CATRINA (2024), 30 (1):21-29

Seedling Evaluation of Native Perennials for Implementing Large-scale Revegetation Projects in Arid Lands

Mansour T. Abdullah[1*], Meshal M. Abdullah[2], Zahraa M. Al-Ali[3], Mohammad A. Almousa[1], Midhun Mohan[4], Nouf Al-Hashash[5]

[1] Science Department, College of Basic Education, the Public Authority for Applied Education and Training, Alardyia P.O. Box 23167, Safat, Kuwait.

[2] Department of Geography, College of Arts and Social Sciences, Sultan Qaboos University, Muscat, P.O. Box 50, Oman.

[3] Natural Environmental Systems and Technologies Research Group, Ecolife Sciences Research and Consultation, Kuwait.

[4] Ecoresolve Inc., San Francisco, CA 94105, USA

[5] Department of Native Plants Section, Public Authority of Agricultural and Fish Resources, Rabia PO Box 21422 Safat Kuwait.

ABSTRACT

Understanding seedling development and germination processes is crucial for the successful planning and execution of revegetation and restoration initiatives on a large scale. Due to shifting environmental conditions, monitoring seed viability, dormancy, and germination success in the wild is challenging. This study seeks to investigate the optimal germination conditions for seedlings from five distinct wild populations of perennial plants commonly used in local restoration and revegetation projects in Kuwait. Kuwait has a desert climate with summer temperatures that can get as high as 46°C and minimal annual precipitation (< 112 mm). Kuwait's dry climate is home to a restricted range of flora, most of which are desert shrubs that have adapted to the severe weather. Among the well-known perennials studied at The Public Authority of Agriculture Affairs and Fish Resources (PAAF) nurseries in Kuwait were *Rhanterium epapposum, Farsetia aegyptia, Calligonum comosum, Panicum turgidum, and Pennisetum divisum.* In a controlled greenhouse setting, seedling germination experiments were conducted under consistent environmental conditions. The seeds were obtained from well-developed mother plants, washed, thoroughly dried, and stored in a cold, dry environment without undergoing any dormancy-breaking treatments. As a result, all five species were able to exhibit a high rate of germination, and the proportion of seedlings that emerged between 37 and 55 days ranged from 78.2 % for *Pennisetum divisum* producing the fewest seedlings, while *Farsetia aegyptia* produced the most 95.4%. This study provides essential information to land restoration managers for them to implement appropriate strategies and achieve good results for large-scale revegetation projects. However, to determine seedling growth and establishment in revegetated sites, an active ecological monitoring technique is required.

Keywords: Arid climate; Desert plain ecosystem; Germination; Native plants; Native perennials; Revegetation; Seedlings evaluation.

INTRODUCTION

Arid ecosystems face the challenge of intensive deterioration due to anthropogenic activities and climate change. The flora has been adversely damaged by human activities, such as unsustainable agricultural practices, destructive camping, gravel quarrying, oil extraction, urban growth, war-related damage, and natural processes such as soil erosion and soil compaction leading to desertification (Khordagui and Al-Ajmi, 1993; Al-Awadhi, 2001; Baby *et al.*, 2014). The United Nations Environment Programme (UNEP) has defined desertification as 'land degradation in arid, semiarid, and dry sub-humid areas, resulting mainly from adverse human impact and partially from climatic factors' (UNEP, 1994).

Desertification is a severe ecological issue that affects nearly all arid lands, placing natural resources under severe stress. A combination of climatological and geological processes is the major driver of desertification, with extensive human activities in sandy areas accelerating these processes. Desertification processes are influenced by climatic variables through the following phenomena: (1) the scarcity and irregularity of rainfall, (2) the frequency of drought periods, and (3) the occurrence of strong winds during the dry season, which encourages sand transport and soil erosion, and (4) the occurrence of intense rainfall in a single storm, which results in the accumulation of massive amounts of primarily sand and silt outwash material, which then contributes to sand supply (Al-Awadhi *et al*., 2003).

