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USING SOME TECHNIQUES TO IMPROVE THE GERMINATION OF TWO ATRIPLEX SPECIES

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ABSTRACT

The seeds of two Atriplex species (*Atriplex Nummlaria* L. *Canescens* L.) were collected from the Field Crops Department/College of Agriculture and Forestry/University of Mosul, Nineveh, Iraq. These varieties are used in combating drought and pastoral plants within an agricultural program within the AL-Hather area in Nineveh Governorate. The study aimed to improve the germination rate in different ways before planting. The experiment was carried out on 400 seeds, which were divided into five groups treated before planting with the following treatments (soaking with regular water for 24 hours, with boiling water for one hour, with sulfuric acid at a concentration of 5% for one second, mechanical scratching, as well as a comparison treatment). Experiment results showed that soaking with boiling water impeded and reduced germination by 100% for two species. The acid treatment increased the germination rate of (*Atriplex Canescens* L.) by 72%. The effect of the other treatments was insignificant compared with the treatment control, while the (*Atriplex Canescens* L.) germination rate increased to 67% for soaking with plain water treatment.

INTRODUCTION

The Arab world suffers from a scarcity of rainfall, as most of its lands are in arid and semi-arid regions. The problem of desertification, along with salinity, is considered one of the most important problems facing agriculture from both economic and environmental terms in the world, where the percentage of desertified lands reaches 68% of the Arab world (Nikalje *et al.,*2018), while the rate of lands threatened by desertification is about 89% of the Arab world. The percentage of saline land in the Arab region is about 134.17 million hectares (James *et al.,* 2020). The area of land affected by salts is estimated at 7% of the world's land and more than 50% of agricultural land (Chaudhary, 2019).

The first step to renewing natural pastures and increasing their production lies in the proliferation of good pastoral plants. Atriplex is considered one of the good types resistant to salinity and drought, and it is recommended for the rehabilitation and renewal of pastures or the reclamation of saline lands. Biologically, a gradual decline in palatable species has been observed to the point of extinction, which negatively affects the richness of plant biodiversity (Rosbakh *et al.,* 2020). The decline in pastoral plant species is mainly due to overgrazing, which is caused by the increasing number of animals and groundwater salinization. The possibility of investing in saline agricultural lands depends on the development of salt-tolerant pastoral species, with the aim of re-cultivating them in degraded saline lands and testing their suitability for the production of fodder in salt-affected areas (Bhatt *et al.,* 2020). The Atriplex genus includes more than 200 species, most of which are found in dry and saline areas. Many species of this genus are perennial, remain green throughout the year, and make good fodder for livestock in dry and saline areas. The significance of Atriplex species stems from their role as an excellent livestock forage, attributed to their high levels of crude, which is preferred by livestock (Atzori *et al.,* 2017; Tang *et al.,*2021). It is also used for the rehabilitation and development of dry areas because they are well adapted to a low rainfall environment (150 - 250 mm/year). The technique of seed treatment, or what is called primary seed preparation (Seed priming) before planting, is one of the methods that stimulates germination, accelerates it, homogenizes plant growth, and reduces the required amount of seeds (Nisar *et al.,*2019). Germination is a critical stage in the life cycle of halophytes (Bekmirzaev *et al*, 2020). Dispersal and germination strategies of halophytes determine their establishment and survival in harsh environments. The capacity to preserve seed viability during exposure to these conditions and to trigger germination once stress is removed is one of the mechanisms that allow tolerant species to persist (Gao *et al.,* 2018).

The research difficulty consists of overcoming difficult seediness. Various pretreatments, such as hot water, cold water, and mechanical and chemical scarifications, have been proposed to overcome hard seediness. The successful establishment of plants depends initially on a high germination percentage over the shortest period of time. Atriplex seeds have a problem with germination. This plant's low germination rate is caused by the fruiting coat's incapacity and obstruction to the germination process. The study aims to improve the percentage of seed germination in shrubs of two kinds of the pastoral Atriplex plant (*Atriplex canescens* L., *nummlaria* L.) In order to increase the yield of Atriplex fruit for the production of pastoral nurseries—that is, to produce more seedlings from the same number of seeds to restore lands, particularly saline and degraded lands, from natural ones in arid and semi-arid areas—the seeds should be treated directly before planting and then subjected to the best of those treatments. These plants play a major role in sustaining pasture lands and reducing the effects of climate change, as they are drought and salinity-resistant plants.

