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# RESPONSE OF TWO CHERRY ROOTSTOCKS TO SALINITY

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## ABSTRACT

One of the most significant abiotic stressors limiting the productivity of woody perennial crops is soil salinity, which impedes the uptake of essential nutrients and water. In regions with saline irrigation water, the ability of cherry rootstocks (*Prunus avium* L.) to withstand salt is crucial for maintaining the sustainability and yield of orchards. The aim of this study was to evaluate the tolerance of two sweet cherry rootstocks to NaCl stress, on the main morphological and growth traits. In this study two commercial cherry rootstocks Maxima 14 (*Prunus mahaleb* × *P. avium*) and Gisela 6 (*Prunus cerasus* × *Prunus canescens)*, were used to evaluate their response to increasing concentrations of sodium chloride (NaCl). Over a four-month period, four salinity treatments (0, 1.022, 2.044, and 4.090 g NaCl/l) were administered weekly. Morphological parameters, including plant height, root and total fresh weight, leaf number and fresh weight, stem/root diameter, and root length were measured. The findings of the study revealed significant differences between the two rootstocks in various growth indices. Maxima 14 showed better stability under salt stress, whereas Gisela 6 was more sensitive even at moderate NaCl concentrations. These findings offer important insights for rootstock selection in cherry cultivation under saline conditions.

**Keywords**: *rootstocks, salinity stress, Gisela 6, Maxima 14, sodium chloride.*

## INTRODUCTION

The cherry tree (*Prunus avium*) is a deciduous tree belonging to the Rosaceae family. In Greece, its cultivation is particularly widespread in mountainous and semi-mountainous areas, where the climate is ideal for its growth. Sweet cherry (*Prunus avium* L.) is one of the most important fruit crops worldwide, valued for its high nutritional content, sensory quality, and significant economic role in both fresh consumption and processing industries. In Greece, cherry production occupies approximately 10,000 ha, with the regions of Central and Western Macedonia—particularly Pella and Imathia—representing the major production zones. Annual production fluctuates between 40,000 and 60,000 tons depending on climatic conditions during flowering and fruit development, while average yields range between 4.5 and 6.5 t $ha^{-1}$. Despite its economic importance, cherry cultivation faces significant challenges arising from both biotic and abiotic stresses. Among abiotic constraints, water scarcity, salinity, extreme temperatures, and soil-related disorders have emerged as major limiting factors for orchard productivity and fruit quality. In recent decades, climate change and the expansion of irrigated agriculture in semi-arid areas have exacerbated problems associated with salinity stress.

Soil salinity is currently one of the most severe abiotic stresses limiting crop productivity worldwide, affecting plant physiology and development (Flowers, 1990; Parida & Das, 2005). One of the primary effects of sodium toxicity is the displacement of calcium ions from root cell membranes, which compromises membrane stability and selectivity (Cramer et al., 1985). Elevated salt concentrations disrupt plant water relations, nutrient uptake, and metabolic processes, ultimately reducing biomass accumulation and yield (Chartzoulakis, et al., 2002; Läuchli, and Grattan, 2007; Abdallah et al., 2016). Salinity tolerance varies widely among species and genotypes, depending on their genetic background and adaptive mechanisms. Plants respond to salinity through a variety of mechanisms, including selective ion uptake and exclusion, osmotic adjustment via the accumulation of compatible solutes, and structural modifications of membranes and photosynthetic apparatus (Acosta-Motos, et al., 2017). However, tolerance is highly species- and genotype-dependent, often controlled by complex genetic and biochemical interactions.

The use of tolerant rootstocks has been widely recognized as an effective strategy to mitigate salt stress, as demonstrated in grapevine where $Cl^-$-excluding rootstocks significantly improved growth under saline conditions (Gibberd et al., 2003). Recent advances in biotechnology have further contributed to the understanding and enhancement of plant tolerance mechanisms to abiotic stresses, including salinity (Pérez-Clemente et al., 2012). Practical guidelines have also been developed for determining threshold values of salinity tolerance in agricultural crops, which are valuable tools for growers and advisors (Kotuby-Amacher et al., 2000). In Greece, cherry cultivation is among the most important fruit industries, with a strong concentration in the regions of Macedonia (Kazantzis, 2013).