Recently, revegetation efforts in Kuwait have been launched to restore ecosystem functionality, increase biodiversity, and enhance sustainability. The United Nations Compensation Commission's Governing Council (GC-UNCC) approved compensation payments of US$ 3 billion to be spent on six significant claims resulting from war-related damage, requiring extensive remediation and restoration initiatives (UNCC, 2005). In 2006, the Kuwaiti government formed the Kuwait Environmental Remediation Program (KERP) with this funding. Due to military activities that impacted the desert soil surface and vegetation, contributing to wind erosion and sand mobilization, one of the initiatives under the KERP

* *Corresponding author e-mail: m.taleb@paaet.edu.kw*

umbrella is terrestrial restoration and revegetation programs (Al-Dousari and Al-Awadhi, 2012).

Native desert plants are highly tolerant to extreme environmental conditions, such as high temperatures, limited water availability, and high salinity tolerance. Therefore, revegetation efforts have aimed to reintroduce native plant species, create thriving eco-systems, and replenish vegetation cover (Bhatt *et al*., 2023). In these projects, a range of strategies, including direct seeding, seedling transplantation, and the establishment of plant nurseries, have been employed. The choice between direct seeding and seedling trans-plantation for restoration efforts depends on several factors, such as the biological context, project goals, site conditions, and resource availability as highlighted by Lázaro-González et al. (2023). Each approach comes with its own set of advantages and consi-derations. This study aims to investigate the benefits and limitations of each technique individually, providing a comprehensive analysis to aid in decision-making for large-scale revegetation projects in arid lands.

Plant seeding involves dispersing seeds directly onto the restoration site, allowing them to establish and grow naturally. Several reasons why seeding may be a preferable strategy include: (1) Cost-effectiveness: Seeding is generally more economical than using seed-lings as it eliminates the need for nursery production and plant transportation; (2) Genetic diversity: By incorporating seeds from a wider range of individuals, seeding promotes genetic variation within plant populations, aiding in their long-term resilience; (3) Adaptability: Seeding is particularly well-suited for challenging terrains or remote locations where transp-lanting seedlings may be impractical or challenging (Leverkus et al., 2021). On the other hand, there are a number of factors to take into account while choosing seeding. Among these factors are: Successful germination: To ensure successful germination, the presence of optimal conditions such as adequate moisture, suitable temperature, light exposure, and appropriate microsites is crucial. Failure to provide these conditions could lead to low germination rates and uneven or limited establishment of seeded plants; Intense competition: Seeded plants may face significant competition from existing vegetation, including inv-asive species, which can delay their establishment and growth on the restoration site; Time frame: Seeded plants typically require a longer time to establish compared to seedlings, as they need to pass through the germination and early growth stages before becoming fully established (Vidak *et al*., 2022).

Experiments have been carried out on direct seeding to restore desert habitats along with breaking seed dormancy techniques (Suleiman *et al*., 2009; Suleiman *et al*., 2011a; Suleiman *et al*., 2011b; Bhatt and Pérez-garcía, 2016; Almulla *et al*., 2017; Bhatt *et al*., 2020). On the other hand, growing plants from collected seeds or clippings in nurseries before transplanting them to the restoration site is known as using seedlings. On the other hand, there are several advantages to utilizing seedlings: Increased establishment rates: Seedlings hold an edge over seeds during the establishment phase due to their developed root systems and foliage, boosting their likelihood of survival and successful establishment on the restoration site; Quality and species control: Nurseries facilitate the selection of preferred plant species and ensure the health and quality of the seedlings intended for restoration projects, providing greater control over the species used; Competitive advantage: Larger seedlings with well-established root systems may outcompete existing vegetation, offering a competitive edge in the resto-ration process (Grossnickle and MacDonald, 2018).

