SALT ACCUMULATION IN POLYTUNNEL SOILS UNDER TOMATO CULTIVATION IRRIGATED WITH SURFACE WATER

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Abstract

Tomatoes cultivated in polytunnels require frequent irrigation due to high evapotranspiration rates and intensive production. When surface water from rivers or lakes is used, its elevated mineral content can gradually lead to soil salinization and structural alterations. The accumulation of salts in the root zone negatively affects tomato growth and yield, mainly by reducing water uptake and causing nutrient imbalances. This study investigates salt accumulation in the soil over the course of one growing season in a polytunnel located in Iași County, Romania. Soil samples collected before and after the season confirmed a progressive buildup of salts, highlighting the long-term risks associated with the repeated use of mineral-rich surface water in protected tomato cultivation systems. Every two weeks, analyses of irrigation water samples revealed carbonate concentrations ranging from 0.4 to 0.8 me/L, with maximum values of 2.85 me/L, and bicarbonate concentrations between 2.34 and 5.81 me/L. The results suggest that even within a single cultivation cycle, measurable salinization can occur, potentially predisposing soils to degradation over time.

Key words: carbonates, SAR, soil pH, soil salinity, TDS

The cultivation of tomatoes in polytunnels is an increasingly widespread agricultural practice in Romania, due to the advantages related to protection against adverse climatic factors and the extension of the growing season. However, the frequent use of irrigation water with high mineral content, often from surface water sources, can lead to the accumulation of salts in the soil and structural changes, negatively affecting crop growth and yield. Studies have shown that high soil salinity negatively influences tomato growth by reducing water uptake and causing nutrient imbalances (Roșca *et al*, 2023; Karaca *et al*, 2022).

In soil, salts gradually accumulate through repeated application of mineral-rich irrigation water, and their movement depends on soil texture, structure, and the irrigation regime. Consequently, salts can migrate to deeper layers, affecting the root zones and reducing nutrient uptake efficiency (Jiang et al., 2025; Cantore et al., 2012; Razi & Khadhir, 2021).

Over time, excessive salt accumulation can lead to increased soil electrical conductivity and osmotic stress in plants, precipitation of calcium and magnesium carbonates that can alter soil structure, as well as variations in soil pH. These changes may cause structural degradation of the soil, reducing its capacity to support optimal plant development (Yan *et al*, 2024; Furdi *et al*, 2013).

In this context, the present study aims to investigate salt accumulation in the soil over a growing season in a polytunnel located in Iași County, Romania. By monitoring irrigation water weekly and analyzing soil samples collected at different depths, the study seeks to highlight the long-term risks associated with the repeated use of mineral-rich water for irrigating tomatoes in protected systems.

MATERIAL AND METHOD

The experiment was carried out in a 600 m² polytunnel located in Iași County, cultivated with tomato, grown in a single cropping cycle The crop was established in March 2024, and harvesting was carried out from June 10 to October 22, 2024. Fertilization was applied at a rate of 60 tons/ha of fermented manure and incorporated into the soil prior to mulching. Soil beds were then covered with polyethylene film, and drip irrigation was applied. Irrigation water originated from the Jijia River and was collected directly from the drip irrigation tapes inside the polytunnel.

The applied irrigation regime provided a weekly water volume of 8–12 m³, depending on the developmental stage of the plants.

Soil sampling was performed before irrigation at four depths, taken at 10 cm intervals depth. The soil was analyzed for carbonate, bicarbonate, and TDS, as well as for organic matter, phosphorus (P), and potassium (K), with P

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and K extracted in water, in order to assess both salt accumulation and overall soil fertility. Water samples were collected at every two-week irrigation event. All analyses were conducted in the "Plant Nutrition and Soil Fertility" Laboratory of the "Ion Ionescu de la Brad" Iași University of Life Sciences.

The following analytical methods were applied:

- Soil and water pH was measured in a 1:5 soil-to-water suspension using a glass electrode from Hannah Instruments.
- Total dissolved salts (TDS) were determined using the gravimetric method, by evaporating the water and weighing the residual solids.
- Calcium and magnesium concentrations were quantified by complexometric titration with EDTA (Complexon III), classical method.
- Sodium and potassium content was measured using flame photometry, allowing precise determination of alkali metal concentration.
- Carbonates and bicarbonates in water were determined by acid titration with sulfuric acid in the presence of phenolphthalein and methyl orange indicators, a standard volumetric procedure.
- Chlorine concentration in soil was determined by Mohr method
- SAR Sodium Adsorption Ratio - mathematical calculation

Sampling and analyses were repeated every two weeks, throughout the growing season, for the irrigation water to assess the dynamics of salinity and mineral accumulation.