Materials and Methods

Atriplex seeds (Atriplex nummlaria *L*., canescens *L*.) were collected from the field crops department/College of Agriculture and Forestry/University of Mosul, and these varieties are used in combating drought within an agricultural program in the Hatra region in Nineveh governorate, as they are always described as pastoral plants. The seeds of the studied species were sown on 12/5/2020 in plastic pots 25 cm in diameter and 20 cm in depth, at a rate of ten seeds per pot, 2cm in depth, and at a rate of four replications per treatment. The following five treatments were applied to the seeds: soaking in ordinary water for a whole day, boiling water for an hour, sulphuric acid at 5% concentration for a second, mechanical scratching, and comparing. The first group of seeds was soaked in regular water for 24 hours before planting, the second group was soaked in boiling water in a bowl for one hour, the heat source was removed and then dried and planted, while the third group was mechanically scratched using regular softening paper, the fourth group of seeds were immersed in sulfuric acid at a concentration of 5% for one second and then washed directly with normal water to remove the acid from it. The soil used in this study was brought from the Tal Zalat area, about 30 km from Mosul, from agricultural land cultivated with the barley crop. The pots were irrigated with plain water, and readings were taken daily from the day after the date of planting and for a period that lasted for forty days, which is the period specified for the seed germination test (Koobonye and Mogotsi, 2018) The values were obtained by counting the number of seeds that germinated, and the rootstock was deemed sprouted when it was visible to the unaided eye, i.e., when the length of the rootstock is 2 mm or more, to determine the germination percentage and to give an idea of the speed of germination in the different treatments separately and compare it with each other. The experiment data were analyzed statistically to assess the significance between average numbers of germinated seeds in replicates of studied treatments and, accordingly, between averages of germination ratios to different treatments.

Germination indices measured were:

1- Germination percentage (GP): total number of germinated seeds/total seeds x 100.
2- Mean daily germination (MDG): total number of germinated seeds/total number of days of germination period.
3- "Germination speed (GS): was calculated following the formula as follows: n1/d1 + n2/d2 + n3/d3 + ..., where n – number of germinated seeds and d – number of days". (Czabator, 1962).
4- Mean germination time (MGT), was calculated following the formula given by Ellis and Roberts (1981): Σ nTi MGT =…………, Σn , where T1 is the number of days from the beginning of experiment and n is the number of newly germinated seeds on day Ti,
5- Seedling vigor index (SVI) was determined according to formula given by Abdul- Abdul-Baki and Anderson (1973) as: seedlings length (cm) x germination percentage/100.

RESULTS AND DISCUSSION

1– *Atriplex canescens*

The effect of the four treatments on the germination of A. canescens is shown in Table (1). The seeds present varied behavior towards treatments in the sulphuric acid at the time of their germination. Different parameters related to seed germination were affected by applied treatments. In general, compared to control, the treatments had stimulatory and inhibitory effects. The stimulatory was recorded in seeds soaked in sulfuric acid and was significantly compared with the control Figure (2) and has the highest effect in seed germination. Soaking in the sulphuric acid is favorable for the seeds of A. canescent (Table 1), improving GP, MDG, and GS from 55%, 0.95 %, and 0.78 seed/day for the control to 72%, 1.2%, and 1.15 seed/day for the sulphuric acid treatment, respectively. However, wetting with tap water for 24 hours and mechanical scratching showed unfavorable evolution on GP and MDG, but the GS increased from 0.78 to 1.21 seed/ day when the seeds were wetted in tap water, and they were not significant compared with the control. The lowest GP, GS, and MGT values were recorded for mechanical scratching compared with other treatments. The inhibitory effect was recorded in seeds soaked in hot water. Germination of Atriplex canescent seeds in this experiment started earlier on the seventh day of planting in all replicates compared with the control treatment, which started on the thirteenth day of planting and was all leveled after 20 days (Figure 1).

