EFFECTS OF SALINITY STRESS ON GROWTH AND MINERAL CONCENTRATIONS OF SESUVIUM PORTULACASTRUM

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TÓM TẮT

ẢNH HƯỞNG CỦA ĐỘ MẶN ĐẾN SỰ PHÁT TRIỂN VÀ HÀM LƯỢNG MUỐI KHOÁNG CỦA CÂY SAM BIỂN (SESUVIUM PORTULACASTRUM)

Ảnh hưởng của các nồng độ mặn khác nhau (10‰, 20‰, 30‰ và 40‰) đến sinh trưởng và hàm lượng các nguyên tố khoáng của cây Sam biển (Sesuvium portulacastrum) được nghiên cứu trong nhà lưới của Trung tâm Nghiên cứu và Chuyển giao Công nghệ - Viện Khoa học và Công nghệ Việt Nam đặt tại Thị xã Hoàng Mai, tỉnh Nghệ An. Số lượng lá và rễ trung bình của mỗi cây trong các nghiệm thức đã được báo cáo, và sinh khối của thân và rễ được xác định sau khi sấy khô ở 80°C cho đến khi khối lượng không đổi. Hàm lượng các nguyên tố dinh dưỡng trong lá và thân của cây Sam biển được phân tích bằng máy ICP-MS. Kết quả, độ mặn 20‰ đã thúc đẩy cây Sam biển tăng trưởng và phát triển, trong khi các độ mặn cao hơn (30‰ và 40‰) lại cho tác dụng ngược lại. Tương tự, hàm lượng các nguyên tố K và Ca cao nhất được tìm thấy ở công thức thí nghiệm 20‰, trong khi các giá trị thấp hơn của K và Ca được tìm thấy ở các công thức thí nghiệm có độ mặn cao hơn (30‰ và 40‰). Đặc biệt, hàm lượng Na và Mg trong thân và lá tăng lên khi độ mặn thí nghiệm tăng trong quá trình thí nghiệm. Nghiên cứu này cho thấy rằng các nguyên tố dinh dưỡng như Na, K, Ca và Mg được hấp thụ ở nồng độ cao, sau đó được vận chuyển và tích lũy trong thân và lá của cây Sam biển. Đây có thể xem là cơ sở để nghiên cứu và ứng dụng loài thực vật này trong các công nghệ khử mặn bằng thực vật để loại bỏ muối và tạo ra nguồn nước sinh hoạt đáp ứng cho nhu cầu sử dụng của người dân ở các khu vực bị nhiễm mặn.
Từ khóa: *Sesuvium portulacastrum, khử mặn bằng thực vật, nhiễm mặn*

1. INTRODUCTION

Sesuvium portulacastrum L. is considered as a pioneer plant species, used for desalination, sand-dune fixation and phytoremediation along coastal regions over the world. The plant could be developed under stress conditions such as drought, salinity and toxic metals. In addition, *S. portulacastrum* is also used as a vegetable for human, food for domestic animals and as a decorative plant. Particularly, *S. portulacastrum* is widely distributed and grows naturally in the tropical, sub-tropical, coastal and warmer areas around the world and well developed at 100–400 mM NaCl concentrations [1, 2]. *Sesuvium portulacastrum* is used in the phytodesalination of soils irrigated over a long-term period with paper mill effluent under non-leaching conditions [3]. Furthermore, *Sesuvium portulacastrum* is the most convenient halophyte to be used for desalination on saline soils under nonleaching conditions in comparison with *Arthrocnemum indicum* (Willd.) Moq. and *Suaeda fruticosa* Forsk [4]. In the other study, *S. portulacastrum* is being used as a phytoremediant to remove NaCl in tannery wastewater discharged open lands containing TDS levels of 12,300 ppm in Tamilnadu state of India. After 15 months (April 2008 – June 2009), the soil TDS level decreased to 2,700 ppm at harvesting time of *S. portulacastrum*. An average of 77% of Na^+ and 63% of Cl^- was absorbed by the plants after 15-month of the experiments [5]. These data demonstrate that, *Sesuvium portulacastrum* is a potential halophyte widely used in phytodesalination of the soils over the world, however, there was no research use this species in desalination for marine water, and less information about the in impact of salt stress on the biomasses and nutrient concentration in this species. Therefore, in this study, we investigated the influence of different salinity concentrations on the leaf number, shoot and root biomasses, and several mineral elements such as Na, K, Ca, Mg, and Fe…

