

Salinity Reduction in Agricultural using *Sesuvium Portulacastrum* and *Aptenia Cordifolia*

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Saline soils are caused by different problems such as salinization, acidification, erosion and various human activities that disturb soil quality. The phytoremediation tests were carried out in 50 m x 50 m soil plots for each plant species, prioritizing only the growth of *Sesuvium portulacastrum* and *Aptenia cordifolia* in the respective plots. The treatment was carried out *in situ* for a period of 63 days, monitoring at times of 0, 30 and 63 days after planting, in order to obtain the reduction values. The results showed that, *Sesuvium portulacastrum* was able to reduce soil salinity from 5.58 to 3.30 mS/cm and from 5.58 to 1.06 mS/cm in 30 and 63 days, respectively. While, *Aptenia cordifolia* was able to reduce salinity from 5.51 to 4.60 mS/cm and from 5.51 to 3.6 mS/cm in 30 and 63 days, respectively. This highlights the potential of both plants, reaching a salinity reduction of 81 % with *Sesuvium portulacastrum*. Therefore, it is concluded that the use of both plants are efficient methods to reduce salinity in saline soils, and can be applied in different agricultural areas, considering their adaptability and growth.

1. Introduction

Soil degradation is a global problem that has been occurring in different countries (Bekuzarova et al., 2020). Problems such as salinization, acidification and erosion are generated by inadequate management that directly affect soil quality, leading to problems of crop decline, lack of vegetation and fertility (Ke et al., 2021; Unnikrishnan et al., 2022). Excess salinization has been one of the factors that degrade the soil (Rodríguez Ledesma et al., 2019), generating problems in the growth of plantations (Mamani Flores et al., 2020). Globally, there are one billion hectares of soils with this problem, representing 7% of the total land on the planet (Gorji et al., 2020; Hopmans et al., 2021). Salt stress reduces vegetation, affects development and even causes plant extinction (Peng et al., 2019; Taheri et al., 2018). In Latin American countries, 31,000,000 ha are presented with the problem of production limitation, salt stress and salinity (Nikalje et al., 2018). Agricultural soils have a high degree of production and are affected by the salts accumulated inside them, leading to a decrease in the production of their crops and sometimes to the abandonment of these crop areas (Gamboa et al., 2021). In environmental biotechnology, different remediation methods have been used (Estacio et al., 2022; Pinchi et al., 2022), and some to reduce salinity in soils. Among these methods are chemical methods such as leaching (Mahanta et al., 2019), agrotechnical methods such as fertilizers (Srivastava, 2020; Zhou et al., 2019), biological methods such as halophyte plants (Mu et al., 2021; Sassi et al., 2018), among others. The use of halophytic plants is more common because they reduce salt and can be used as field crops (Mokrani et al., 2022), storing salt inside their salt glands in the extension of their leaves (Litalien & Zeeb, 2020). Among the halophytic plants are *Sesuvium portulacastrum* and *Aptenia cordifolia* that are easily adapted to wet sites and near coasts (He et al., 2021; Rivas-Sánchez, 2020). Measuring the variation of excess salinity in soils and improving fertility is done by evaluating main parameters such as electrical conductivity, pH, organic matter and temperature (Ren et al., 2022). Electrical conductivity is a reference indicator for soil salinity, whose value of 4 mmho/cm indicates that the soil is saline (Lastiri-Hernández et al., 2019).

Sesuvium portulacastrum is able to develop in high salinity and abiotic stress conditions, within the metabolic development it possesses valuable antioxidants that allow it to agglomerate sodium chloride in values between 100 to 400 milliliters (Barcia-Piedras et al., 2019). This species is suitable for desalination and phytoremediation (Slama et al., 2017), fulfilling a role of osmolyte and antioxidant accumulation (He et al., 2021). On the other

hand, *Aptenia cordifolia* has similar characteristics to *Sesuvium portulacastrum* that allow it to adapt to degraded soils and in excess salinity, in varied climates and low water resources (He et al., 2021), maintaining an acid metabolism that requires the minimum of moisture for its correct adaptability in extreme salinity levels (Karakas et al., 2020; Rivas-Sánchez, 2020). These plants can restore affected soils, achieving crop varieties to develop in better conditions and with higher productivity (Ramaswamy et al., 2017).