Table (1): Effects of treatments on various parameters related to germination of *Atriplex canescens*

Treatment	GP (%)	MDG (%/day)	GS (seed/day)	MGT (days)
control	55	0.95	0.78	13.1
Wetting with tap water for 24 hours	47	0.82	1.21	13.9
Mechanical scratch	42	1.0	0.61	12.8
wetting with H_2SO_4 acid for one second	72	1.2	1.15	13.5
Wetting with boiling water for one hour	0	0	0	0

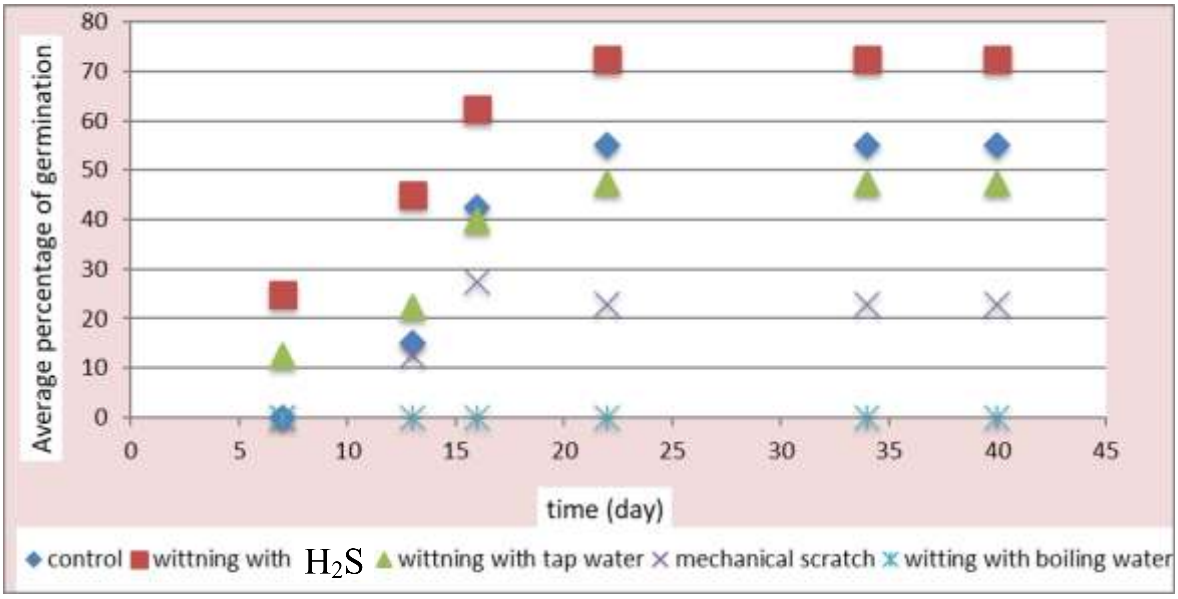

Figure (1): Shows the relationship of time with the average germination of *Atriplex canescens*