2. MATERIALS AND METHODS

2.1. Plant material, soil and water

Seedlings of *Sesuvium portulacastrum* plants were collected from the mother-plants grown under moderate saline soil areas in Quynh Luu district, Nghe An province, Vietnam (19º06’48.1”N and 105º41’53.5”E) (Figure 1). Each seedling consisted of 6 leaves and had a dry weight of 0,3 g in the beginning of the experiment. The studied plants were grown in the plastic troughs (300 cm x 20 cm x 13.5 cm as the length x width x height) using a loamy soil of 24% clay, 57% silt, 19% sand, and without salinity (0‰), with a density of 200 seedlings per trough. The saline water used in this study was made by dissolving different contents of 10, 20, 30 and 40 $g.L^{-1}$ NaCL into tap water forming the corresponded different concentrations of 10‰, 20‰, 30‰ and 40‰.

Figure 1. Sesuvium portulacastrum L colected at Quynh Luu district, Nghe An province, Vietnam

2.2. Experimental design

The experiment was designed as the Figure 2 with 02 storage tanks (100 L), 06 planting plastic troughs (300 cm × 13.5 cm × 20.5 cm × 13.5 cm, as the length ×the bottom width × the mouth width × the height), 01 collection tank (60 L), 01 recycle pump (with a capacity of 1 $m^3.h^{-1}$), and 04 valves, which were connected to each other by PVC Ø21 pipes, elbows and valves. The experiments were carried out during 60 days after *Sesuvium portulacastrum* acclimatized to the experimental conditions on the troughs (after the third week), and conducted in the greenhouse of Center for Research and Technology Transfer - Vietnam Academy of Science and Technology located in Quynh Luu district, Nghe An province.

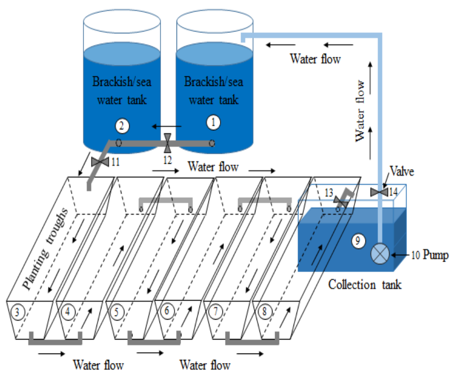

Figure 2. The desalination system using Sesuvium portulacastrum L

((1-2) storage tanks; (3-8) planting plastic troughs; (9) collection tank; (10) recycle pump; (11-14) valve)

2.3. Determination of plant biomass

Plant samples were thoroughly washed with tap water, then with deionized water before dividing into leaves, shoots, and roots. The average leaf number of each plant in the treatments was reported. Shoot and root tissues were dried at 80^{o}C by a fan-forced oven until a constant weight, and then were immediately weight for biomass measurement.

2.4. Measurement of nutrient element contents

A high-speed pulverizer was used to grind the dried shoots and roots to fine powder, the amount of 30 mg/samples was soaked in 5 mL (99%) HNO_3 for 24h, then 3mL H_2O_2 was added and digested on the electricity plate at 180^{o}C for 4-5h to 1 mL of solution remained. It was then diluted with deionized water and analyzed by using ICP-MS (Inductively Coupled Plasma Mass Spectrometry) to determine sodium and nutrient element contents.