Therefore, this research evaluated the salinity reduction efficiency of *Sesuvium portulacastrum* and *Aptenia cordifolia* in an agricultural soil in the city of Chancay in Peru, considering the measurement of soil physicochemical parameters, before and during plant development.

2. Materials and methods

2.1 Study area

The study was conducted in the district of Chancay (11°46' 41.86" S, 77°28' 35.86" W) in Lima, Peru, located between 0 and 15 masl. This place has an arid climate because it is within the coastal strip. For the study an extension of approximately 2 ha was taken.

2.2 Measurement of physical-chemical parameters

For the measurement of physicochemical parameters such as hydrogen potential (pH), electrical conductivity (EC), temperature (T), organic matter (OM), texture, nitrogen (N), phosphorus (P) and potassium (K), samples of 1 kg were collected for each sampling point. Measurements were taken monthly, focusing on electrical conductivity to determine salinity behavior as plants grew.

2.3 Desalination process and measurement of the phenomenological characteristics of the plants

For the desalination process, a 50 m x 50 m plot was considered for each plant species. In each plot, 25 cm deep pits were dug for soil sampling (1 kg per point) and transplanting of plants (20 *Sesuvium portulacastrum* and 20 *Aptenia cordifolia*). Soil salinity monitoring was carried out for 63 days, collecting soil samples monthly. In addition, the phenological characteristics of the plants were measured weekly.

3. Results and discussion

3.1 Variation of physicochemical parameters in the soil plot using *Sesuvium portulacastrum* and *Aptenia cordifolia*

Table 2 and Table 3 shows the values of soil physicochemical parameters, both initial and after treatment with *Sesuvium portulacastrum* and *Aptenia cordifolia*.

Table 2: Physicochemical parameters measured in the field plot using *Sesuvium portulacastrum*

Physicochemical parameters	Values		
	Initial (Day 0)	Intermediate (Day 32)	Final (Day 63)
pH	8.32	7.2	6.6
Electrical conductivity (mS/cm)	5.58	3.3	1.06
Temperature (°C)	20.8	22.1	21.5
Organic matter (%)	0.54	1.43	2.12
Texture (%)	Sand	44	39
	Silt	28	30
	Clay	28	31
Nitrogen (%)	0.82	1.27	1.42
Phosphorus (mg/kg)	11.10	12.27	13.10
Potassium (mg/kg)	10.80	12.30	12.90

By measuring the physicochemical parameters during the 63 days, improvements were evidenced in the plot with *Sesuvium portulacastrum*, resulting in a pH value in the range of 8.32 to 6.60, organic matter from 0.54 to 2.12%, nitrogen from 0.82 to 1.42%, phosphorus from 1.11 to 1.31%, potassium from 1.08 to 1.29% and electrical conductivity from 5.58 to 1.06 mS/cm. The *Aptenia cordifolia* plot had a pH value in the range of 8.22 to 6.60, organic matter from 0.58 to 1.90%, nitrogen from 0.84 to 1.20%, phosphorus from 1.09 to 1.22%, potassium from 1.06 to 1.17% and electrical conductivity from 5.51 to 3.60 mS/cm, increasing and improving the quality of the saline soil. In other research, Vásquez Tenorio (2017) achieved salinity reduction in soil with *Sesuvium Portulacastrum* from 0.2420 mS/cm to 0.1960 mS/cm in a time of 3 months, pH decreased from 8.43 to 8.05 and organic matter from 5.9 to 5.1%. Similarly, Iniyalakshimi et al. (2019) through a study on saline-

sodic soils using *Sesuvium portulacastrum* in 90 days of application obtained improvements in soil physicochemical parameters. The pH, nitrogen, phosphorus, potassium and chloride ranged from 8.17 to 7.25, 156 to 161.2 kg/ha, 26.5 to 21.6 kg/ha, 163.8 to 179.4 ppm and 85.2 to 67.45 ppm, respectively.

