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Effects of soil salinity on growth and physiological responses of *Sempervivum tectorum* and *Petrosedum rupestre*

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ABSTRACT

The widespread application of sodium chloride (NaCl) for winter road maintenance contributes to the accumulation of soluble salts in soils, resulting in osmotic stress and physiological drought in plants. Succulents possess specialized water-storage tissues and physiological adaptations that may enhance their tolerance to saline conditions. The aim of this study was to evaluate the tolerance of two succulent species, *Petrosedum rupestre* and *Sempervivum tectorum*, to soil salinity induced by road de-icing salt. Young plants were cultivated in soil subjected to three salinity levels: control (0.172 mS·cm⁻¹), moderate salinity (6 mS·cm⁻¹), and high salinity (12 mS·cm⁻¹). The experiment lasted eight months and was conducted under controlled conditions. Plant growth, biomass increment, morphological changes, and chlorophyll content were assessed at the end of the growing period. The results demonstrated that both species survived exposure to elevated salinity levels throughout the experiment. However, increasing salinity significantly reduced biomass production and limited root and shoot development. *Petrosedum rupestre* exhibited substantially greater growth under saline conditions than *Sempervivum tectorum*. Under high salinity, biomass accumulation was markedly reduced in both species, although all individuals remained viable. Chlorophyll analyses did not reveal a clear decrease in pigment concentration in response to salinity stress. The findings indicate that succulent species of the Crassulaceae family may be suitable for use in urban areas periodically exposed to road salt contamination. Among the tested species, *Petrosedum rupestre* showed the highest tolerance to soil salinity and appears to be a promising candidate for plantings established in salt-affected environments.

Keywords: Crassulaceae, road salt, sodium chloride, soil salinity, succulents, urban soils.

INTRODUCTION

Soil is one of the fundamental components supporting life on Earth. It constitutes a three-phase element of the lithosphere formed under the influence of climatic conditions and soil-forming organisms (Mocek, 2021). Because soil formation is an extremely slow process, soil degradation poses a serious environmental concern. Deterioration of soil physicochemical properties may result from both natural processes, such as wind and water erosion, and anthropogenic activities (Wang et al., 2023). Among the most important human-induced causes of soil degradation are deforestation, overgrazing, inappropriate agricultural practices, and industrial activity (Gomiero, 2016). Another major factor contributing to soil degradation is salinization.

The origin of soil salinity depends on the source of readily soluble salts present in the soil environment. In Poland, naturally saline soils occur primarily in coastal areas influenced by seawater. However, anthropogenic activities constitute the dominant source of salt input into terrestrial ecosystems. Salts originate from mineral fertilizers, including sodium nitrate and potassium chloride (Brożek, 2013), improper wastewater management, and, most importantly, the application of sodium chloride during winter road maintenance (Sobczyk and Gliniak, 2013).

Although soil salinization is commonly associated with human activity, it also occurs naturally in regions where evaporation exceeds precipitation (Brożek, 2013). Two major types of naturally saline soils are distinguished: Solonchaks and Solonetz. Solonchaks develop as a result of salt accumulation originating from groundwater and weathering of sedimentary rocks. Soluble salts, predominantly chlorides, accumulate in the upper soil horizons (Khayrulina et al., 2022). These soils are characteristic of arid and semi-arid regions with high evaporation rates (Gliniak and Sobczyk, 2013). In contrast, Solonetz soils are characterized by a loose surface horizon, a dense and poorly permeable subsurface layer, and a strongly saline C horizon. Saline environments are inhabited by halophytes and less salt-tolerant glycophytes. Salt tolerance in these plants is associated with tissue-level mechanisms that prevent cellular damage caused by the accumulation of Na^+ and Cl^- ions (Flowers et al., 2015).

Urban soils are generally not classified as naturally saline. Nevertheless, anthropogenic activities may lead to the formation of secondary saline soils (Shrivastava and Kumar, 2015).