RESULTS AND DISCUSSIONS

During the vegetation period, the irrigation water content showed significant variations, influenced both by spring precipitation and by high summer temperatures. The values of the analyzed water parameters provide a clear picture of its quality and allow for their classification within the accepted limits (**Table 1**).

Table 1

Recommended chemical content of the irrigation water

Water Parameter	Desired Range
pH	6.5–8.4
ECw	<0.75 dS/m
TDS	<480 ppm
SAR	<6
Hardness	>50 and <150 ppm
CO_3^{2-}	<0.5 meq/L
HCO_3^-	<2 meq/L
Cl	<70 ppm
B	<0.5 ppm

The average concentrations of carbonates and bicarbonates were approximately twice the recommended levels, namely 0.9 meq/L for CO_3^{2-} and 4.3 meq/L for HCO_3^-. The pH of the irrigation water, recorded during the first five irrigations in April–May, remained within the neutral range. However, starting in June, the water reaction became alkaline, reaching maximum values of 9.1 (Table 2).

The slight variation in bicarbonate content indicates that these ions remained in solution, while the increase in carbonate concentration correlates with the marked rise in pH, which exceeded the maximum recommended value for irrigation water.

Table 2

Chemical content of the irrigation water*

Parameter	pH	TDS (mg/L)	SAR	CO_3^{2-} (meq/L)	HCO_3^- (meq/L)	Na^+ (meq/L)	Ca^{2+} (meq/L)	Mg^{2+} (meq/L)
U1	7.4	400	3.82	0.82	4.99	6.09	1.82	3.26
U2	7.7	470	4.04	0.61	4.79	6.26	2.02	2.78
U3	7.5	420	3.89	0.82	5.81	6.43	2.11	3.36
U4	7.7	330	4.00	0.41	4.79	6.22	1.82	3.02
U5	7.3	380	4.01	0.41	5.20	6.09	1.44	3.17
U6	8.1	330	4.40	0.41	2.34	6.26	1.06	2.98
U7	8.5	300	4.52	2.85	4.69	6.26	0.96	2.88
U8	8.8	320	4.40	1.20	3.46	6.09	1.06	2.78
U9	9.1	360	4.38	1.22	2.65	6.43	1.15	3.17
Mean	8.0	367	4.16	0.97	4.30	6.2	1.50	3.00
Min.	7.3	300	3.82	0.41	2.34	6.09	0.96	2.78
Max.	9.1	470	4.52	2.85	5.81	6.43	2.11	3.36
Median	7.7	360	4.04	0.82	4.79	6.26	1.44	3.02
Interval	1.8	170	0.70	1.44	3.47	0.34	1.15	0.58

*analyses were performed on 9 samples(U1-U9) taken in April-July

The concentrations of sodium, calcium, and magnesium were analyzed to determine the Sodium Adsorption Ratio (SAR). A greater variation was observed in calcium content (range: 1.15), a smaller variation in magnesium (range: 0.58), and high stability in sodium (range: 0.34). This indicates that calcium and magnesium ions are prone to precipitation, while sodium remains in solution. Under these conditions, the SAR showed slight increases, reaching a maximum value of 4.52, which remains below the maximum limit allowed for irrigation water. The total dissolved solids (TDS) content ranged between 300 and 470 ppm, with only the maximum value reaching the upper admissible limit (Table 2).

Soil analysis was carried out at the beginning of May at two depths. The soil is classified as moderately alkaline, with a pH of 8.1–8.2, and shows a higher TDS content in the upper layer. A higher concentration was also observed for chloride ions, with values decreasing from 22.5 meq/L to 15 meq/L at a depth of 20–40 cm (Table 3). These two factors negatively affect plant development due to their high presence in the plant root zone.

The observed vertical distribution of chloride and total dissolved solids indicates a strong accumulation of soluble salts in the upper 0–20 cm layer, which is typical for clay loam soils under greenhouse conditions (Table 3). Similar trends were reported in irrigated vegetable systems in northeastern Romania, where limited drainage and high evapotranspiration favored surface accumulation of salts (Stan et al., 2022). Such accumulation poses potential risks for tomato crops, as both salinity and alkalinity can alter nutrient uptake and root physiology (*Qadir et al*, 2007).

