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Characteristics of growth rates as a result of salt impact on seedlings of *Suaeda*

This article presents the experiment data on pre-sowing treatment of *Suaeda salsa* Pall. seeds by different concentrations of salts (Na_2SO_4 and NaCl) and soil extract solutions (0 %, 0.6 %, 1.2 %, 1.8 %, 2.8 %, and 3.6 %). The reaction of seedlings and young roots of *S. salsa* was observed, grown after treatment to salt solutions and soil extracts. In addition, based on the results of the growth of young roots and shoots which are exposed to salt, a comparative description of the growth rates of seedlings and young roots before and after salt stress was made. The results of the experiment showed that *S. salsa* seeds have a high germination capacity after the elimination of the high level of salt stress and soil extract solution. The significant changes in development rate of *S. salsa* juvenile root and shoot during and after the salt stress, as well as increasing the germination rate after influence of salt stress were noticed. It was discovered that the growth rates of young roots and shoots of *S. salsa* are different, salt solutions considerably inhibited the growth of roots of plants seedlings compared to soil extract solution. The salt concentration has a greater effect on roots development. It was found that after the removal of salt stress, the germination rate and regenerative capacity of *S. salsa* seedlings increased.

Keywords: saline soil, halophytes, salt concentration, soil extract solution, salt stress, seeds, seedlings, *Suaeda salsa.*

Introduction

Salinity is a significant abiotic factor that limits plant development and decreases agricultural capacity [1, 2]. More than eight hundred million hectares or approximately 6 % of the entire land area on the planet are impacted by salt [3]. Salt-affected soil reduces agricultural production by more than 12 billion US dollars per year, and this amount is still rising. Simultaneously, as more arable land is lost due to the urban expansion, agricultural production is being pushed into marginal areas [4]. Halophytic plants are one of the resources that can be effective in coping with salt-affected environments.

Halophytes are plants that are resistant to salt concentrations which lead to 99 % death of other plant species. Although halophytes have been known for hundreds years, their definitions have remained the same. They are plant species that are capable of continuing life process at concentration of a minimum of 200 mM NaCl with the circumstances that are comparable to those observed in nature [5]. Based on the definition of the life cycle, it was possible to distinguish halophytes from plants that cannot live in saline conditions.

There are 5000–6000 species of halophytes, which make up about 2 % of all angiosperms [6]. Only a few of the halophyte species (less than 500 species) are resistant to the salinity of seawater, and most halophytes can be tolerant only low salt concentrations. The agricultural system's salinity of saline soils can be equal to half of sea water, so some halophytes have the potential to be exploited as salt-tolerant crops. Understanding how halophytes endure saline soils can help for plant breeders and molecular biologists to improve the salt resistant of traditional agricultural crops [7].

Suaeda is a halophyte belonging to the family *Amaranthaceae*. Several species, such as *S. acuminata, S. aegyptiaca, S. arcuata, S. argentinensis, S. australis, S. baccifera,* are known as salt resistant plants. Many species of these plants grow well in saline or alkaline soils, such as coastal saline plains and sedimentary wetlands. They are adapted to grow in areas with high salt accumulation (halophytic plants). *Suaeda salsa* Pall. has been demonstrated to be resistant to salinity up to 500 mM [8]. At the same time, it is an important key in the restoration of deserts, solonetz and sea coasts.

S. salsa is commonly used for both edible and non-edible purposes. The shoots of the plant are used in salads or processed into salty drinks, vinegar. On the other hand, making soap from these plants and using it as a source of soda (sodium carbonate) has been a common practice for centuries [9].

Some species of *Suaeda* (*S. salsa*) are grown commercially for biofuel production, animal fattening, salt and fat production. Recent studies have shown that some species of *Suaeda* can be used as bio-indicators of zinc and copper. In addition, the medicinal and nutritional properties of the plant *Suaeda* contributed to the growing interest in it [10].

Although the use of these plants is widespread, the use of halophytes as cultivated plants is still limited due to barriers including loosening the soil and uneven seed germination. In fact, some species of halophytes are salt-tolerant during the mature shrub, but undergo salinity — resistant ecotypic feedback during seed germination [11].

Seed germination is usually high in fresh water and germination decreases with increasing salinity, but in some species, low salt concentrations may stimulate seed germination [12]. Often, after the rainy season, when the salinity of the soil decreases, the germination of seeds is high and the risk of stress on the seeds of salt plants is reduced [13].