Sodium chloride remains the most widely used de-icing agent because of its high effectiveness and relatively low cost. Road salt is commonly applied to eliminate ice, frost, packed snow, and slippery road conditions. Studies conducted in the United States have demonstrated that winter road salting significantly improves traffic safety and substantially reduces the number of road accidents (Mazur, 2015). Alternative de-icing agents include calcium chloride ($CaCl_2$) and magnesium chloride ($MgCl_2$). However, their higher costs and storage limitations make sodium chloride the most frequently used option. Commercial de-icing mixtures are also available, although NaCl usually accounts for 67–80% of their composition (Czarna, 2013).

After entering the soil environment, sodium chloride dissociates into sodium (Na^+) and chloride (Cl^-) ions, which may be absorbed by plant roots and subsequently accumulated in leaf tissues. Elevated concentrations of these ions disturb ionic homeostasis and impair metabolic processes. Excess sodium displaces essential nutrients required for normal plant growth, whereas chloride ions increase the mobility of certain heavy metals in soils (Łuczak et al., 2021). Soil salinity lowers the osmotic potential of the soil solution, leading to physiological drought. Unlike meteorological drought, physiological drought occurs despite the presence of water in the soil because plants are unable to absorb it due to unfavorable osmotic conditions (Novák, 2009). Salinity stress may reduce biomass production, inhibit photosynthesis, and impair seed germination Typical symptoms include chlorosis, necrosis, growth inhibition, and reductions in chlorophyll content. (Acosta-Motos et al., 2017).

Given that soil salinization is particularly common in urban environments, the selection of salt-tolerant plant species is an important aspect of sustainable urban green infrastructure. Ground-cover vegetation not only survives under adverse conditions but may also contribute to reducing salt migration within the soil profile (Mazur, 2015).

Succulents constitute a group of plants that possess a range of adaptations enabling survival in water-deficient habitats. Together with sclerophytes, they belong to the xerophytes. The classification of succulents remains debated because water-storage tissues differ among taxonomic groups. In most members of the Crassulaceae family, water is stored in specialized parenchyma tissues, whereas cacti accumulate water primarily in stem cortex and pith tissues (Mauseth, 2006). Regardless of taxonomic differences, the presence of water-storage tissue, known as hydrenchyma, is considered the principal morphological feature of succulent plants (Chiang et al., 2013).

Water is essential for maintaining cellular turgor and regulating plant temperature. To minimize water loss through transpiration, many succulents have evolved reduced leaves or transformed them into protective structures. Unlike most vascular plants, succulents open their stomata predominantly at night, when temperatures are lower and evaporative losses are reduced (Zimny, 2008). This adaptation is associated with Crassulacean Acid Metabolism (CAM), a specialized photosynthetic pathway characteristic of the Crassulaceae families and Cactaceae, as well as several epiphytic species (Gilman and Edwards, 2020).

The aim of this study was to assess the tolerance of two succulent species, *Petrosedum rupestre* and *Sempervivum tectorum*, to soil salinity induced by sodium chloride-containing road de-icing salt and to evaluate their potential suitability for planting in urban areas exposed to periodic salt contamination.

CHARACTERISTICS OF THE STUDIED SPECIES

The first of the selected succulent species is a plant from the genus *Petrosedum* – the tasteless stonecrop, *Petrosedum rupestre*. Although it is alternately referred to as *Sedum rupestre* or *Sedum reflexum*, it belongs to the distinct clade *Petrosedum* (Messerschmid et al. 2020). It is one of the few succulent representatives of the Polish native flora, occurring naturally throughout Europe with the exception of Western Europe. Its evergreen leaves are covered with a cuticle that protects said plant against high UV exposure and water loss (Kim et al. 2022).