Ravindran et al. (2007) studied the restoration of saline soils with halophyte plant, managing to determine that within 120 days there was a reduction of electrical conductivity in soils with *Sesuvium portulacastrum*, decreasing from 4.9 to 2.5 dS/m. Similarly, Sassi et al. (2018) showed that *Sesuvium portulacastrum* can be used in phytodesalinization of soils with electrical conductivity between 10.1 and 23.3 dS/m, reaching phytodesalinization yields of 32.3%. Mamani Flores et al. (2020), in their research in highly saline soils evidenced that *Suaeda fruticosa* Moq. and *Sesuvium portulacastrum* had phytodesalinization yields of 24.6% and 23.4%, respectively. Also, Ramaswamy et al. (2017) worked with *Sesuvium portulacastrum*, reducing the electrical conductivity from 13.04 to 7.37 dS/m in 30 days, and after 120 days a further decrease could be observed, reaching a value of 5.34 dS/m.

Karakas et al. (2020), in their research used *Aptenia cordifolia* in non-saline (EC: 1.38 dS/m), slightly saline (EC: 3.54 dS/m) and very saline (EC: 9.58 dS/m) soils, during the 100 days of treatment. Physicochemical parameters such as pH, organic matter and organic matter showed changes in the three salinity levels, varying in very saline soils from 7.86 to 7.88, 0.57 to 0.77 % and 9.58 to 7.53 dS/m, respectively. On the other hand, Tesen Rojas & Bernabé Quintana (2020) applied *Salicornia fruticosa* for the recovery of saline soils, and as a result obtained that the physicochemical parameters such as pH, organic matter, nitrogen, phosphorus and potassium varied from 7.5 to 7.9, 0.86 to 1.30%, 0.066 to 0.074%, 2.6 to 3.9 ppm, 320 to 1200 ppm, respectively.

Table 3: Physicochemical parameters measured in the field plot using *Aptenia cordifolia*

Physicochemical parameters	Values		
	Initial (Day 0)	Intermediate (Day 32)	Final (Day 63)
pH	8.22	7.4	6.6
Electrical conductivity (mS/cm)	5.51	4.6	3.6
Temperature (°C)	20.7	22.0	22.2
Organic matter (%)	0.58	1.08	1.90
Texture (%)	Sand	43	35
	Silt	28	32
	Clay	29	33
Nitrogen (%)	0.84	1.12	1.20
Phosphorus (mg/kg)	10.90	11.50	12.20
Potassium (mg/kg)	10.60	11.10	11.70

3.2. Salinity reduction efficiency of the plants

The results showed a salinity reduction efficiency value of 81% with *Sesuvium portulacastrum* and 34.7% with *Aptenia cordifolia* (Table 4), indicating that the use of *Sesuvium portulacastrum* presented better performance in reducing soil salts. Similarly, Iniyalakshimi et al. (2019) applying *Sesuvium portulacastrum* in saline-sodic soils absorbed sodium, achieving a salinity reduction of 56.8% in a time of 30 days.

Mamani Flores et al. (2020) by using *Sesuvium portulacastrum* in saline soils achieved a salinity reduction efficiency of 76.8% in 70 days. Similarly, Ramaswamy et al. (2017), He et al. (2021) and Mu et al. (2021) by using *Sesuvium portulacastrum* in salinized soils achieved similar reduction efficiencies with values of 70.8%, 91.7% and 93.25 % for 56, 85 and 90 days, respectively. On the other hand, Ramesh Kannan et al. (2009) determined that in 15 months of planting *Sesuvium Portulacastrum* in saline soils achieved a decrease in NaCl from 12,300 to 2,700 ppm, with 77% of sodium and 63% of chlorine being absorbed. Carhuatocto Tolentino & Morales Palacios (2019), in their research used beans and chickpea for the reduction of electrical conductivity, showing that it reduces by 51.9%.