Halophytes are studied widely because of their importance in the development of saline arable lands. An example is the eugalophytic herb *Suaeda* (*S. salsa*). Eugalophytes can dilute salts in their leave sand stems, indicating that they have a high salt tolerance. This information will be useful in determining how dicotyledonous plants tolerate salt [14]. The possibility of using salt-tolerant, juicy halophytes (especially *Suaeda* and *Salicornia species*) in amaranth in saline fields is given in several articles [15]. *S. salsa* is highly salt-tolerant; for its growth, the ideal salt concentration is 200 mM NaCl, which germinates as well as in 400 mM NaCl solution in 10 mM NaCl solution [16]. A number of genes related to the salt resistance of *S. salsa* was cloned and their functions were studied before. That is, halophytic plant species are a promising model for understanding salt tolerance. In addition, the leaves of this species have been studied as vegetables, and its seeds are high in fatty acids that are edible and unsaturated, which can be used as crops. The value of *S. salsa* is considered from the economic and ecological point of view. The purpose of this study was to assess the growth and recovery of Aksora *(S. salsal)* seedlings under the influence of various salt stress.

Experimental

Test materials were obtained in late September, 2020 from the saline soils of Lake Maraldy, Pavlodar region. The seeds were obtained from a complete and mature European calf plant, the experiment was performed in the laboratory of the Department of Environmental Management and Engineering, L.N. Gumilyov Eurasian National University.

The light intensity was 12 h/day, the temperature was 25 °C (day time)/15 °C (night), the relative humidity was 75–80 %. Basic salts to be tested: NaCl, Na_2SO_4 and a soil extract solution (SES) soil sample obtained from Lake Maraldy, Pavlodar region. The proportion of basic elements in 10 grams: Cl — 0.679 %, K — 3.375 %, Ca — 2.326 %, Fe — 8.819 %, S — 0.039 %. Concentration of stress salts: 0 %, 0.6 %, 1.2 %, 1.8 %, 2.8 %, 3.6 %.

The plant seeds collected for the experiment are sterilized for 10 minutes with a 10 % hydrogen peroxide (H_2O_2) solution, then cleaned multiple times with distilled water. The cleaned seeds are dried on filter paper. This is done to prevent the seeds from rotting under the influence of bacteria and fungi [17]. Two layers of filter paper (10 cm in diameter) are placed on each Petri dish, and then 25 pieces of sterile plant seeds are placed on top of the filter paper. Distilled water is used to prepare different saline solutions, and each experiment is repeated 4 times. The number of seeds grown must be monitored and recorded daily (from the time the seedling grows 2 mm from the seed coat) [18]. The total duration of the experiment is 14 days.

Results and Discussion

Aksora *(S. salsa)* has young roots with different concentrations of salts (Na_2SO_4 and NaCl) and soil extract solutions (0 %, 0.6 %, 1.2 %, 1.8 %,2.8 %, 3.6 %). The results are demonstrated in Figure 1.

Figure 1 depicts the salt stress effect on development of the young roots of Aksora*,* depends on the type and concentration of salt, and the main trend in the growth of young roots is an increase in root growth retardation due to increased salt concentration.

It was found that low concentrations of salts are effective for the growth of young roots. At 0.6 % of salts and soil solutions, the root growth rate was 1.8–2.5 cm, which had a positive effect on their growth. When the salt concentration is more than 1.8 percent, it is demonstrated that the growth of young roots is inhibited, and inhibition grows with increasing salt concentration, and the degree of growth and inhibition depends on the type and concentration of salt, significantly inhibited.

Results of growth of Aksora seedlings at different concentrations of salts (Na_2SO_4 and NaCl) and soil extract solutions (0 %, 0.6 %, 1.2 %, 1.8 %, 2.8 %, 3.6 %) are illustrated in Figure 2.