Similarly to *Petrosedum rupestre*, *Sempervivum tectorum* belongs to the Crassulaceae family. Like most succulent plants, it is characterized by Crassulacean Acid Metabolism (CAM) (Hartwell et al., 2016). It is a low-growing plant whose fleshy leaves form characteristic rosettes. It occurs in dry and strongly sun-exposed habitats. It has been used by humans for thousands of years, not only as an ornamental plant but also for medicinal purposes. Its antioxidant, anti-inflammatory, and detoxifying properties are attributed to phenolic compounds present in the leaf sap (Gentscheva et al., 2021).

MATERIALS AND METHODS

Plant material

Two succulent species commonly found in urban environments in Poland and belonging to the Crassulaceae family were selected for the study: *Petrosedum rupestre* and *Sempervivum tectorum*. Specimens of *P. rupestre* were collected from a natural population located in southern Poland (50°20′22.482″ N, 18°11′9.084″ E). Individuals of *S. tectorum* were obtained from a commercial nursery. The species were selected due to their contrasting growth forms and frequent use in ornamental and urban plantings. Young offsets with a diameter of approximately 1 cm were used in the experiment.

Soil preparation and experimental design

The soil used in the experiment was collected from a natural site, air-dried, and sieved through a 2-mm mesh sieve. Particle-size distribution was determined using the Casagrande method modified by Prószyński. Prior to planting, all experimental plants were weighed and cultivated in non-saline soil for a two-week acclimation period to allow root development and minimize transplant shock (Cabahug et al., 2018).

Three salinity treatments were established using a commercial road de-icing salt solution:

- Control (N): rainwater, electrical conductivity: EC = 0.172 $mS \cdot cm^{-1}$;
- Moderate salinity: EC = 6 $mS \cdot cm^{-1}$;
- High salinity: EC = 12 $mS \cdot cm^{-1}$ (Małuszyńska and Małuszyński, 2009).

For each treatment, three independent replicates were prepared for each species. Replicates 1–3 represented the control treatment, replicates 4–6 the moderate salinity treatment, and replicates 7–9 the high salinity treatment.

Salt solutions were applied once by subirrigation at the beginning of the experiment. Throughout the study, plants were watered exclusively by subirrigation using settled rainwater in order to prevent salt leaching from the substrate (Łukasiewicz, 2012). Irrigation was performed whenever the soil became completely dry. All containers were placed in an east-facing exposure under identical environmental conditions. Soil pH was determined using a KCl extract.

Plant growth assessment

The experiment was conducted over an eight-month growing period. Plant growth and morphological responses were monitored regularly throughout the study.

At the end of the experiment, plants were carefully removed from the containers without damaging the root systems and weighed again to determine biomass increment. Additionally, chlorophyll content was analyzed because visible differences in leaf coloration were observed among treatments.

For *P. rupestre*, the number of lateral shoots and total shoot length were also recorded as additional indicators of growth performance.

Chlorophyll determination

Leaf samples with a maximum total fresh mass of 0.5 g were collected from each replicate. Due to differences in plant size, lower sample masses were accepted when sufficient material was unavailable.

The collected tissues were homogenized in 20 cm³ of acetone cooled to 0°C using a mortar and pestle. After complete tissue disruption, the suspension was filtered through a double layer of quartz wool into a 100 cm³ volumetric flask. The quartz wool was rinsed with small portions of acetone to ensure complete pigment extraction.

Subsequently, 5 cm³ of distilled water was added to obtain an 80% aqueous acetone solution. Samples were protected from light until analysis. Absorbance was measured at wavelengths of 645, 652, and 663 nm using a UV–Vis spectrophotometer.

Chlorophyll concentrations were calculated using the following equations:
- Chlorophyll a = 12.7A663 − 2.7A645.
- Chlorophyll b = 22.9A645 − 4.7A663.
- Total chlorophyll (a + b) = 20.2A645 + + 8.0A663 = 27.8A652.

The results were expressed as $mg \cdot dm^{-3}$ and subsequently recalculated in relation to sample mass.

Soil analysis

Following completion of the experiment, the soils from all treatments were subjected to chemical analysis. A suspension was prepared by mixing 10 g of soil with 100 cm³ of redistilled water. Samples were shaken for 1 h using a laboratory shaker to extract water-soluble ions and then filtered.

