is different for different soils. The study was done for the soils at the experimental orachard of the Institute of Agriculture – Kyustendil, Bulgaria, which are Chromic Luvisolssoils with acidity pH = 4.5-6.0. This soil is rich of the clay mineral montmorrilonite. As a result of extreme rainfalls the soil in the studied experimental field, the clay mineral montmorillonite starts to separate sodium Na, The area is rich also of chloritized slates which enriched the soil of chlorite Cl as the result is - salinization of the soil, enriching of NaCl.The amounts of precipitation needed for soil salinization, which causes damages - ckracking of cherry fruits. As a result of the present study, the critical amount of precipitations, causing damages – cracking on sweet cherry fruits is estimated on about 28 l/m$^2$. With these amounts of precipitation, a deterioration in the quality of the crop can be expected and even with forecast amounts of precipitation, it can be counteracted by adding of agricultural gypsum(the mineral gypsum) to the soil, according to the cited reference. In 2024, because of the high precipitations level, the salinity of the soil was very high in NaCl and this was the cause for which the harvest of sweet cherries was lost as many cherry trees died.*

**Key words**: *precipitations, sweet cherry cracking, fruit damages, juice quality, fruit harvest, climate changes*

## INTRODUCTION

The climate in the Kyustendil region is transitional-continental with relatively mild winters and warm and dry summers. The climatic conditions in the region are largely determined by its location and its good protection by mountain ranges, which diversify the relief and contribute to some difference in the different micro-regions. The winter is mostly mild and the summer is relatively warm for the altitude [8].

The aim of the study is to investigate the juices of 9 different sweet cherry cultivars and 1 hybrid 5645 for their technological parameters with a focus on Salt content (ppm) and total dissolved solids (TDS, ppm) and to be established the critical amounts of precipitation,causing damages to cherry fruits.

## MATERIALS AND METHODS

The research was carried out in an experimental orchard field of the Institute of Agriculture – Kyustendil, Bulgariaduring time period from April to June 2024. The experimental field of the study is 7.7 da. The sweet cherry plantation was grafted onto a prunus mahalebk and were planted in the spring of 1996 at 6 x 5m distances. Each cultivar was represented by 5 experimental trees, with each tree counted as a separate replicate, grown under non-irrigated conditions and formed into a freely growing crown. The object of the study were nine early ripening sweet cherry cultivars and one sweet cherry hybrid 5645 with different genetic origin as follow: Primavera, Superstar, Seneca, Diana, Fabulay, Ranna cherna edra, Tavrichanka, Bigarreau Burlat, Ranna ot Vil.Bigarreau Burlatis used for control cultivar for early ripening sweet cherry. The soil in the experimental plot is highly leached, slightly sandy-clay, *Chromic Luvisols* soils with a low-to medium acid reaction [5].

Stocking with absorbable phosphorus is low to medium, and with absorbable nitrogen very low. The soil surface is maintained in black fallow by periodic shallow tillage during the growing season, and in autumn by plowing to a depth of 15-18 cm. From the established methodology by [9] in Bulgaria, according to the period of ripening, cherry varieties are divided into 3 groups: early ripening (the first 1-2 weeks of sweet cherry ripening), medium ripening (3-4 weeks) and late ripening (5-6 weeks).

The juices of the cherry fruits by varieties were produced by the cold-pressing method with a single-shaft juicer Star Light SJB-150 R in laboratory, unpasteurized, without additives, at temperature 20°C in regular air environment. Minimum 5 measurements of the technological parameters of each cherry variety were done and average value is presented in the Table 1.

Soil survey instrument was used for measurement of the pH value and temperature (t°C) of the soil directly (*in situ*). The EC, TDS, and Salt in the soil were studied after aqueous extract in a ratio of soil: distilled: water=1:1. For this purpose, rain was simulated by adding 100 g of distilled water in 100 g of soil to activate the exchange of cations and for formation of electrolytes, necessary for the measurement [1].

A DigiScope 2.0 digital microscope was used for the microscopic soil studies, using white LED and UV-ultraviolete light.

For determination of the technological parameters of the sweet cherry fruits and their juice and soil aqueous extract, digital instruments were used as follow: Refractometer "Atago-Pal 1"- Australia. Bluetooth compatible water quality intelligent tester "Yieryi BLE-C600"-Chinaand instrument "Lovibond-SensoDirect 150"- United Kingdomwere used for determination of total acidity (pH), electrical conductivity (EC, µS/cm),total dissolved solids (TDS, ppm), total salt content (Salt, ppm,%), Specific Gravity (S.G.), Eh - Redox potential (mV), and temperature (°C).