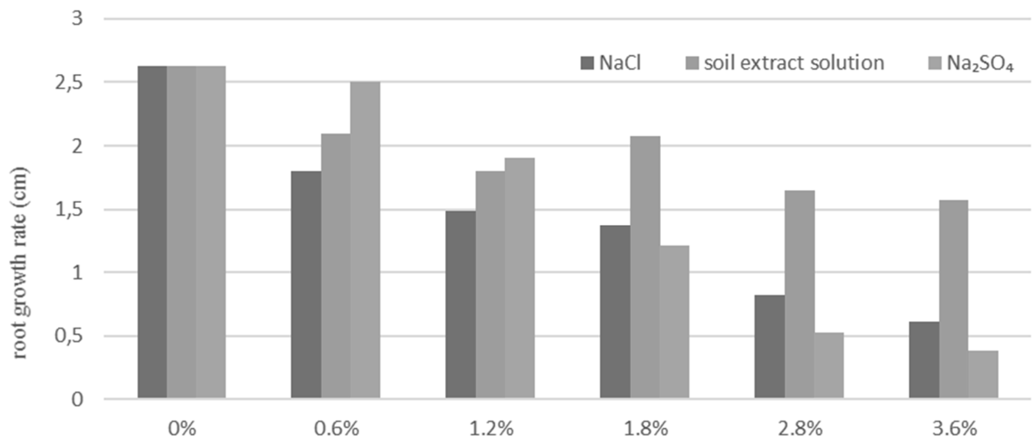

Figure 1. *Suaeda salsa* root growth rate (cm)

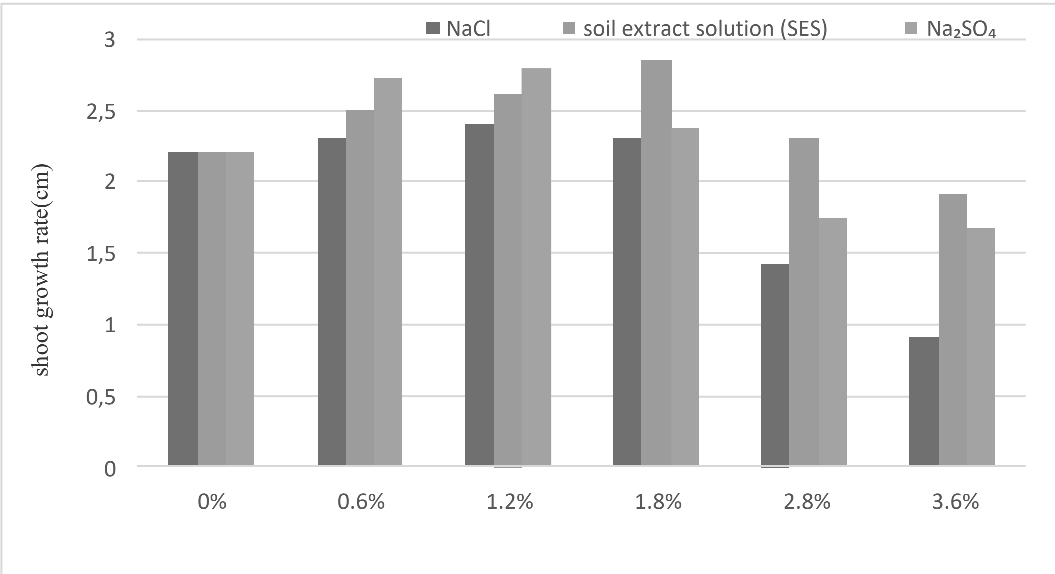

Figure 2. *Suaeda salsa* shoot growth rate (cm)

Figure 2 indicates that increasing the concentration of salts and soil extract solutions has a good effect on the development of *S. salsa* seedlings. At a concentration of 0.6 % of salts and soil solutions, the length of the growth was 2.31–2.73 cm, while at 1.2 % it was 2.40–2.80 cm. When the salt level exceeds 1.8 percent, the growth of the seedlings is inhibited; however, the effect of soil solution on seedling development is negligible.

It was established that the degree of inhibition of salinity in young shoots and young roots is different, the change in the parameters of young roots is clearly visible, and the change in young shoots is relatively slow. Only when the salt concentration exceeds 1.8 percent, there is a significant change in the growth rates of young roots and shoots. This indicates that the concentration of salts has an effect on the growth rate of *S. salsa* seedlings. In particular, these salts have been shown to have a greater effect on the growth of *Suaeda* roots.

There is an assessment of the growth of *S. salsa* seedlings after the elimination of salt stress. Figure 3 designates the normal growth rates of *Suaeda* seedlings after the elimination of high-concentration salt stress.