The obtained soil extracts were analyzed to determine the concentrations of selected ions and assess changes in soil chemical properties resulting from salinity treatments.

RESULTS AND DISCUSSION

Soil characteristics and salinity treatments

The soil used in the experiment had a pH of 6.35 and an electrical conductivity (EC) of 172 $\mu S \cdot cm^{-1}$. Based on particle-size analysis, the substrate was classified as sandy loam (Table 1). Chemical analysis of the road de-icing salt solutions confirmed substantial differences in ionic composition between the salinity treatments (Table 2). As expected, concentrations of sodium and chloride ions increased proportionally with electrical conductivity, reaching 410.4 $mg \cdot dm^{-3}$ and 2170 $mg \cdot dm^{-3}$, respectively, in the 12 $mS \cdot cm^{-1}$ treatment.

Plant growth response

Biomass production is one of the most important indicators of plant adaptation to environmental stress. The results demonstrated a clear negative effect of salinity on the growth of both succulent species (Tables 3 and 4).

Despite exposure to elevated salt concentrations, all experimental plants survived until the end of the eight-month cultivation period. However, biomass increment decreased progressively with increasing salinity. The highest growth

Table 1. Particle-size distribution of the soil used in the study

Fraction size	Particle-size fraction (%)	Particle-size class and subclass
> 2 mm	2	loamy sand
< 2 mm	98	
2-1 mm	1	
1-0.5 mm	7	
0.5-0.25 mm	35	
0.25-0.1 mm	22	
0.1-0.05 mm	11	
Σ 2-0.05 mm	76	
0.05-0.02 mm	12	
0.02-0.005 mm	5	
0.005-0.002 mm	3	
Σ 0.05-0.002 mm	20	
<0.002 mm	4	

Table 2. Ionic composition of the applied salt solutions

Ion	Salinity: EC = 6 mS·cm⁻¹ [mg·dm⁻³]	Salinity: EC = 12 mS·cm⁻¹ [mg·dm⁻³]
Na^+	212.5	410.4
K^+	8.120	15.57
Ca^{+2}	18.67	37.52
Mg^{+2}	15.17	31.21
Cl^-	1133	2170
NO_2^-	0.090	0.170
NO_3^-	3.300	6.320
F^-	0.686	1.150
SO_4^{-2}	242.0	463.7

Table 3. Fresh weight (FW) of plants at the beginning and end of the experiment

No.	Salinity [mS·cm⁻¹]	*Petrosedum rupestre*		*Sempervivum tectorum*	
		Initial FW [g]	Final FW [g]	Initial FW [g]	Final FW [g]
1.	N	0.268	2.361	0.166	0.553
2.	N	0.256	1.772	0.235	0.812
3.	N	0.272	1.591	0.266	0.605
4.	6	0.368	0.955	0.353	0.364
5.	6	0.358	1.127	0.281	0.497
6.	6	0.201	0.901	0.144	0.098
7.	12	0.311	0.443	0.134	0.181
8.	12	0.409	0.609	0.293	0.317
9.	12	0.247	0.371	0.226	0.258

Table 4. Increase in fresh weight (FW) of the studied plants

No.	Salinity [mS·cm⁻¹]	*Petrosedum rupestre*			*Sempervivum tectorum*		
		FW increase [g]	X(SD)	CV [%]	FW increase [g]	X(SD)	CV [%]
1.	N	2.093	1.643(0.402)	24.5	0.387	0.434(0.127)	29.3
2.	N	1.516			0.577		
3.	N	1.319			0.339		
4.	6	0.587	0.685(0.091)	13.3	0.011	0.060(0.138)	230
5.	6	0.769			0.216		
6.	6	0.700			−0.046		
7.	12	0.132	0.152(0.042)	27.8	0.047	0.034(0.012)	35.3
8.	12	0.200			0.024		
9.	12	0.124			0.032		

rates were observed in the control treatment, whereas the lowest values occurred under high salinity conditions.