In fruit trees, and particularly in cherries, rootstock selection is a critical factor for orchard establishment and long-term sustainability. Rootstocks selection plays a key role in cherry adaptability to soil and water salinity. Understanding the response of different genotypes helps optimize orchard performance. The objective of this study was to evaluate the tolerance of two cherry rootstocks, to NaCl stress on the main morphological and growth traits.

## MATERIALS AND METHODS

The experiment was conducted using 90 one-year-old cherry rootstock seedlings: 45 of ‘Gisela 6’ (*Prunus cerasus* cv. Schattenmorelle × *Prunus canescens*) and 45 of ‘Maxima 14’ (*Prunus mahaleb* × *Prunus avium*). Each seedling was transplanted into 33 L pots filled with a soil mixture consisting of light loam, enriched with peat and perlite to improve aeration and water-holding capacity.

The experimental design was RCB with ten replications, with four treatments per rootstock. Treatments consisted of different concentrations of sodium chloride

(NaCl) applied through irrigation water (0 g $L^{-1}$ NaCl control, 1.022 g $L^{-1}$ NaCl, 2.044 g $L^{-1}$ NaCl, 4.090 g $L^{-1}$ NaCl). Each pot received 2 L of the respective solutions once per week during the summer season (from early May to mid-September). All plants were initially irrigated with fresh water for several weeks to allow uniform establishment before salinity treatments commenced.

The experiment was conducted in a plastic-covered Macedonian-type greenhouse to prevent rainfall interference and ensure controlled irrigation. Standard horticultural practices were followed. During the growing period, morphological and physiological parameters (leaf number, biomass, root length, stem thickness, SPAD) were recorded. Observations of visible salt stress symptoms (leaf burn, necrotic spots, defoliation, reduced vigor) were also documented weekly.

Collected data were subjected to analysis of variance (ANOVA) to determine the effects of salinity, rootstock genotype, and their interaction on the measured parameters. Means were compared using the Least Significant Difference (LSD) test at $p \leq 0.05$. Statistical analyses were performed using standard agronomic software packages.

## RESULTS AND DISCUSSION

From May 12, 2023 (first irrigation with saline solutions) to mid-June, seedlings of both subjects in all treatments did not show visible alterations on the leaf surface or overall appearance. After mid-June, the first differences were observed. In the control (treatment 1), plants of both ‘Gisela 6’ and ‘Maxima 14’ remained unaffected. In treatment 2 (1.022 g $L^{-1}$ NaCl), the first discoloration of the older leaves began, which quickly developed into necrotic spots. These symptoms gradually became more intense. From mid-July until mid-September, the condition of Gisela plants continued to deteriorate during treatments 2 and 3, while in treatment 4, the defoliation reached ~90%. The Maxima 14 rootstock initially did not show any severe symptoms in treatments 3 and 4, but by mid-September (final observation), Maxima 14 seedlings in treatments 1 and 2 showed no further symptoms, but in treatment 3, they exhibited sudden crown collapse, and in treatment 4, complete leaf necrosis.

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Table 1. Mean number of leaves per plant of ‘Gisela 6’ and ‘Maxima 14’ under different salinity treatments.

| Treatments | Number of leaves/plant |
|---|---|
| Treatment 1 (control) | 519,2a |
| Treatment 2 (1.022 g $L^{-1}$ NaCl) | 214,7b |
| Treatment 3 (2.044 g $L^{-1}$ NaCl) | 91,5c |
| Treatment 4 (4.090 g $L^{-1}$ NaCl) | 10,3d |