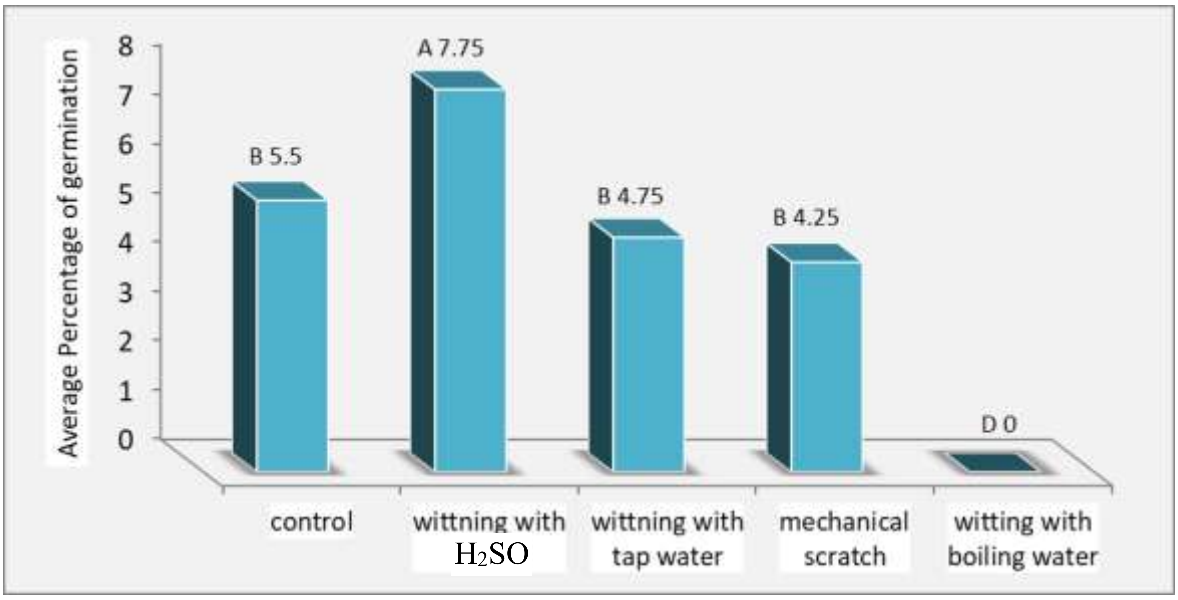

Figure (2): Showing average germination of *Atriplex canescens*

Seed scarification by immersion in H_2SO_4 is often used to eliminate barriers delaying germination (Ben-Asher *et al.,* 2021). The highest stimulatory effect of sulfuric acid scarification on seed germination had been reported in Atriplex canescens by Nosrati et al. and in other plants such as Tamarindusindica (L.) (Muhammad and Amusa, 2003), Centrosemapubescens (Bekmirzaev *et al.,* 2021) in seeds of Leucaena. This finding is similar to the report of Lastiri-Hernández *et al.* (2021) that acid treatment of seeds removes the waxy layer of the seed coat by chemical decomposition of the seed coat components is similar to the breakdown process occurring during the microbial attack. Seed scarification by immersion in

H_2SO_4 is often used to eliminate barriers delaying germination (Chaudhary *et al.,* 2019). In the present study, the soaking period was only one second in 5% sulphuric acid and was enough to increase germination percentage by 17%; however, (Lastiri-Hernández *et al.,* 2021) stated that increased time of sulfuric acid (3-4) hours treatment caused germination percentage to grow to 95% in Canna indicia L. Higher figures for soaking and germination has also been reported by other workers, germination of L. arboreus Sims seeds without scarification was 5%, and increased to 80% after 60 min in H_2SO_4 (Mackay *et al.,* 2001).In the same context, Nosrati *et al.* (2008), found that effective methods for breaking the dormancy of A. canescens seeds were scarification by 90% sulfuric acid for 30 min. Opposite to the above finding (Matinzadeh *et al.,* 2019) indicated that 0.1 KNO_3 and 100 mg L^{-1} acetylsalicylic acid were the most effective treatments for the improvement of seed germination percentage in A. lentiform and A. canescens, respectively compared with sulfuric acid, immersion in hot water, pretreatment with thiourea and pre-chilling. Figure (3) shows the average germination rate and the highest average germination according to the statistical analysis when the soaking was treated with tap water for 24 hours. There were no significant differences between the control treatment and the other treatments (Castillo *et al.,* 2021).

2– Oldman saltbush (*Atriplex nummularia*)

Seeds with their bracts (fruits) were subjected to physical (scratching, water soaking) and chemical (sulfuric acid) treatments. Wetting with tap water for 24 hours is favorable for the seeds of A. nummularia (Table 2), recording GP, MDG, and GS of 67%, 0.77 %, and 0.95 seed/day, lowered to 35%, 0.46%, and 0.57seed/day for the mechanical scratching treatment and 42%, 0.40% and 0.49seed/day for the control respectively. The lowest GP, GS, and MGT values were recorded for the chemical sulphuric acid treatment, being only 17%, 0.4%, and 0.49 seed per day for GP, MG, T, and GS, respectively, compared with other treatments. It seems that the time of soaking was not enough to stimulate seed germination and remove the waxy layer of the seed coat. The highest germination percentage (67%) was observed in treatment with tap water and was significant compared with the control (42%); the lowest percentage (0%) was obtained with boiled water, and they were significantly different according to the results of ANOVA test Figure (3), unlike the results of the acid treatment which was not significantly different from the control. Figure 3 stated that seeds treated with acid and tap water, besides the control, started to germinate on the 7^{th} day, but the differences between them widened as time passed. Bracteoles on fruiting structures in Atriplex species may serve to control the timing of seed germination and also aid the wind or water dispersal of seeds (Bekmirzaev *et al.,* 2021).