## RESULTS AND DISCUSSIONS

Table 1 shows the results of measurements of the technological parameters of the cherry juice of the different varieties. The content of the total amount of sugars varies from 12.0% to 16.2%. The total acidity varies within a narrow range from 3.35 to 3.75. The redox potential varies from 79 mV to 207 mV. The salinity varies from 0.10% to 0.18%.

Table 1. Results of measurements of the technological parameters of cherry juice from different varieties

| No. | Sweet cherry cultivar/ Hybrid | Total Sugar content, Brix % | Acidity pH | Redox potential Eh, mV | Salt, % | Salt, ppm | Total Dissolved Solids TDS, ppm | Electro conductivity EC, µS/cm | Salt+TDS, ppm | Ratio Brix/pH | Ratio EC/TDS | Ratio EC/Salt | Specific gravity S.G. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Primavera | 12.0 | 3.37 | 79 | 0.15 | 1,713 | 1,560 | 3,160 | 3,273 | 3.56 | 2.03 | 1.84 | 1.0 |
| 2 | Superstar | 11.9 | 3.46 | 111 | 0.13 | 1,140 | 1,130 | 2,310 | 2,270 | 3.44 | 2.04 | 2.03 | 1.0 |
| 3 | Seneca | 16.2 | 3.38 | 138 | 0.11 | 1,180 | 1,170 | 2,350 | 2,350 | 4.79 | 2.01 | 1.99 | 1.0 |
| 4 | 5645 | 15.3 | 3.60 | 132 | 0.13 | 1,300 | 1,290 | 2,580 | 2,590 | 4.25 | 2.00 | 1.98 | 1.0 |
| 5 | Diana | 13.6 | 3.75 | 147 | 0.11 | 1,110 | 1,110 | 2,220 | 2,220 | 3.63 | 2.00 | 2.00 | 1.0 |
| 6 | Fabulay | 14.3 | 3.43 | 164 | 0.14 | 1,480 | 1,460 | 2,920 | 2,940 | 4.17 | 2.00 | 1.97 | 1.0 |
| 7 | Ranna cherna edra | 14.6 | 3.41 | 204 | 0.11 | 1,120 | 1,110 | 2,230 | 2,230 | 4.28 | 2.01 | 1.99 | 1.0 |
| 8 | Tavrichanka | 14.3 | 3.35 | 174 | 0.10 | 1,040 | 1,040 | 2,080 | 2,080 | 4.27 | 2.00 | 2.00 | 1.0 |
| 9 | Bigarreau Burlat | 13.6 | 3.45 | 207 | 0.18 | 1,870 | 1,840 | 3,690 | 3,710 | 3.94 | 2.01 | 1.97 | 1.0 |
| 10 | Ranna ot Vil | 14.0 | 3.46 | 181 | 0.17 | 1,750 | 1,720 | 3,440 | 3,470 | 4.05 | 2.00 | 1.97 | 1.0 |

Source: Original data from the experiment.

Fig. 1 shows the values of the content of total dissolved salts and the total amount of dissolved solids in the juice, which are almost equal.

From Fig. 2, it can be seen that the values of the electrical conductivity of the juice and the sum of the values of Salt+TDS, ppm by varieties are almost equal.

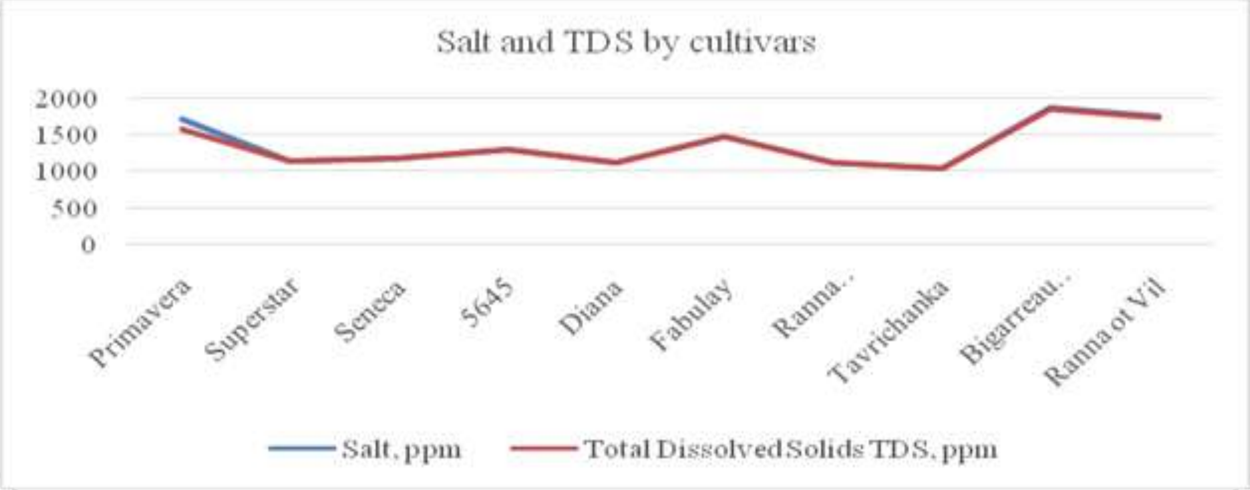



Fig. 1. Values of electrical conductivity of juice and the sum of Salt+TDS, ppm by variety, the lines almost coincide, because the values are very close
Source: Original figure.