In the control treatment, the average biomass increase of *Petrosedum rupestre* reached 619% relative to the initial fresh mass. In contrast, *Sempervivum tectorum* exhibited a mean increase of 201%. Under moderate salinity (6 mS·cm⁻¹), biomass accumulation declined markedly, with average increases of 241% and 16% for *P. rupestre* and *S. tectorum*, respectively. Exposure to the highest salinity level (12 mS·cm⁻¹) further reduced growth, resulting in biomass increases of only 47% for *P. rupestre* and 19% for *S. tectorum* (Fig. 1).

These findings indicate that both species were capable of tolerating saline conditions; however, growth performance was substantially impaired.

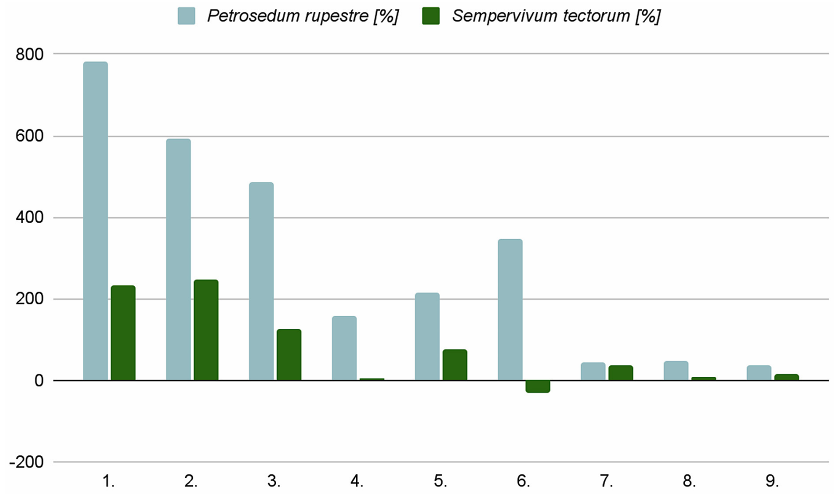

Fig. 1. Percentage change in the mass of individuals of *Petrosedum rupestre* and *Sempervivum tectorum* after the experiment.

The results also reveal a clear interspecific difference in salt tolerance, with *P. rupestre* consistently outperforming *S. tectorum* across all treatments.

A similar pattern was reported by Hooks and Niu (2019), who observed survival of Crassulaceae species under saline conditions accompanied by reduced biomass production. The ability of the investigated succulents to maintain positive growth even under severe salinity stress suggests the presence of effective physiological mechanisms enabling adaptation to osmotic stress.

Salinity negatively affected root development in both species. Plants cultivated in non-saline soil produced numerous well-developed fibrous roots, whereas root abundance and length declined with increasing salinity (Fig. 2–4).

The response of *Sempervivum tectorum* was particularly pronounced. Several individuals exposed to moderate salinity developed poorly expanded root systems, which likely contributed to their limited biomass accumulation. Reduced root growth under saline conditions has been widely reported and is commonly associated with osmotic stress and ion toxicity.

Additional growth parameters were assessed for *Petrosedum rupestre*. Both the number of lateral shoots and total shoot length decreased as salinity increased (Table 5). Mean shoot length in