Table (2): Effects of treatments on various parameters related to germination of *Atriplex nummulria*

Treatment	GP (%)	MDG (%/day)	GS (seed/day)	MGT (days)
control	42	0.40	0.49	10.8
Wetting with tap water for 24 hours	67	0.77	0.95	11.6
Mechanical scratch	35	0.46	0.57	12.3
wetting with H_2SO_4 acid for one second	17	0.18	0.49	16.3
Wetting with boiling water for one hour	0	0	0	0

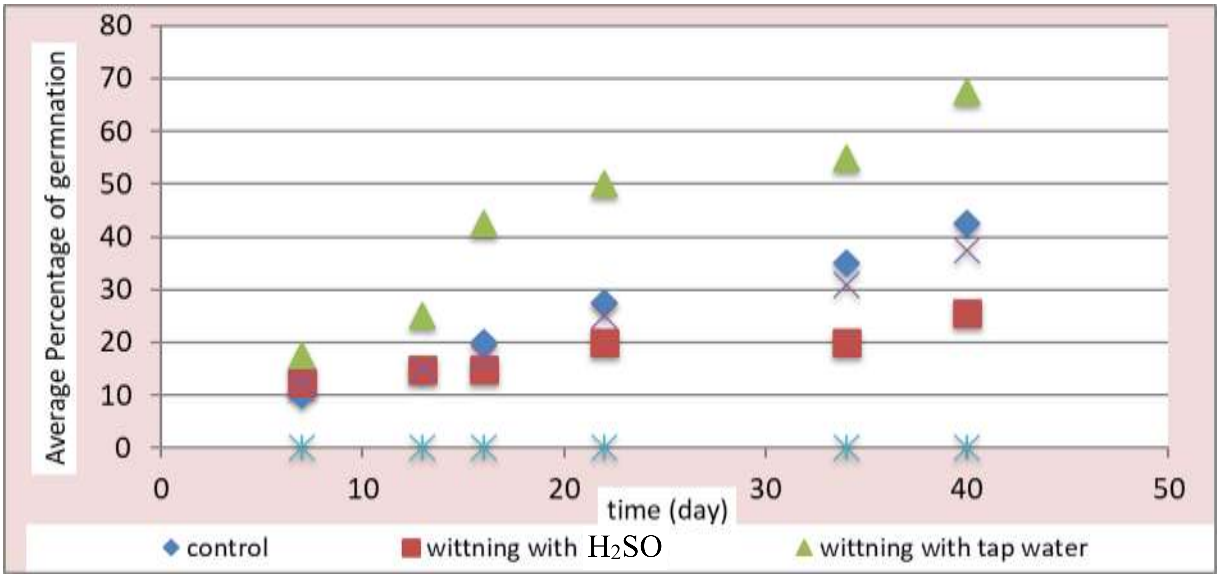

Figure (3): Shows the relationship of time with the average germination of *Atriplex nummulria*

Inhibition of seed germination of Atriplex spp. by bracteoles has been reported in the literature (Khan and Weber,2004), determined that removal of the fruiting bracteoles of Atriplex halimus L. increased germination from 35 to 98 %. (Grigore and Toma, 2017) observed that partially debated seed of Atriplex nummularia (Lind.) showed maximum germination of 50.7% and 75.3% of water-cleaned. The treatment with sulfuric (25% for 10 min, 50% for 10 and 20 min) had a highly significant ($P < 0.0001$) effect on seed germination of Oldman saltbush (Atriplex nummularia) (Abu-Zanat and Samarah, 2005). This is explained by the presence of relatively high concentrations of dissolved salts in bracteoles. The results indicate that the inhibiting factors of germination must be located in the bracts. Future work should focus on developing technologies to remove the bracts surrounding the true seed of *A.*

nummularia. Figure (4) shows the average germination rate and the highest average germination according to the statistical analysis when the soaking was treatment soaking with sulfuric acid at a concentration of 5% for one second. There were no significant differences between the control treatment and the other treatments (Abdul-Kareem and Ekhlayef, 2013).