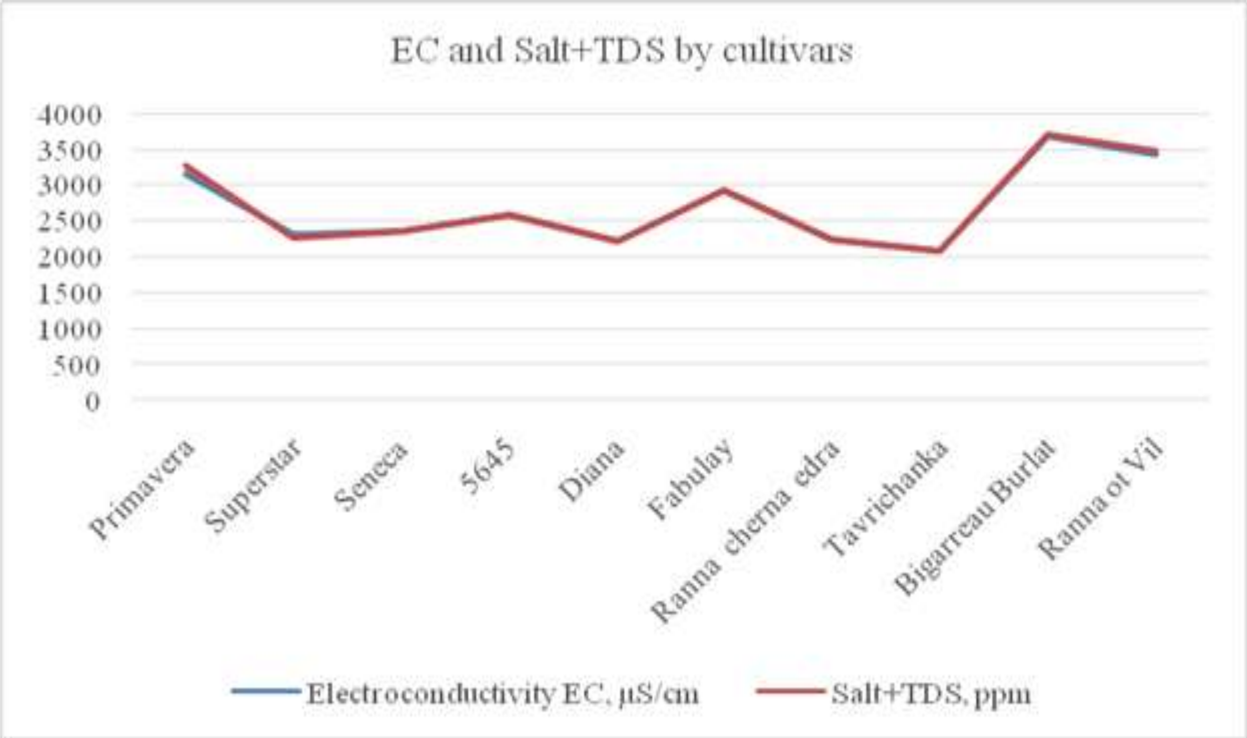



Fig. 2. Values of the content of total dissolved salts and total amount of dissolved solids in cherry juice by variety, the lines almost coincide, because the values are very close
Source: Original figure.

The authors of the present paper have worked on this topic for 5 years and the results are presented in Table 2. Actually, the problem concerns all cherry varieties, conditionally divided of early, medium and late ripening without any differences. During the years 2020, 2021 and 2022 the precipitations were often in smaller quantities, reaching up to 10 liters per sq. m. for a rainy period.

Table 2 shows that for these three years TDS are in greater quantities than Salt in cherry juice in all varieties, both early and late ripening.