Concerning the number of leaves of the rootstock seedlings, increasing salinity (NaCl addition) progressively reduced leaf number, with the lowest value (10.3 leaves plant$^{-1}$) recorded at the highest salinity level, while control plants exhibited the statistically highest leaf count (519.2 leaves plant$^{-1}$). A significant interaction between rootstock and salinity was detected, indicating that NaCl affected the two genotypes differently. The seedlings of the rootstock 'Maxima 14' consistently maintained a higher number of leaves compared to those of 'Gisela 6'. In 'Gisela 6', even the lowest salt concentration induced substantial leaf drop, whereas in 'Maxima 14' salinity resulted only in a gradual reduction of leaf number (Table 1, diagram 1). Seedlings of the rootstock 'Maxima 14' exhibited significantly greater leaf fresh weight compared to those of 'Gisela 6', which is expected since Maxima 14 also maintained a higher number of leaves overall. Increasing salinity (NaCl addition) progressively reduced leaf biomass, with the lowest value (0.55 g plant$^{-1}$) recorded at the highest salinity level, while control plants exhibited the statistically highest value (118.2 g plant$^{-1}$) (Table 2). A significant interaction between rootstock and salinity was observed, indicating that NaCl addition affected the two genotypes differently. In 'Gisela 6', even the lowest NaCl concentration caused complete defoliation, whereas in 'Maxima 14', the decline in leaf biomass was gradual.

Table 2. Leaf fresh weight of 'Gisela 6' and 'Maxima 14' under different salinity treatments.

| Treatments | Leaf fresh weight (gr) |
|---|---|
| Treatment 1 (control) | 118,2a |
| Treatment 2 (1.022 g L$^{-1}$ NaCl) | 51,2b |
| Treatment 3 (2.044 g L$^{-1}$ NaCl) | 16,6c |
| Treatment 4 (4.090 g L$^{-1}$ NaCl) | 0,55d |

**Root Fresh Weight**

Table 3. Root fresh weight of 'Gisela 6' and 'Maxima 14' under different salinity treatments.

| Treatments | Root fresh weight (gr) |
|---|---|
| Treatment 1 (control) | 283.2a |
| Treatment 2 (1.022 g L$^{-1}$ NaCl) | 247.1b |
| Treatment 3 (2.044 g L$^{-1}$ NaCl) | 163.8c |
| Treatment 4 (4.090 g L$^{-1}$ NaCl) | 158.3d |

Increasing salinity (NaCl addition) progressively reduced root biomass, with the lowest values recorded at the two highest salinity levels (163.8 and 158.3 g plant$^{-1}$), while control plants exhibited the statistically highest value (283.4 g plant$^{-1}$).

**Whole seedling fresh weight**

Table 4. Whole seedling fresh weight of ‘Gisela 6’ and ‘Maxima 14’ under different salinity treatments.

| Treatments | Root fresh weight (gr) |
|---|---|
| Treatment 1 (control) | 332.4a |
| Treatment 2 (1.022 g $L^{-1}$ NaCl) | 309.3b |
| Treatment 3 (2.044 g $L^{-1}$ NaCl) | 263.2c |
| Treatment 4 (4.090 g $L^{-1}$ NaCl) | 241.4d |

Salinity stress (NaCl addition) progressively reduced biomass, with the lowest value (241.4 g $plant^{-1}$) recorded under the highest salt concentration, while control plants presented the statistically highest weight (332.4 g $plant^{-1}$).

**Stem thickness (lower part)**

Table 5. Stem thickness (lower part) of ‘Gisela 6’ and ‘Maxima 14’ under different salinity treatments.

| Treatments | Stem thickness (lower part) |
|---|---|
| Treatment 1 (control) | 29.84b |
| Treatment 2 (1.022 g $L^{-1}$ NaCl) | 31.89a |
| Treatment 3 (2.044 g $L^{-1}$ NaCl) | 30.78ab |
| Treatment 4 (4.090 g $L^{-1}$ NaCl) | 26.87c |

No significant differences were detected between the two rootstocks in lower stem diameter. Salinity initially induced an increase in basal stem thickness, with the highest value (31.89 mm) recorded at the lowest NaCl concentration. However, further increases in salinity resulted in a reduction, with the smallest value (26.87 mm) observed at the highest NaCl level. No significant rootstock × salinity interaction was recorded, indicating that both genotypes responded similarly for this parameter. Seedlings of ‘Maxima 14’ exhibited significantly greater upper stem diameter compared to ‘Gisela 6’. This indicates that stem thickness in the upper part remained relatively stable under salinity stress for both genotypes.