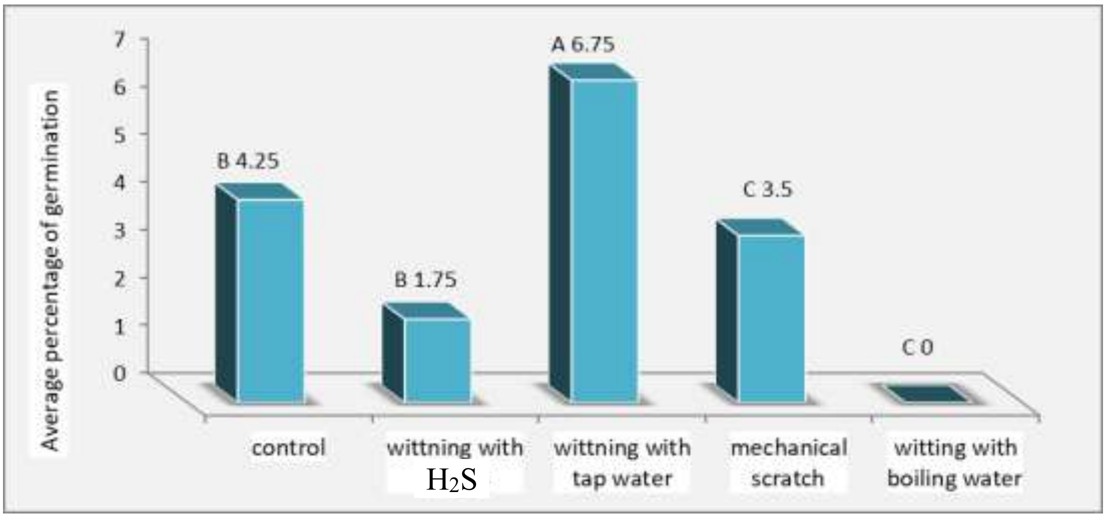

Figure (4): Showing average germination of *Atriplex nummulari*

CONCLUSIONS AND RECOMMENDATIONS

1. Soaking (Atriplex canescens *L*. nummlaria *L*.) seeds for one hour with boiling water kills the seed embryo, so the seed is no longer able to germinate. Therefore, we recommend not performing this treatment.
2. Soaking (Atriplex canescens *L*.) seeds for one second in sulfuric acid at a concentration of 5% gave a high plant percentage, which is higher than the comparison treatment. Therefore, we recommend that this treatment be carried out on a different concentration of sulfuric acid to determine the best concentration that can stimulate germination faster. This treatment was not given. High results with Australian rag, so we recommend using a different concentration of sulfuric acid to see its effect on germination.
3. There was no discernible difference in the germination rate of the seeds when they were mechanically scratched prior to planting. We advise employing specialised machines for this reason because physically scratching the seeds is a slow operation and it is impossible to determine how a treatment will affect the seeds.
4. Soaking the Atriplex nummlaria *L*. seeds for 24 hours with plain water before planting gave positive results. We recommend using this treatment with Australian clam seeds before planting them in pastoral nurseries.
5. This research has applied the economic importance represented in consuming seeds for the production of American and Australian ragweed seedlings and

consuming the fewest seeds in the production of the largest number of seedlings.

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CONFLICT OF INTEREST

Conflict of interest: the author declares that there is no conflict of interest with regard to the publication of this article.

استخدام بعض التقنيات لتحسين انبات صنفين من نبات الرغل *Atriplex species*

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الخلاصة

جمعت بذور صنفين من الرغل (*Atriplex nummlaria* L. , *canescens* L.) من قسم المحاصيل الحقلية /كلية الزراعة والغابات/جامعة الموصل وتستخدم هذه الاصناف في مكافحة الجفاف ضمن برنامج زراعي ضمن منطقة الحضر في محافظة نينوى وفي الوقت نفسه لوصفها نباتات رعوية. بهدف تحسين نسبة الانبات بطرق مختلفة قبل الزراعة، نفذت التجربة على 400 بذرة قسمت الى خمس مجاميع تعامل قبل الزراعة بالمعاملات التالية (النقع بالماء العادي لمدة 24ساعة، النقع بالماء المغلي لمدة ساعة واحدة، النقع بحامض الكبريتيك بتركيز5% لمدة ثانية واحدة، الخدش الميكانيكي، معاملة المقارنة) أظهرت نتائج التجربة ان النقع بالماء المغلي يعيق ويخفض الانبات 100% ولكلا الصنفين. ان معاملة حامض الكبريتيك رفعت نسبة انبات الرغل الامريكي 72% لم يكن تأثير المعاملات الاخرى معنوي مقارنة مع معاملة المقارنة لنفس الصنف، اما الرغل الاسترالي ارتفعت نسبة الانبات الى 67% لمعاملة النقع بالماء العادي ولم يكن تأثير المعاملات الأخرى معنوي للصنف نفسه.