Table 2. Average values of the technological parameters of the sweet cherry juices

| Year | 2020 | 2021 | 2022 | 2023 | 2024* | 2024** |
|---|---|---|---|---|---|---|
| Salt, ppm | 1,280 | 1,400 | 1,190 | 1,510 | 1,367 | 1,344 |
| TDS, ppm | 1,660 | 1,820 | 1,560 | 1,490 | 1,367 | 1,286 |
| Ratio Salt/TDS | 0.77 | 0.77 | 0.76 | **1.01** | **1.00** | **1.045** |

Source: Original data from the experiments.
Note: Total dissolved solids – TDS (ppm), total salts - Salt (ppm) and the ratio between them Salt/TDS for the last 5years – presented for comparison (previous own data-unpublished) (*-precipitations 28 l/1 sq. m.; **-precipitations more than 28 l/1 sq. m. period 21-26.04.2024).

But in 2023, precipitations of more than 70 liters per square meter was measured, during the ripening period of sweetcherries, as a result of which almost all cherry harvest was damaged, expressed in severe cracking and rotting of the fruits (Fig. 3, Fig. 8).

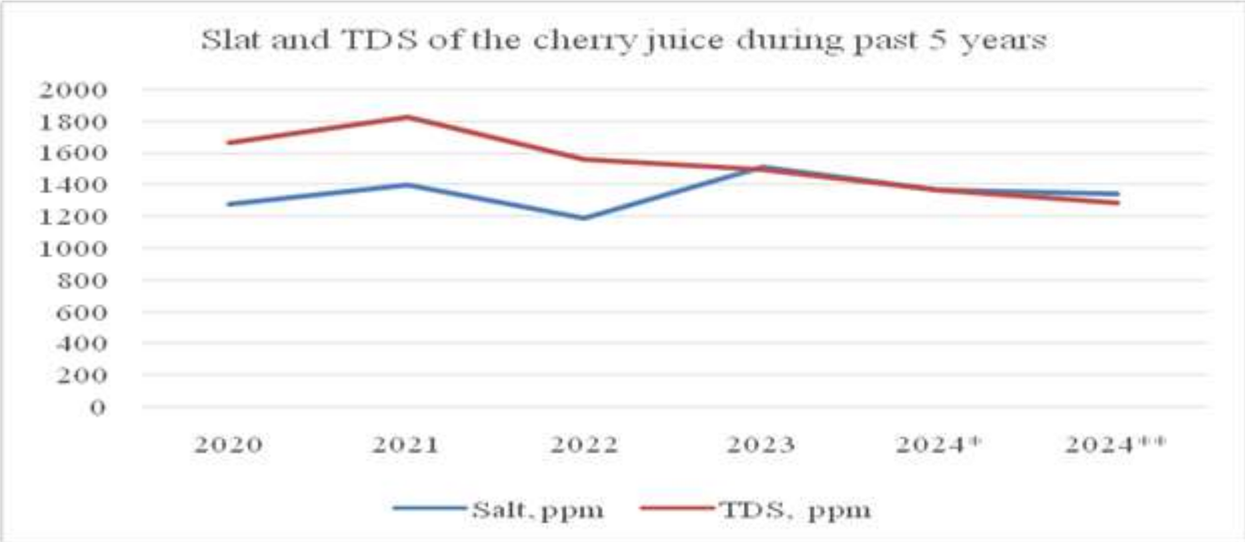



Fig. 3. Measured Salt and TDS content of the cherry juices during past 5 years
Source: Original figure.

In 2024, during the ripening of early sweet cherry varieties, there was precipitation below 20 l/m$^2$, but alsothere was one period with a total amount of precipitation of about 30 l/m$^2$, as a result of which it was possible to trace the gradual increase of salt content in the soil and in the fruits of all cherry varieties that ripen at that time Table 3, Fig. 4 and Fig. 5. Figure 4 presents the quantity of precipitation during the ripening period of early ripening sweet cherry varieties 2024, while Figure 5 shows the precipitations during the cherry rippening period season 2023– presented for comparison (previous own data-unpublished).