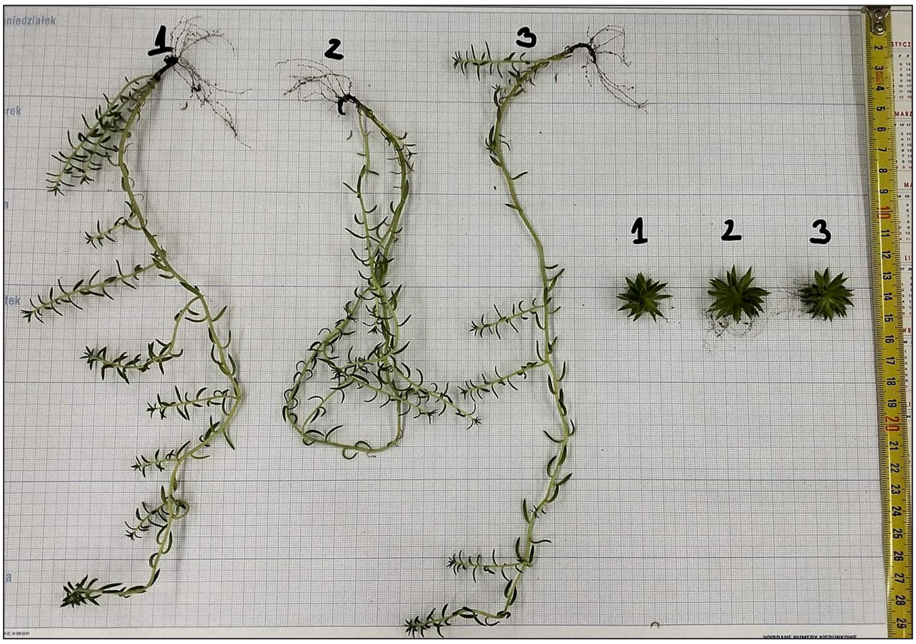

Fig. 2. Plants after the experiment no. 1 – 3 (N)

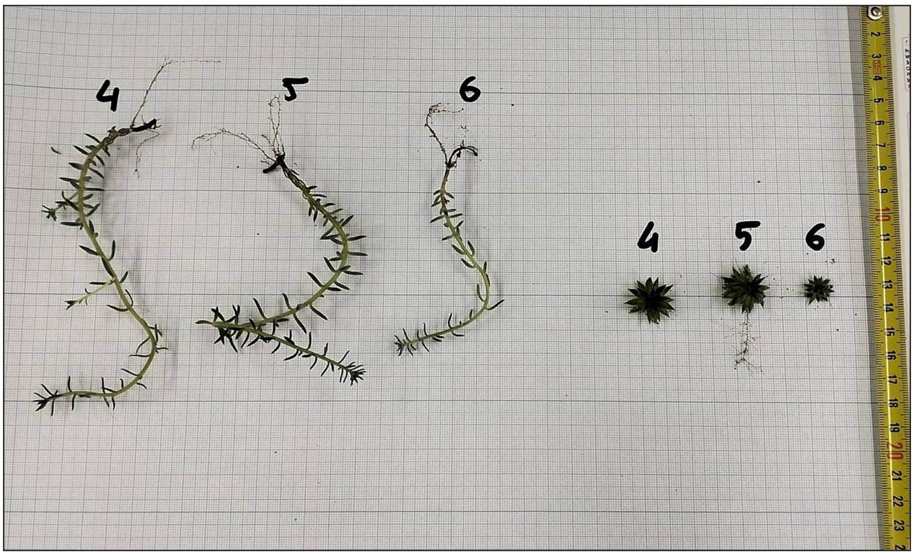

Fig. 3. Plants after the experiment no. 4 – 6 (6 mS·cm⁻¹)

Fig. 4. Plants after the experiment no. 7 – 8 (12 mS·cm⁻¹)

Table 5. Number of lateral shoots and total length of plants after the experiment – *P. rupestre*.

Petrosedum rupestre				X (SD)
No.	Salinity [mS·cm⁻¹]	Number of lateral shoots	Total length [cm]	
1.	N	8	32.2	32.1 (2.65)
2.	N	7	29.4	
3.	N	6	34.7	
4.	6	2	15.3	14.2 (3.35)
5.	6	0	16.8	
6.	6	0	10.4	
7.	12	0	6.8	8.57 (1.98)
8.	12	0	8.2	
9.	12	0	10.7	

the moderate-salinity treatment represented only 44.1% of that recorded in the control, while plants exposed to high salinity reached only 26.7% of the control value. Furthermore, lateral shoot formation was completely inhibited at the highest salinity level.