كلمات مفتاحية: نبات الرغل، انبات، بذور، شجيرة ملحية، نباتات ملحية.

REFERANCES

Abdul-Baki, A.A. and Anderson, J.D. (1973) Vigor Determination in Soybean Seed by Multiple Criteria. *Crop Science, 13,* 630-633. https://doi.org/10.2135/cropsci1973.0011183X001300060013x

Abu-Zanat, M. M. W., & Samarah, N. (2005). Physical and chemical treatments for enhancing seed germination of Oldman saltbush (Atriplex nummularia). *African journal of range and forage science*, *22*(2), 141-145. https://www.tandfonline.com/doi/abs/10.2989/10220110509485871

Abdul-Kareem, A. W., & Nazzal, K. E. (2013). Phytoremediation of salt-affected soils at Al-Jazeera Northern Irrigation Project, Nineveh, Iraq. *Mesopotamia*

Journal of Agriculture, 41(3), 294–298. https://doi.org/10.33899/magrj.2013.80354

Atzori, G., de Vos, A. C., van Rijsselberghe, M., Vignolini, P., Rozema, J., Mancuso, S., and van Bodegom, P. M. (2017). Effects of increased seawater salinity irrigation on growth and quality of the edible halophyte Mesembryanthemum crystallinum L. under field conditions. *Agricultural Water Management*, *187*, 37-46. https://doi.org/10.1016/j.agwat.2017.03.020

Bekmirzaev G, Ouddane B, Beltrao J, Fujii Y (2020). The Impact of Salt Concentration on the Mineral Nutrition of Tetragonia tetragonioides, *Agriculture 10,* 238. https://doi.org/10.3390/agriculture10060238

Bekmirzaev, G., Ouddane, B., Beltrao, J., Khamidov, M., Fujii, Y., & Sugiyama, A. (2021). Effects of salinity on the macro-and micronutrient contents of a halophytic plant species (Portulaca oleracea l.). *Land, 10(5),* 481. https://www.mdpi.com/2073-445X/10/5/481

Ben-Asher, J., Beltrao, J., Bekmirzaev, G., & Panagopoulos, T. (2021). Crop response to combined availability of soil water and its salinity level: Theory, experiments and validation on golf courses. *Agronomy*, *11*(10), 2012. https://www.mdpi.com/2073-4395/11/10/2012

Bhatt, A., Gairola, S., Carón, M. M., Santo, A., Murru, V., El-Keblawy, A., & Mahmoud, T. (2020). Effects of light, temperature, salinity, and maternal habitat on seed germination of Aeluropus lagopoides (Poaceae): an economically important halophyte of arid Arabian deserts. *Botany*, *98*(2), 117-125. https://doi.org/10.1139/cjb-2019-0096

Castillo, J. M., Curado, G., Muñoz-Rodríguez, A. F., & Grewell, B. J. (2021). Germination syndrome divergence among pairs of sympatric sister species along an estuarine salinity gradient. *Environmental and Experimental Botany, 181,* 104274. https://doi.org/10.1016/j.envexpbot.2020.104274

Chaudhary, D. R. (2019). Ion accumulation pattern of halophytes. In *Halophytes and climate change: adaptive mechanisms and potential uses* (pp. 137-151). Wallingford UK: CABI. https://doi.org/10.1079/9781786394330.0137

Chaudhary, D. R. (2019). Ion accumulation pattern of halophytes. In *Halophytes and climate change: adaptive mechanisms and potential uses* (pp. 137-151). Wallingford UK: CABI. https://www.cabidigitallibrary.org/doi/abs/10.1079/9781786394330.0137

Czabator, F. J. (1962). Germination value: an index combining speed and completeness of pine seed germination. *Forest science*, *8*(4), 386-396. https://doi.org/10.1093/forestscience/8.4.386

Ellis, R. H., & Roberts, E. H. (1981). The quantification of ageing and survival in orthodox seeds. *Seed Science and Technology (Netherlands)*, *9*(2).

https://agris.fao.org/search/en/providers/122514/records/6471244d3c73b155c849720b