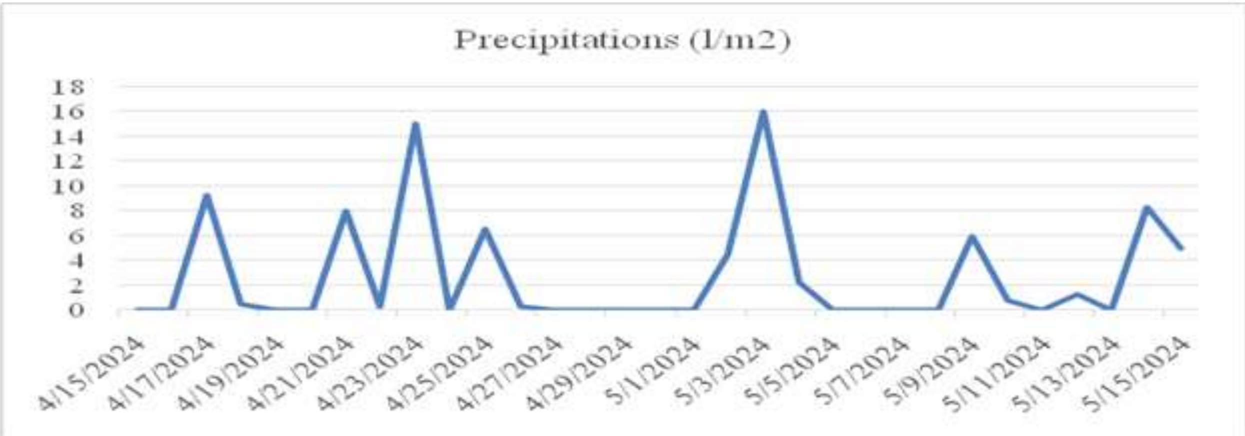



Fig. 4. Quantity of precipitation during the ripening period of early ripening cherry varieties 2024
Source: Original figure.

Table 3 presents the metereological data for the studied period in terms of: maximum air temperature, average air temperature, average air humidity, dew point, precipitations amount, soil moisture at 30 and 70 cm, soil temperature at 30 cm, and foliar moisture.

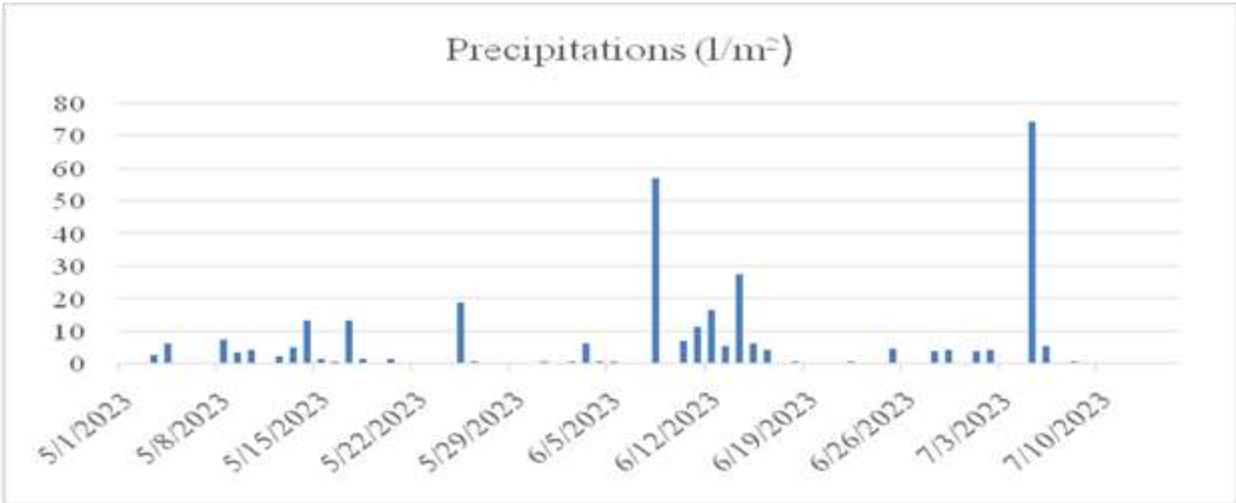



Fig. 5. Precipitations during the cherry rippening period season 2023– presented for comparison (previous own data-unpublished)
Source: Original figure.