These observations indicate that although *P. rupestre* remained capable of growth under saline conditions, salt stress substantially limited its vegetative development.

Chlorophyll content

Progressive changes in leaf coloration were observed in both species during the experiment. Plants cultivated in the control treatment exhibited an intense green color, whereas those exposed to increasing salinity developed a grey-green appearance with reduced color saturation.

Such visual symptoms are commonly associated with salinity-induced physiological stress and are frequently linked to chlorophyll degradation and impaired photosynthetic activity (Hichem et al. 2009). Salinity may disrupt chloroplast structure, alter ionic balance, and reduce carbon assimilation through stomatal closure (Hameed et al., 2021). However, chlorophyll analyses did not reveal a consistent decrease in pigment concentrations with increasing salinity (Tables 6–8). In several cases, chlorophyll concentrations measured in plants exposed to saline treatments were comparable to or even higher than those recorded in control plants.

This apparent contradiction may result from differences in tissue water content. Succulents cultivated under saline conditions likely contained lower amounts of water in their tissues, which could have increased chlorophyll concentration when expressed per unit fresh mass. Because hydrenchyma tissue contains relatively low chlorophyll concentrations compared with photosynthetically active chlorenchyma, variations in tissue hydration may influence the final results.

Therefore, future studies should determine chlorophyll concentrations on a dry-weight basis to eliminate the confounding effect of tissue water content. Nevertheless, hydrenchyma may help maintain chlorenchyma functionality, because these tissues support plant physiological function under stress conditions (Ogburn and Edwards, 2010). It suggests that chloroplast degradation in succulent species may be less pronounced than in many non-succulent plants. Some species are also capable of slightly increasing chloroplast production under stress conditions (Mikiciuk et al. 2006), which may also have occurred in the case of the studied species from the Crassulaceae family.

Changes in soil chemical properties

Chemical analysis of soils collected after the experiment confirmed substantial accumulation of salts in the treated substrates (Table 9). Concentrations of sodium, chloride, magnesium, calcium, fluoride, and sulfate ions increased with increasing salinity treatment. The highest concentrations were recorded in soils subjected to the 12 $mS \cdot cm^{-1}$ treatment.

In contrast, the control soil exhibited only trace concentrations of most analyzed ions. These results confirm the effectiveness of the experimental design and demonstrate that the observed plant responses were directly associated with elevated salt concentrations in the growth medium.

Table 6. Chlorophyll content a. b, and a+b

No.	Salinity [$mS \cdot cm^{-1}$]	Chlorophyll a [$mg \cdot dm^{-3}$]		Chlorophyll b [$mg \cdot dm^{-3}$]		Chlorophyll a+b [$mg \cdot dm^{-3}$]	
		St	Pr	St	Pr	St	Pr
1.	N	14.606	25.763	8.658	18.017	23.964	43.618
2.	N	9.932	24.741	5.588	16.380	15.874	41.283
3.	N	12.420	23.980	6.639	15.468	19.627	34.361
4.	6	12.041	20.234	6.144	12.373	18.654	48.066
5.	6	15.044	26.378	8.077	18.665	23.769	31.553
6.	6	4.928	18.491	3.016	12.014	8.201	40.366
7.	12	6.416	23.484	3.166	15.290	10.036	65.469
8.	12	8.519	28.145	4.184	30.780	13.150	27.550
9.	12	7.764	16.653	3.894	10.088	12.121	43.618

Table 7. Chlorophyll a, b, and a+b concentrations relative to sample fresh weight (FW)