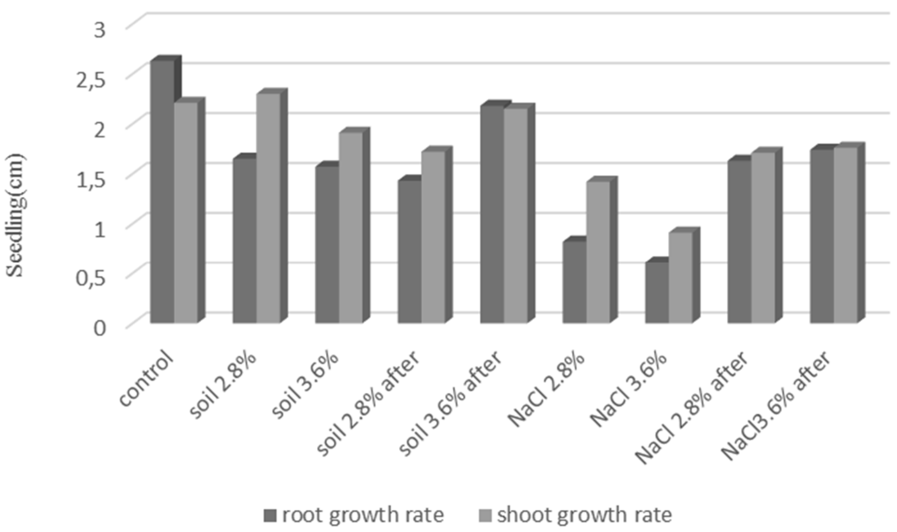

Figure 3. Comparison after re-cultivation of *Suaeda salsa* seedlings in distilled water, (cm)

Figure 3 demonstrates that after re-cultivation of *S. salsa* seedlings in distilled water, the growth of young roots exceeded the control data by more than 65 %, while the growth of young shoots exceeds that of the control by more than 80 percent. Before planting, the development of roots and shoots of *Suaeda salsa* seedlings was slowed down because of the increase in salt concentration, and after this process and treatment, the growth of roots and seedlings showed a tendency to increase concentration of saline solutions. As a result, it was found that the ability of *Suaeda* seedling store cover after the elimination of salt stress has improved. In addition, there were differences in the growth of seedlings and roots under stress and stress relief at different concentrations of salt, and at high concentrations of soil solution (3.6 %) there was a significant change in the growth of seedlings and roots before and after re-cultivation in water. It can be seen that the length of young roots and shoots increased by 1.57–2.18 (cm) and 1.91–2.15 (cm), respectively. However, before and after the stress of NaCl salt, there were paramount differences in the development of roots and branches, and high concentrations of NaCl significantly affected the growth of *Suaeda* seedlings.

Conclusions

It is illustrated that the growth of seedlings of Aksora *(S. salsa)* is directly related to the type and concentration of salt, and the degree of inhibition of seedling roots grows with increasing salt concentration under the stress of salt and soil solutions. Under stress of 0.6–1.8 %, the growth rates of young shoots increased to varying degrees, but the scale of change was negligible. It was found that the concentrations of salts and soil solutions have a greater effect on young roots than on shoots. *S. salsa* seeds not only germinate normally after high concentration of salt stress, but can grow normally in their seedlings, young roots and shoots can be used in 65 % and above 80 % salt-free conditions, and after exposure to salt, *S. salsa* improves the ability to restore the growth of seedlings.

Significant changes in the growth rate of white seedlings before and after treatment with NaCl salt were observed. Germination and germination of seeds in a saline environment will be a crucial and sensitive stage in the growth of halophytes [19]. Studies presented that Aksora has a strong ability to adapt to salt, so it is recommended to grow and use it extensively in saline-alkaline areas. The results of the experiment demonstrated that the *Suaeda* seeds still have a high germination capacity after the stressful effects of salts and soil extract solutions on the *Suaeda* seeds have been eliminated. Considerable changes in the growth rate of young roots and shoots of the plant *Suaeda* were observed during the salt stress. The improvement of seed germination rate after the removal of stress was identified. Consequently, the growth rates of young roots and shoots of *Suaeda* in different saline solutions were different, and the salt concentration had a greater effect on the roots. It was studied that after the elimination of salt stress, the germination rate and regenerative capacity of *Suaeda* seedlings increase.