Table 3. Metereological data for the studied period

| Date | Air temperature max. (°C) | Air temperature average (°C) | Air humidity average (%) | Dew point (°C) | Precipitation (l/m$^2$) | Soil moisture 30 cm (%) | Soil moisture 70 cm (%) | Soil temperature 30 cm (°C) | Foliar moisture (%) |
|---|---|---|---|---|---|---|---|---|---|
| 15.4.24 | 32.92 | 17.4 | 59.6 | 7.7 | 0 | 84.5 | 99.9 | 15.8 | 7.9 |
| 16.4.24 | 28.08 | 16.7 | 66.5 | 9.8 | 0 | 84.4 | 99.9 | 16 | 0 |
| 17.4.24 | 19.23 | 13.1 | 85.3 | 10.5 | 9.25 | 84 | 99.9 | 15.7 | 12.3 |
| 18.4.24 | 14.16 | 9.1 | 74.8 | 4.4 | 0.5 | 83.3 | 99.7 | 14.5 | 3.2 |
| 19.4.24 | 17.36 | 8.5 | 67.1 | 1.8 | 0 | 83 | 99.6 | 13.6 | 5.4 |
| 20.4.24 | 20.46 | 11.2 | 64.4 | 4.3 | 0 | 83.1 | 99.6 | 13.8 | 0.9 |
| 21.4.24 | 12.77 | 7.3 | 90.4 | 5.7 | 8 | 82.8 | 99.6 | 13.8 | 17.5 |
| 22.4.24 | 19.99 | 9.8 | 74.3 | 4.7 | 0.25 | 82.5 | 99.5 | 13.1 | 7.3 |
| 23.4.24 | 12.84 | 10 | 91.2 | 8.6 | 15 | 82.6 | 99.5 | 13.4 | 14.6 |
| 24.4.24 | 24.43 | 14.6 | 72.9 | 9 | 0 | 84.7 | 99.1 | 13.4 | 4.9 |
| 25.4.24 | 12.51 | 9.6 | 89.4 | 7.9 | 6.5 | 86 | 99.1 | 14.1 | 17.9 |
| 26.4.24 | 21.44 | 9.8 | 79 | 5.6 | 0.25 | 87.9 | 99.4 | 13.4 | 7.3 |
| 27.4.24 | 24.17 | 11.7 | 74 | 6.3 | 0 | 90.9 | 99.8 | 13.9 | 14.6 |
| 28.4.24 | 25.61 | 14.4 | 67.4 | 7.2 | 0 | 92.5 | 99.7 | 14.5 | 11.7 |
| 29.4.24 | 24.74 | 15 | 63.8 | 7.1 | 0 | 92.9 | 99.8 | 15.4 | 10.7 |
| 30.4.24 | 23.35 | 15.3 | 67.3 | 9.1 | 0 | 92.3 | 99.2 | 15.9 | 0 |
| 1.5.24 | 22.24 | 15.9 | 71.6 | 10.6 | 0 | 92.6 | 99.6 | 16.3 | 0 |
| 2.5.24 | 23.95 | 15.5 | 80 | 11.9 | 4.5 | 92.2 | 100 | 16.7 | 6.6 |
| 3.5.24 | 16.25 | 11.3 | 89.6 | 9.6 | 16 | 96.4 | 100 | 16.3 | 18.4 |
| 4.5.24 | 19 | 12.6 | 82.3 | 9.5 | 2.25 | 100 | 99.3 | 15.3 | 11.6 |
| 5.5.24 | 25.15 | 15.4 | 71.1 | 9.2 | 0 | 100 | 100 | 15.1 | 17.7 |
| 6.5.24 | 26.47 | 15 | 72.8 | 9.2 | 0 | 100 | 100 | 16.2 | 14.4 |
| 7.5.24 | 28.48 | 16.5 | 72.3 | 10.7 | 0 | 100 | 100 | 16.8 | 15.8 |
| 8.5.24 | 23.65 | 15.6 | 81.5 | 12.2 | 0 | 100 | 100 | 17.4 | 13.5 |
| 9.5.24 | 23.15 | 15.3 | 87 | 13 | 6 | 99.7 | 100 | 17.3 | 13.9 |
| 10.5.24 | 17.66 | 12.7 | 81 | 9.4 | 0.75 | 100 | 100 | 16.9 | 2 |
| 11.5.24 | 23.07 | 15 | 62.7 | 6.9 | 0 | 100 | 99.1 | 16.2 | 0.5 |
| 12.5.24 | 24.88 | 12.1 | 79.2 | 8.1 | 1.25 | 100 | 100 | 16.7 | 18 |
| 13.5.24 | 22.95 | 15.1 | 69.2 | 8.6 | 0 | 100 | 100 | 16.8 | 10.1 |
| 14.5.24 | 18.75 | 11.8 | 86.1 | 9.4 | 8.25 | 99.3 | 100 | 17 | 11.6 |
| 15.5.24 | 14.77 | 11.8 | 94.3 | 10.9 | 5 | 97.4 | 100 | 16.2 | 15 |

Source: Original data from own metereological station.

Christov and Stoeva (2015) [4] found that in the early-ripening cultivars Bigarreau Burlat, cracked fruits were within 26%, in the medium-ripening Kakianes (80%), Vega (79%), and in the late-ripening Elites 6541 (34%), 6528 (30%) and Regina (8%).

Chivu et al. (2023) published data about sweet cherry fruit cracking as a chronic problem in the era of climate change [3]. They think that the reason for cracking is that “as the fruit develops, the xylem (the only pathway through which calcium is transported) breaks the connection with the fruit, and the fruit's needs will be provided by the phloem, which leads to a continuous decrease of calcium in the fruit" [2]. Even if the results are contradictory, the use of calcium-based foliar products is used as a method to reduce sweet cherry fruit cracking".

[7] described the opposite climate effect - drought resistance and its influence on flower formation in sweet cherry.