No.	Salinity [mS·cm⁻¹]	Chlorophyll a [mg·dm⁻³]		Chlorophyll b [mg·dm⁻³]		Chlorophyll a+b [mg·dm⁻³]	
		St	Pr	St	Pr	St	Pr
1.	0	786.9	1325	466.9	926.8	1291	2378
2.	0	531.6	1306	299.1	864.6	849.7	2302
3.	0	653.6	1254	349.4	808.9	993.2	2159
4.	6	804.8	967.2	410.6	591.4	1246	1642
5.	6	791.7	1389	434.1	983.3	1251	2532
6.	6	1332	942.6	815.5	612.4	2217	1608
7.	12	891.1	1460	439.7	951.2	1393	2511
8.	12	687.0	1279	337.4	1399	1060	2975
9.	12	905.2	1272	454.0	770.6	1413	2104

Table 8. Mean concentrations of chlorophyll a, b, and a+b (N=3)

Salinity [mS·cm⁻¹]	Chlorophyll a [mg·kg⁻¹]		Chlorophyll b [mg·kg⁻¹]		Chlorophyll a+b [mg·kg⁻¹]	
	St	Pr	St	Pr	St	Pr
N	657.4(127.7)	1295.0(36.8)	371.8(86.1)	866.8(59.0)	1044.6(225.1)	2279.7(111.2)
6	976.2(308.2)	1099.6(250.9)	553.4(227.3)	729.0(220.5)	1571.3(559.2)	1927.3(523.9)
12	827.8(122.1)	1337.0(106.6)	410.4(63.6)	1040.3(323.5)	1288.7(198.3)	2530.0(435.8)

Table 9. Measurements of bioavailable soil micronutrients after the experiment

Ion	N (EC = 0.175 mS·cm⁻¹) [mg·dm⁻³]	Salinity: EC = 6 mS·cm⁻¹ [mg·dm⁻³]	Salinity: EC = 12 mS·cm⁻¹ [mg·dm⁻³]
Na^+	0.844	327.5	397.4
K^+	0.830	2.720	5.150
Mg^{+2}	2.132	16.58	28.67
Ca^{+2}	7.498	9.470	16.83
Cl^-	1.470	983.3	2031
NO_2^-	<0.05	<0.05	0.199
NO_3^-	<0.05	0.06	0.09
F^-	1.430	13.17	24.86
SO_4^{-2}	0.18	0.686	1.520

Ecological Implications

The results indicate that representatives of the genera *Petrosedum* and *Sempervivum* possess considerable tolerance to soil salinity. Although plant growth was reduced, all individuals survived throughout the experiment, even at the highest salinity level. Compared with previous studies on glycophytic species exposed to similar salinity levels (Małuszyńska and Małuszyński, 2009), the investigated succulents exhibited relatively high resistance to osmotic stress. Nevertheless, their tolerance was lower than that reported for specialized halophytic succulents such as *Sarcocornia* or *Salicornia* (Ventura and Sagi, 2013).

The superior performance of *Petrosedum rupestre* suggests that this species may be particularly suitable for planting in urban environments affected by road salt contamination. Its greater biomass production, more extensive root system, and continued shoot development under saline conditions indicate a higher capacity to withstand salt-induced stress compared with *Sempervivum tectorum*.

The observed tolerance is likely associated with physiological mechanisms commonly found in salt-tolerant plants, including the accumulation of compatible solutes such as proline, glycine betaine, and soluble sugars, as well as enhanced intracellular sequestration of sodium and chloride ions (dos Santos et al., 2022; Nikalje et al., 2018).

CONCLUSIONS

The laboratory experiment involving *P. rupestre* and *S. tectorum* confirmed that the survival mechanisms of succulents in nutrient-poor and contaminated soils are also effective under high salinity stress. Although morphological changes were observed, primarily a gradual reduction in biomass, all tested plants survived the experiment.

Plants from the Crassulaceae family are suitable candidates for growth under harsh urban conditions, particularly *Petrosedum rupestre*. Owing to their turf-forming ability, they may act as a form of phytostabiliser, limiting the migration of Na^+ and Cl^- ions.

The study demonstrated that *P. rupestre* exhibited greater tolerance to salinity than *S. tectorum*.

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