Gao, R., Wei, X., He, Z., Zhao, R., Wang, K., Yang, X., & Walck, J. L. (2018). Soil salt and NaCl have different effects on seed germination of the halophyte Suaeda salsa. *Journal of Plant Nutrition and Soil Science*, *181*(4), 488-497. https://doi.org/10.1002/jpln.201700544

Grigore, M.N. and Toma, C. (2017) Anatomical Adaptations of Halophytes; A Review of Classic Literature and Recent Findings. *Springer International Publishing, Cham.* https://doi.org/10.1007/978-3-319-66480-4

http://dx.doi.org/10.2135/cropsci1973.0011183X001300060013x

James, A. R., Burnette, T. E., Mack, J., James, D. E., Eckhart, V. M., & Geber, M. A. (2020). Species-specific variation in germination rates contributes to spatial coexistence more than adult plant water use in four closely related annual flowering plants. *Journal of Ecology*, *108*(6), 2584-2600. https://doi.org/10.1111/1365-2745.13408

Khan, M. A., Gul, B., & Weber, D. J. (2004). Temperature and high salinity effects in germinating dimorphic seeds of Atriplex rosea. *Western North American Naturalist,* 193-201. https://www.jstor.org/stable/41717362

Koobonye, M., Maule, B. V., & Mogotsi, K. (2018). Mechanical scarification and hot water treatments enhance germination of *Leucaena leucocephala* (Lam.) seeds. *Livestock Research for Rural Development, 30*(1), Article 15.https://www.lrrd.org/lrrd30/1/kbmo30015.html

Lastiri-Hernández, M. A., Álvarez-Bernal, D., Moncayo-Estrada, R., Cruz-Cárdenas, G., & Silva García, J. T. (2021). Adoption of phytodesalination as a sustainable agricultural practice for improving the productivity of saline soils. *Environment, Development and Sustainability*, *23*(6), 8798-8814. https://link.springer.com/article/10.1007/s10668-020-00995-5

Lastiri-Hernández, M. A., Álvarez-Bernal, D., Moncayo-Estrada, R., Cruz-Cárdenas, G., & Silva García, J. T. (2021). Adoption of phytodesalination as a sustainable agricultural practice for improving the productivity of saline soils. *Environment, Development and Sustainability*, *23*(6), 8798-8814. https://link.springer.com/article/10.1007/s10668-020-00995-5

Mackay, W. A., Davis, T. D., & Sankhla, D. (2001). Influence of scarification and temperature on seed germination of Lupinus arboreus. *Seed science and technology*, *29*(3), 543-548. https://www.researchgate.net/publication/287006472_Influence_of_scarification_and_temperature_on_seed_germination_of_Lupinus_arboreus ResearchGate

Matinzadeh, Z., Akhani, H., Abedi, M., & Palacio, S. (2019). The elemental composition of halophytes correlates with key morphological adaptations and taxonomic groups. *Plant Physiology and Biochemistry*, *141*, 259-278. https://doi.org/10.1016/j.plaphy.2019.05.023

Muhammad, S., & Amusa, N. A. (2003). Effects of sulphuric acid and hot water treatments on seed germination of tamarind (Tamarindus indica L). *African journal of biotechnology*, *2*(9), 376-279. https://doi.org/10.5897/AJB2003.000-1056

Nikalje, G. C., Srivastava, A. K., Pandey, G. K., and Suprasanna, P. (2018). Halophytes in biosaline agriculture: Mechanism, utilization, and value addition. *Land Degradation & Development, 29,* 1081-1095. https://doi.org/10.1002/ldr.2819

Nisar, F., Gul, B., Khan, M. A., & Hameed, A. (2019). Germination and recovery responses of heteromorphic seeds of two co-occurring Arthrocnemum species to salinity, temperature and light. *South African Journal of Botany*, *121*, 143-151. https://doi.org/10.1016/j.sajb.2018.10.035

Rosbakh, S., Phartyal, S. S., & Poschlod, P. (2020). Seed germination traits shape community assembly along a hydroperiod gradient. *Annals of Botany*, *125*(1), 67-78. https://doi.org/10.1093/aob/mcz139 .

Tang, B., Chen, J., Wang, Z., Qin, P., & Zhang, X. (2021). Mercury accumulation response of rice plant (Oryza sativa L.) to elevated atmospheric mercury and carbon dioxide. *Ecotoxicology and Environmental Safety*, *224*, 112628. https://doi.org/10.1016/j.ecoenv.2021.112628