Actually our investigations shows that the problem is in the soil, after high amount of precipitations. For the studied area – experimental orchard field of Institute of Agriculture-Kyustendil, Bulgaria, this critical amount of precipitations, caused damages on the cherry fruits is calculated aboput 28 liters per sq. m. per a precipitation period (hours or days) as shown in Fig. 5, Fig. 6, and Fig. 7.

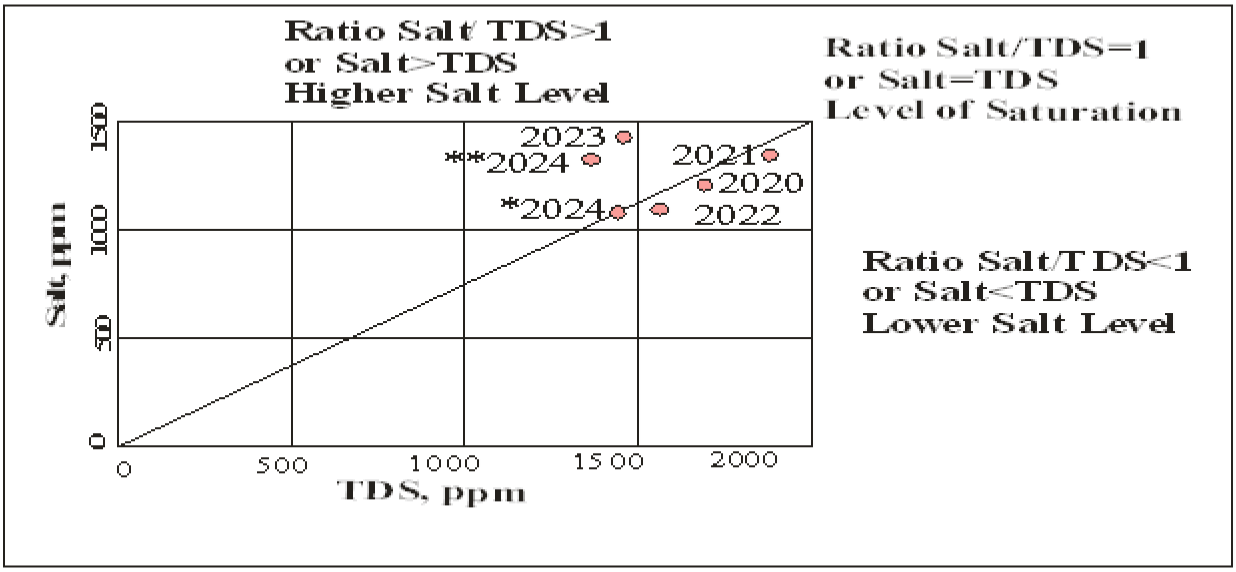



Fig. 6. Ratio Salt-TDS diagram of the cherry juice (*-precipitations 28 l/1 sq. m.; **-precipitations more than 28 l/1 sq. m. period 21-26.04.2024).
Source: Original figure.

Fig. 7. Sweet cherry fruit cracking on variety Ranna ot Vil, May 2024
Source: Original figure.

The soil on the territory of the experimental field of the Institute of Agriculture in Kyustendil is defined as leached *Chromic Luvisols* (FAO-ISRIC-IUSS, 2006) [13], as the soil pH varies from 5.0 to a depth of 0-10 cm and reaches 5.4 at a depth of 100 cm, and the humus is 0.98% at the surface and decreases to 0.40 at 100 cm, according to [14].

Table 4 presents the studied characteristics, related with the soil of the target experimental fields.

As a result of the study was determined that, because of the climatic changes and accompanied abnormal phenomenon as extreme rainfalls, the ordinary soils may become problem soils. As a result of extreme rainfalls the soil in the studied experimental field and especially the clay mineral montmorillonite, according to [10], who started to separate sodium Na, and the area is rich of chloritized slates which enriched the soil of chlorite Cl as the result is salinization of the soil, mainly NaCl.

Because of this reason the harvest from cherries was damaged and many cherry trees died in the area. For figuring out the problem soil we suggested using of the mineral gypsum as appropriate method to improve the soil fertility and structure during periods of extreme rainfalls.