Table 3

Soil parameters in May, 2024

Parameters of soil salinity	0–20 cm depth	20–40 cm depth
pH	8.1	8.25
TDS (%)	0.49	0.17
Cl^- (meq/kg)	22.5	15.0
Ca^{2+} (meq/kg)	2.2	4.8
Mg^{2+}(meq/kg)	12.5	12.0
K^+ (meq/kg)	7.0	5.5
Na^+(meq/kg)	3.4	3.0
CO_3^{2-} (meq/kg)	0.1	0.1
HCO_3^- (meq/kg)	0.8	1.01
$CaCO_3$ (%)	18.1	20.3

The seasonal evolution of total dissolved solids (TDS) in the soil profile is illustrated in Figure 1. The data reveal a distinct temporal and vertical pattern. The mean TDS values increased from 0.33% in May to a peak of 0.64% in July, followed by a decline to 0.36% in October.

This pattern corresponds to the combined influence of temperature, irrigation frequency and evapotranspiration intensity. During the summer months, higher evaporation rates and repeated irrigation promote the upward movement of salts, leading to surface accumulation (Rhoades *et al*, 1992; Qadir *et al*, 2007).

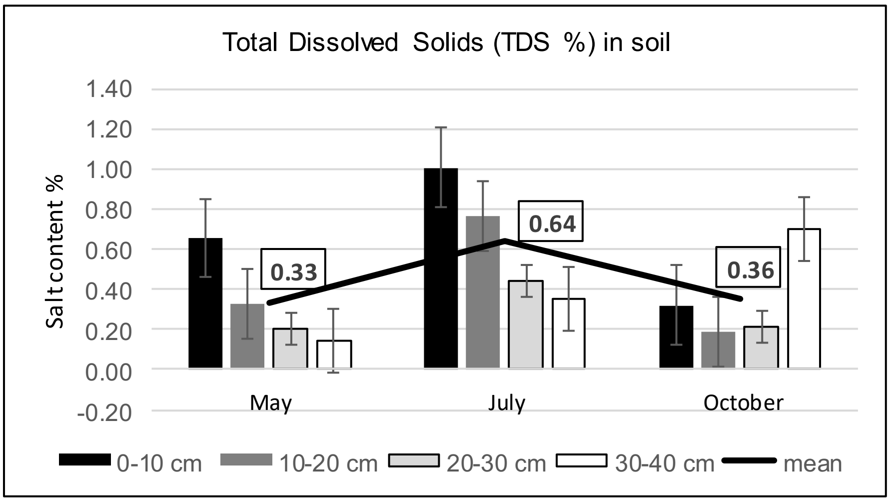

Figure 1 **The impact of irrigation water on soil TDS (%), year 2024**

Throughout the season, the highest TDS values were consistently recorded in the 0–10 cm soil layer, while the lowest values appeared at 30–40 cm, showing a decreasing gradient with depth. Such a distribution suggests limited leaching and confirms the tendency for salts to concentrate within the rhizosphere in greenhouse conditions (Bauder *et al*, 2014; Al-Rawahy *et al*, 2011).

The mid-season maximum observed in July coincides with periods of increased irrigation and the highest air temperatures, when evapo-concentration processes dominate. Similar behavior was described in studies on tomato crops irrigated with river and well water sources, where salinity peaks occurred during summer (Karaca *et al*, 2022).

The decline in TDS values recorded in October can be explained by reduced irrigation intensity and partial leaching due to autumn precipitation. These processes allow a temporary downward migration of salts, as also observed by Stan *et al* (2022) in Moldavian soils with comparable texture and water regime. However, the persistence of higher salt contents in the upper layer suggests that leaching is incomplete, emphasizing the importance of active management practices to prevent long-term accumulation.

The measured pH (up to 9.1), high bicarbonate and carbonate levels, and moderate TDS values point to a potential bicarbonate-induced alkalinity hazard. When calcium and magnesium precipitate as carbonates, the effective sodium proportion in the soil solution increases, potentially elevating SAR and impairing soil structure over time (Bauder *et al*, 2014; Jalali & Najafi, 2010). Although current SAR levels remain within the safe range, continued use of such irrigation water, combined with poor drainage typical of greenhouse systems, may gradually enhance sodicity risks (Ayers & Westcot, 1985; Al-Rawahy *et al*, 2011).

CONCLUSIONS

Irrigation with surface water characterized by elevated carbonate and bicarbonate levels led to slight soil alkalization and promoted salt accumulation in the upper soil layer.

Vertical distribution of salts revealed a decrease in TDS with depth, indicating limited leaching and a tendency for salt accumulation in the root zone.

Although SAR and TDS values remained within acceptable limits, continuous monitoring and periodic leaching are essential to prevent long-term soil salinization.

These findings highlight the importance of regular monitoring of irrigation water quality and soil salinity in greenhouse tomato cultivation. Implementing preventive management practices such as leaching and calcium amendments can ensure sustainable soil fertility and maintain long-term crop productivity under semi-arid conditions.

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