3. RESULTS AND DISCUSSION

3.1. Effects of salinity treatment on growth of Sesuvium portulacastrum

As can be seen from the Fugure 3, the number of leaves and roots per each plant was significantly different ($P < 0.05$) between different salinity concentrations in *Sesuvium portulacastrum*. The number of leaves and roots was 116 leaves.plant^{-1} and 10 roots.plant^{-1} as maximum at 20‰ treatment, respectively; the leaf and root numbers decreased with the increasing salinity concentration from 20-40‰. There were 79 leaves.plant^{-1} and 8 roots.plant^{-1} found at 30‰ treatment, whereas values of 72 leaves.plant^{-1} and 3 roots.plant^{-1} were reported as the leaf number and root number of *Sesuvium portulacastrum* under 40‰ treatment, respectively. Obviously, the leaf number was 40 leaves.plant^{-1} as the minimum upon 10‰ salinity concentration, however, its root number (4 roots.plant^{-1}) was higher than that of 40‰ salinity concentration while lower than those of 20‰ and 30‰. Similarly, the effects of salinity concentrations on shoot and root biomasses were determined at Figure 5 (C and D). There was a significant difference ($P < 0.05$) in the dried shoots and dried roots between different salinity treatments after 60 days of transplanting. The highest dried shoot and dried root weights of *Sesuvium portulacastrum* were 3.45 (g.plant^{-1}) and 0.25 (g.plant^{-1}) at 20‰ salinity concentration, respectively; whilst the lowest values of the dried shoots and dried roots were found at 1.34 (g.plant^{-1}) and 0.18 (g.plant^{-1}) under 10‰ treatment, respectively. In addition, the shoot biomasses of *Sesuvium portulacastrum* exposed with 30‰ and 40‰ treatments were 1.79 (g.plant^{-1}) and 1.56 (g.plant^{-1}), respectively; which were 48.16% and 54.89% lower than plants treated with 20‰ salinity concentration. However, no significant difference was reported in the root biomass of *Sesuvium portulacastrum* between 20‰ and 30‰ salinity concentrations, while the dried roots of plants released with 40‰ (0.21 g.plant^{-1}) was lower than those of the 30‰ treatment. It is in agreement with Messedi et al. [6], the dry matter production of *Sesuvium portulacastrum* at low concentrations of NaCl (100 and 200 mM) were significant higher than control and those of the higher concentrations of NaCl. In addition, the higher dose of salt concentrations (400-1000 mM) reduced the growth of *Sesuvium portulacastrum* in leaves and biomass production. In the other research, *Sesuvium portulacastrum* was growing well under the NaCl concentration (100-400 mM) in vitro condition [7, 8, 9]. Furthermore, *Sesuvium portulacastrum* possesses an ability to optimize saline ions and carbon resource absorption and transfer it to different parts of the plant resulting in enhancing succulence following that improving the growth, biomass and net photosynthetic rate of the plant [9, 10]. This illustrates that the salinity concentration plays a pivotal role in the growth of *Sesuvium portulacastrum*, which could be considered as the base to research and apply this plant species in desalination technologies to remediate saline soils and produce fresh water from brackish and marine water.