**Plant height**

Table 6**.** Plant height of ‘Gisela 6’ and ‘Maxima 14’ under different salinity treatments.

| Treatments | Plant height (cm) |
|---|---|
| Treatment 1 (control) | 298.9a |
| Treatment 2 (1.022 g $L^{-1}$ NaCl) | 282.8b |
| Treatment 3 (2.044 g $L^{-1}$ NaCl) | 270.2b |
| Treatment 4 (4.090 g $L^{-1}$ NaCl) | 246.5c |

Increasing salinity (NaCl addition) gradually reduced plant height, with the lowest mean value (246.5 cm) recorded under the highest salinity treatment, while control plants exhibited the statistically highest height.
Other parameters such as root biomass, stem diameter, plant height, and root length showed similar decreasing trends under salinity stress, without significant genotype x salinity interactions.
Salinity stress (NaCl addition) caused a progressive reduction in leaf chlorophyll content, as reflected in SPAD values. Both rootstocks exhibited decreasing chlorophyll levels with increasing salinity, consistent with visual symptoms of chlorosis and necrosis observed during the experiment. 'Gisela 6' showed stronger reductions compared to 'Maxima 14', confirming its higher sensitivity to salt stress.
Particularly in regions where soil or irrigation water contains elevated salt concentrations, salinity strongly affects plant physiology and development by reducing water and nutrient uptake, which can lead to substantial decreases in biomass and yield.
The effect of salinity on cherry rootstocks may vary depending on their genetic background and their ability to adapt to adverse conditions. In the present study, two cherry rootstocks, 'Maxima 14' and 'Gisela 6', were evaluated under different NaCl concentrations. The results revealed significant differences in several growth parameters, including leaf number and weight, root biomass, total seedling weight, stem and root diameter, plant height, and root length.
Seedlings of Maxima 14 consistently produced a higher number of leaves compared to Gisela 6. While both rootstocks were negatively affected by salinity, Gisela 6 showed more severe leaf loss, even at the lowest salt concentration. In contrast, Maxima 14 showed a gradual decrease in leaf number as NaCl concentration increased. Leaf biomass followed a similar pattern: Maxima 14 maintained a higher total leaf weight, while Gisela 6 showed a drastic reduction and almost complete defoliation, indicating the sensitivity of this rootstock. Moreover, according to Lauchli and Grattan (2007), a salt-sensitive genotype differs from a more salt-tolerant one by its inability to prevent salt accumulation in the leaves at toxic levels. Root fresh weight did not differ significantly between the two rootstocks, but salinity reduced root biomass in both, with the most pronounced declines observed at higher concentrations. Plant height decreased under salinity stress, with Gisela 6 generally taller than Maxima 14, although differences were not statistically significant. Root length was not significantly influenced by treatments or genotype, indicating that this parameter is relatively stable under saline conditions. Chlorophyll content declined with increasing salinity in both rootstocks, reflecting reduced photosynthetic capacity. The decrease was more pronounced in Gisela 6, consistent with its greater leaf loss and visible chlorosis. Gebauer, et al., (2004) reported that chlorophyll also decreased with increasing salinity in *Tamarindus indica*, a moderately salt-tolerant fruit tree species.
Overall, the results indicate that while both genotypes were negatively affected by salinity, Maxima 14 demonstrated greater tolerance than Gisela 6. This was evident in its ability to maintain higher leaf number, leaf biomass, and chlorophyll content

under saline conditions. These findings support the use of Maxima 14 as a more suitable rootstock for cherry cultivation in saline soils, whereas Gisela 6 appears highly sensitive and should be avoided under such conditions.

## CONCLUSION

This study demonstrated that salinity significantly reduced growth and physiological performance in cherry rootstocks, with clear differences between genotypes. ‘Maxima 14’ exhibited greater tolerance by maintaining higher leaf numbers, leaf biomass, and chlorophyll content under increasing NaCl concentrations, whereas ‘Gisela 6’ was highly sensitive, showing severe defoliation and reduced vigor even at low salinity levels. These findings suggest that Maxima 14 represents a more suitable choice for cherry cultivation in saline soils or under irrigation with saline water. Further research should focus on the underlying physiological and molecular mechanisms of salt tolerance in cherry rootstocks to support breeding programs and the development of stress-resilient orchards.

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