Table 4. Summarized results from the measurements of the agroecological and agrotechnological parameters of the soils – distilled water extract and precipitations of the studied area

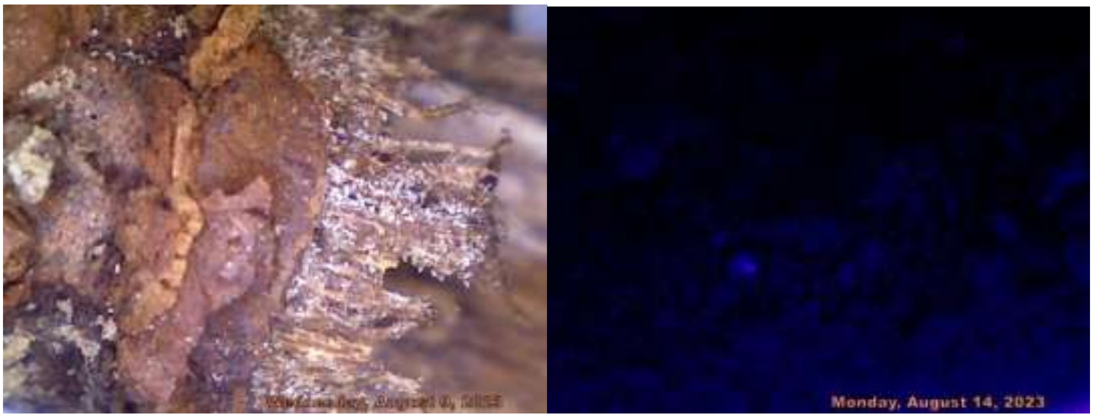
| **Measured Parameter** | **Temperature, °C** | **pH, Total Acidity** | **Conductivity (EC), µS/cm** | **Total Dissolved Solids (TDS), ppm** | **Salt, ppm** | **Redox-potential (Eh), mV** |
|---|---|---|---|---|---|---|
| Average, 49 samples | 7.0 | 4.5-6.0 Average 4.94 | 140.00 | 70.00 | 68.00 | 84.00 |

Source: Original data from experiment.

The classical theory develops the melioration of alkaline soils as a process of ion exchange sweeping of sodium cations on the calcium adsorbent by introducing gypsum materials, which is why this melioration is called gypsum: soil $Na_2+CaSO_4 \Leftrightarrow$soil $Ca+Na_2SO_4$ [6].

Ratio TDS/Salt is described also by [11] and [12] as usually TDS>Salt when during ripening period rainfalls are less than 28 $l/m^2$ per a rain period.

Fig. 8 is a microscopic pictures of the mineral halite into roots of died cherry tree after almost 80 $l/m^2$ rain period during 2023. Fluorescence of the halite was observed with microscope under blue light. The taste of the mineral was salted and bitter.




a) b)

Fig. 8. a) Crystals of the mineral halite (NaCl-salt) in the openings of the roots of sweet cherry tree – reflected light, air environment, magnification x20; b) – The mineral halite as solder between soil grains (the blue grain), ultraviolet light, air environment, magnification x20.
Source: Original figures.

**The impact of the precipitations in the year 2024 on the harvest of sweet cherry trees**

Due to the climatic changes expressed in terms of extreme rainfalls in the year 2024, the ordinary soils have become problem soils. The high rainfalls have deeply affected the soil in the studied experimental field and especially the clay mineral montmorillonite.

Sotirov (2024a) separated clay mineral montmorillonite, which is rich of sodium Na [6], and because the area is rich of chloritized slates [10], the soil has become enriched by chlorite Cl and, in consequence, it resulted the salinization of the soil, mainly NaCl [1,10].

For this reason, in the year 2024, the harvest of sweet cherries was deeply damaged as many cherry trees died in the area.

## CONCLUSIONS

This study concerns the basic causes of cracking of cherry fruits as a result of increased rainfalls during years 2023 and 2024, according to measurements of the Meteo-station "Meteobot", compared with previous years. The study was done for the soils in the cherry plantations, which are *Chromic Luvisols* soils with acidity of pH = 4.5-6.0. This soil is rich of the clay mineral montmorrilonite. As a result of extreme rainfalls the soil in the studied experimental field and especially the clay mineral montmorillonite starts to separate Sodium(Na), and ate the same time the area is rich of chloritized slates which enriched the soil of chlorite Cl as the result is salinization of the soil, mainly with NaCl. The critical amounts of precipitation, which causes soil salinization were estimated of average 28 $l/m^2$ per a precipitation period. With these amount of rain, a deterioration in the quality of the sweet cherry crop, that reach technological maturity at the same time can be expected and also if there is forecast amounts of precipitation, it can be counteracted by agricultural fertilizer –the mineral gypsum.

The main conclusion of this study is that as a result of a certain amount of precipitation that fell for a short period of time on areas with cherry trees during the technological ripening of their fruits, depending on the type and composition of the soil, soil salinization occurs, which caused damages on the cherry fruits as a result of the disturbed water-salt balance of the solutions in the tree. Accordingly, an imbalance of the osmotic pressure of the fruit cells occurs, which can lead to damage to the cherry harvest.

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