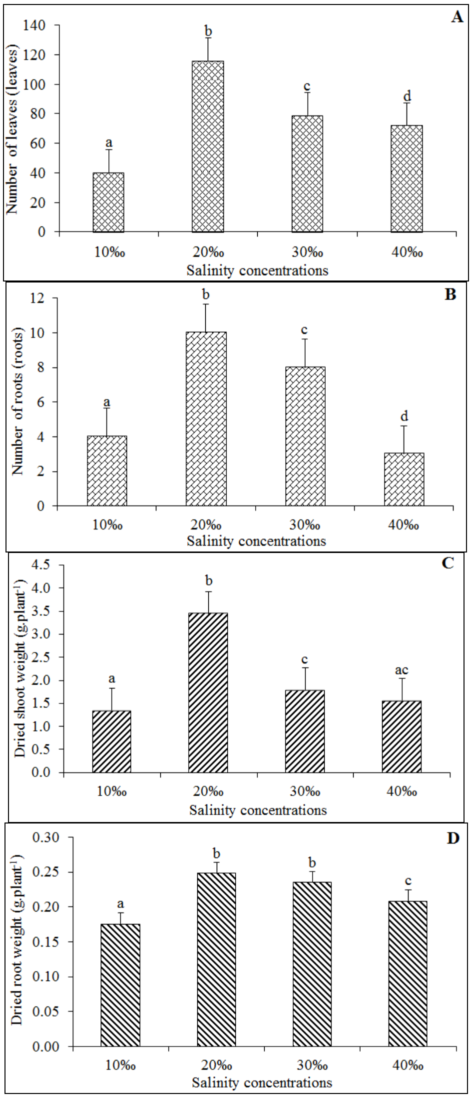

Figure 3. Effects of salinity concentrations on the growth and biomasses of Sesuvium portulacastrum
(A: the number of leaves, B: the number of roots, C: the dried shoot weight, D: the dried root weigh; Different letters on the bars were presented significant difference (P < 0.05) between different salinity concentrations)

3.2. Effects of salinity concentrations on nutrient contents in Sesuvium portulacastrum

Figure 4 shows the influence of salinity treatment on nutrient content in the leaves and stems of *Sesuvium portulacastrum* such as Na, K, Mg, Ca after 60-day exposure. There was a significant difference ($p < 0.05$) in the contents of Na, K, Mg, Ca in the stems and leaves between different salinity concentrations, and between the stems and the leaves upon the same salinity concentration. The concentrations of Na in the stems and leaves of *S. portulacastrum* after 60 days exposed to salinity treatments were illustrated in Figure 4A. There was a significant difference ($p < 0.05$) in Na contents in both leaves and stems between different salinity concentrations as well as the concentrations of Na in stems in comparison with those of the leaves of plants treated with the same salinity concentration. As can be seen from Figure 4A, Na content in the stems increased from 45,519.22 $mg.kg^{-1}$ to 62,639.01 $mg.kg^{-1}$ correspond to salinity concentration up from 10‰ to 40‰, whereas Na concentrations in the leaves were found in values in the range of 13,194.82-17,045.40 $mg.kg^{-1}$. This indicates that high concentration of Na was absorbed by *S. portulacastrum* roots under salinity exposure, and it was then transported to stems and leaves guarantees its normal growth and development in saline environmental conditions. The highest concentrations of K in leaves and stems were 6,942.58 $mg.kg^{-1}$ and 41,064.51 $mg.kg^{-1}$ in *Sesuvium portulacastrum* exposed with the salinity concentration of 20‰, respectively; while the lowest contents of K in the leaves and stems of the plants under 10‰ treatment were 3,320.98 $mg.kg^{-1}$ and 28,954.58 $mg.kg^{-1}$, respectively. A similar content of K in the stems was found at 35,781.88 $mg.kg^{-1}$ and 34,917.56 $mg.kg^{-1}$ in plants treated with 10‰ and 30‰ salinity, respectively; whereas the K content in leaves of plants exposed with 30‰ was 6,351.79 $mg.kg^{-1}$, higher than that of plants exhibited with 10‰ (4,560.78 $mg.kg^{-1}$) (Figure 4B). This is in agreement with the previous study of Messedi et al. (2003) [6], K was absorbed and accumulated in the tissues of *S. portulacastrum*. Similarly, the maximum concentration of Ca was found at 777.57 $mg.kg^{-1}$ in leaves and 2,749.21 $mg.kg^{-1}$ in stems of *S. portulacastrum* under 20‰ exposure, whilst the minimum content of Ca was measured at 271.79 $mg.kg^{-1}$ and 934.64