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Ж. Рахымжан, Р.Р. Бейсенова, Ж.Б. Текебаева, А.Б. Абжалелов

Ақсора көшеттеріне тұздардың әсер ету кезіндегі өсу көрсеткіштерінің сипаттамалары

Мақалада *Suaeda salsa* тұқымдарына тұздар (Na_2SO_4 және NaCl) мен топырақ сығындысы ерітінділерінің әртүрлі концентрациясында (0 %, 0.6 %, 1.2 %, 1.8 %, 2.8 %, 3.6 %) өңдеу жасалды. Өңделгеннен кейінгі өсіп шыққан Ақсора өсімдігінің өскіндерімен жас тамырларының тұздармен топырақ сығындысы ерітінділеріндегі реакциясы бақыланды. Сонымен бірге, тұз стресі жағдайында өсіп шыққан жас тамырлар мен өскіндердің өсу кезіндегі көрсеткіштерінің нәтижелеріне сүйене отырып, тұз стресінен бұрынғы және стрестен кейінгі кездегі өскіндер мен жастамырлардың өсу көрсеткіштерінің салыстырмалы сипаттамасы жасалынды. Эксперимент нәтижелері көрсеткендей, Ақсора тұқымына әсер етуші тұздар (Na_2SO_4 және NaCl) мен топырақ сығындысы ерітіндісінің стрестік әсері жойылғаннан кейін Ақсора тұқымдарының әліде жоғары өнгіштік қабілетке ие екендігі анықталды.

Тұз стресі кезінде және стресс жойылғаннан кейінгі кезде Ақсора өсімдігінің жас тамырлары мен өскіндерінің өсу көрсеткішінде айтарлықтай өзгерістер бар болғандығы, сонымен қатар стрестік әсерден кейін тұқымның өну жылдамдығының жақсарғандығы байқалды. Ақсораның жас тамырларымен өскіндерінің әртүрлі тұз ерітінділеріндегі өсу көрсеткіштерінің түрліше болғандығы, топырақ сығындысының ерітіндісімен салыстырғанда тұз ерітінділері Ақсора көшетінің тамырларының өсуін айтарлықтай тежейтіндігі, яғни тұз концентрациясының тамырларға көбірек әсер ететіндігі анықталды. Тұз стресі жойылғаннан кейін Ақсора көшеттерінің өну көрсеткішінің және қалпына келу қабілетінің жоғарылайтындығы анықталды.

Кілт сөздер: тұзды топырақ, галофиттер, тұз концентрациясы, топырақ сығындысының ерітіндісі, тұз стресі, тұқым, көшеттер, *Suaeda salsa.*

Ж. Рахымжан, Р.Р. Бейсенова, Ж.Б. Текебаева, А.Б. Абжалелов

Характеристики скорости роста при воздействии солей на проростки сведы солончаковой

В статье представлены результаты экспериментов по обработке семян *Suaeda salsa* Pall. различными концентрациями солей (Na_2SO_4 и NaCl) и почвенными экстрактами (0 %; 0,6; 1,2; 1,8; 2,8; 3,6 %). Наблюдали реакцию проростков и молодых корней растений *Suaeda salsa*, выращенных после обработки растворами солей и почвенными экстрактами. Кроме того, по результатам роста молодых корней и побегов, выращенных в условиях солевого стресса, было проведено сравнительное описание темпов роста проростков и молодых корней до и после солевого стресса. Результаты эксперимента показали, что семена сохраняют высокую всхожесть, несмотря на высокие стрессовые условия солей (Na_2SO_4 и NaCl) и растворов почвенных экстрактов, влияющих на семена *Suaeda salsa*. Наблюдались значительные изменения в скорости роста молодых корней и побегов растения *Suaeda salsa* во время и после солевого стресса, а также улучшение скорости прорастания семян после стресса. Выявлено, что темпы роста молодых корней и побегов *Suaeda salsa* в разных солевых растворах различаются, солевые растворы значительно подавляют рост корней проростков *Suaeda salsa* по сравнению с раствором почвенного экстракта, концентрация соли в большей степени оказывает влияние на корни растения. Установлено, что после снятия солевого стресса всхожесть и регенерационная способность проростков *Suaeda salsa* повышаются.

Ключевые слова: засоленная почва, галофит, концентрация соли, раствор, почвенная вытяжка, солевой стресс, семена, проростки, *Suaeda salsa.*

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