Table 4: Efficiency of *Sesuvium portulacastrum* and *Aptenia cordifolia*

Physicochemical parameters	Initial concentration (mS/cm)	Final concentration (mS/cm)	Efficiency (%)
<i>Sesuvium portulacastrum</i>	5.58	1.06	81.0
<i>Aptenia cordifolia</i>	5.51	3.60	34.7

In other research, Moscol Soto (2018), through the application of the endophytic bacterium *Bacillus subtilis* achieved the reduction of electrical conductivity by 88% in 21 days of treatment. On the other hand, Mello et al.

(2020) indicates that the phytoremediation technique using endophytic bacteria helps to reduce the environmental toxicity of mercury-contaminated soils, achieving a decrease of the metal by 62.42% using *Pseudomonas* sp. Bacl38. For Barcia-Piedras et al. (2019), desalination of a soil with the halophyte *Arthrocnemum macrostachyum* obtained a positive result in salt reduction by 31% after 30 days of planting. Likewise, Srivastava (2020) mention that 90% sodium reduction was achieved using the phytostabilization method with *Populus alba* and 90% by using the phytoremediation method with *Leptochloa*.

With all the above mentioned, it is confirmed that bioremediation is a viable and sustainable technique to treat contaminated soils, highlighting the capacity and remediation potential of *Sesuvium portulacastrum* and *Aptenia cordifolia* to significantly reduce salinity. This indicates that both plants can contribute significantly to sustainable remediation projects that aim to improve the quality of saline soils and make them available for agriculture (Imadi et al., 2016).

3.3 Phenological monitoring

Table 5 and Table 6 show the phenological growth monitoring of the halophyte plants in the experiment. In *Sesuvium portulacastrum*, growth was evidenced from day 0 to 63, being higher in the root between day 0 to 7, with a growth of 0.5 cm. In the stem, growth was observed from days 0 to 35 with 2 cm for each week, and in the leaf from days 0 to 7 with 0.2 cm. He et al. (2021), in their research showed that in 90 days *Sesuvium portulacastrum* had axillary buds that reached a growth of 10 to 20 mm.

Table 5: Phenological growth of *Sesuvium portulacastrum*

No. of days	Growth		
	Root (cm)	Stem (cm)	Leaves (cm)
0	1.2	1.5	0.80
7	1.7	1.7	0.10
14	2.1	1.9	0.11
21	2.3	2.0	0.12
28	2.7	2.2	0.12
35	3.0	2.4	0.13
42	3.4	2.5	0.14
49	3.7	2.6	0.14
56	4.1	2.8	0.14
63	4.5	3.0	0.14

In *Aptenia cordifolia*, growth was observed from day 0 to 63, being higher for the root between day 0 to 7 with a growth of 0.2 cm. In the stem, growth was observed from days 42 to 49 with 0.4 cm for each week, and in the leaf from day 0 to 7 with 0.3 cm.

Table 6: Phenological growth of *Aptenia cordifolia*

No. of days	Growth		
	Root (cm)	Stem (cm)	Leaves (cm)
0	1.5	2.0	1.5
7	1.7	2.3	1.8
14	1.8	2.6	1.9
21	2.0	2.9	2.1
28	2.2	3.1	2.3
35	2.3	3.4	2.4
42	2.5	3.7	2.6
49	2.6	4.1	2.6
56	2.7	4.3	2.6
63	2.8	4.5	2.6

4. Conclusions

Through phytoremediation, it was possible to determine that halophyte plants have the potential to reduce salinity in saline soils. The salinity reduction efficiency of *Sesuvium portulacastrum* in saline soil reflects favorable effects, evidencing that in 30 days it reaches a value of 41%, and in 63 days 81%. In the case of *Aptenia cordifolia* it shows that in 30 days it achieved a salinity reduction value of 17%, and in 63 days 35%. Both plants showed favorable growth and their use is viable as an effective method to reduce salinity and achieve effective and economical improvement in saline soils. In addition, these plants can contribute

significantly to sustainable remediation projects in saline soils that seek to improve the economies of developing countries.

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