mg.kg^{-1} in leaves and stems of the plants treated with 40‰, respectively. Ca levels in leaves and stems of the plants exposed with 30‰ were 377.00 mg.kg^{-1} and 1,253.29 mg.kg^{-1}, respectively; which were higher than those of plants under 10‰ salinity concentration with 351.77 mg.kg^{-1} and 1,142.39 mg.kg^{-1}, respectively (Figure 4D). Particularly, Mg contents in the leaves of *S. portulacastrum* significant increased ($p < 0.05$) with the increasing of salinity concentrations. In addition, the significant difference ($p < 0.05$) was reported in Mg concentrations in stems between different treatments of salinity concentrations, and between the leaves and the stems under the same salinity exposure (Figure 4C). Mg plays a critical role in photosynthesis; Mg is involved in chlorophyll synthesis and in the ultrastructure of chloroplasts [11]. The Mg concentration in stems ranged from 37,603.96 mg.kg^{-1} to 65,817.44 mg.kg^{-1}, which was 7.54-12.96 folds higher than in leaves (Figure 4C). From the above results, nutrient contents in *S. portulacastrum* wese reported with 1.32-6.26% Na, 0.39-6.58% Mg, 0.46-4.11% K, and 0.04-0.27% Ca, respectively. It is in agreement with the previous study of Joshi [12], Na content accounting for about 18% of the dry weight, whereas K content of more than 1% of the dry weight, Ca content range from 0.54 to 0.66%, and Mg content in the range of 0.59-1.8%, respectively. In addition, higher concentration of Na was found in the leaves than in the stems, whilst lower concentrations of K, Ca, and Mg were measured in the leaves in comparison with those of the stems. These results suggested that salinity treatments significantly influenced on the nutrient element contents as well as its transport and distribution in the stems and leaves of *S. portulacastrum*. This illustrates that there was an uptake, transport and accumulation of ions in stems and leaves of *S. portulacastrum*, and the higher the concentration of elements absorbed into the stems, the greater their accumulation in the leaves.

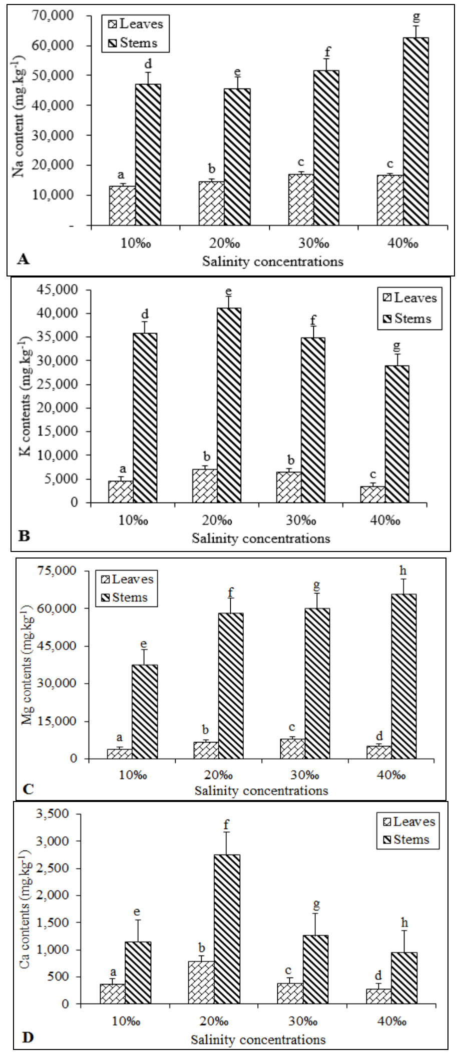

Figure 4. Effects of salinity concentrations on nutrient contents in S. portulacastrum (The mean values are averaged from three replicates and error bars corresponded to three values of standard derivations. Different letters on the bars in the stems (or leaves) indicate signifcant differences (p < 0.05) between different treated salinity concentrations; and different small letters in the same salinity treatment show signifcant differences (p < 0.05) between stems and leaves)

4. CONCLUSION

In summary, salinity had significant influence on the leaves, roots, biomasses and nutrient elements of *S. portulacastrum*, especially, the growth of plants was promoted under 20‰ exposure, whereas the inhibition was reported at higher salinity concentrations (30‰ and 40‰). Similarly, Na and Mg contents in stems and leaves were increased with the increasing of salinity concentrations, however, the highest contents of K and Ca elements were found at 20‰ treatment, while the lower concentrations were showed at the higher exposures of salinity (30‰ and 40‰).

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