In Kuwait and other similar land-degraded dry regions, recent initiatives to revegetate through the transplanting of nursery-grown seedlings have been effective, although the process is time-consuming and expensive, especially in arid environments with limited water resources (Grantz *et al*., 1998; Abella *et al*. 2012; Grina *et al*., 2014; Mangueira *et al*., 2019; Suleiman *et al*., 2023). Take into account the following aspects when using seedlings: Cost and logistics: raising seedlings in nurseries and shipping them to far-off locations or major projects can be costly; Genetic diversity: In contrast to sowing, if seedlings are derived from a limited number of parent individuals, genetic variety may be reduced; Site adaptability: Certain locations may not be ideal for transplanting seedlings because of extreme weather, such as high temperatures, low water levels, or poor soil qualities. A suitable time frame is crucial to prevent transplanting shock. According to Haase *et al*. (2021) and Zeng and Fischer (2021), seedlings should only be transplanted to the field during a specified time of the year with favorable environmental conditions. Therefore, the objective of this research is to assess the planting phases and germination patterns of five indigenous plant species commonly employed in Kuwait for initiatives related to revegetation, forage production, soil stabilization, conservation practices, and restoration of Kuwait's deteriorated natural habitats. The findings of this study are intended to enhance our comprehension of the recruitment dynamics and performance of these species in the absence of seed dormancy-breaking treatments, thereby facilitating the selection of suitable species for incorporation into revegetation schemes. The study aims to address the following inquiries: (1) What is the germination percentage of seeds for each species without the application of seed dormancy-breaking techniques? (2) How does the germination rate vary among different wild populations of these species? (3) What is the feasibility of cultivating diverse seedlings in nurseries for large-scale revegetation accompli-shments?

MATERIALS AND METHODS

Study location

This work was conducted at The Public Authority of Agriculture Affairs and Fish Resources (PAAF) nurseries, which are located at Al-Abdali agricultural areas in the northern part of Kuwait City. Kuwait is located in the northeastern part of the Arabian Peninsula, sharing borders with Iraq to the north and Saudi Arabia to the south. The topography is mostly flat with slight undulation and generally arid landscape with no rivers, except a coastline stretches along the Arabian Gulf to the east. The predominant soil type is mainly characterized by sandy soil except for the saline soils influenced by the proximity to the sea. Kuwait is characterized as an arid ecosystem with hot summers having an average maximum temperature ranges from 42 to 46 °C, short moderate winters with an average minimum temperature ranges from 3 to 13 °C, and occasional rainfall of an average of 112 mm annually. PAAF nurseries' primary goal is to produce a large amount of native plant seedlings to revegetate and restore desert ecosystem. The nursery's facility is divided into three key regions: greenhouses for seed germination, green shaded areas used as a transitional area for plant adaption to the outdoor environment, and external irrigated field areas for establishing native mother plants and harvesting seeds Figure (1).

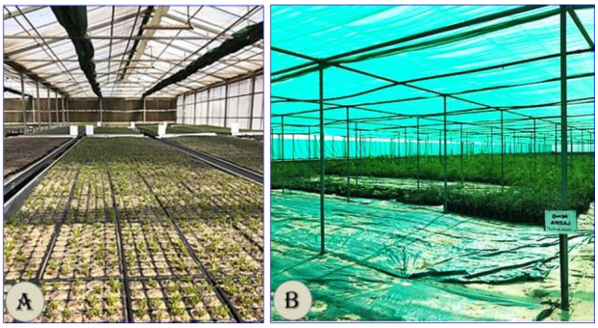

Figure (1): The Public Authority of Agriculture Affairs and Fish Resources (PAAF) Nurseries. A, greenhouse; B, green shaded area.

Planting materials

Seeds from five wild populations of different perennial species *Rhanterium epapposum* Oliv., *Farsetia aegyptia* Turra., *Calligonum comosum* L'Herit., *Panicum turgidum* Forssk., and *Pennisetum divisum* (Forssk. ex J.F.Gmel.) Henrard, (Figure 2A-E) all from mother plants established inside PAAF nurseries representing recent growing season (April-June 2020), were examined. The mother plants were obtained from several locations throughout the Kuwaiti desert (Al-wafra, Alsubiyah, and AlAbdali areas) and grown on the nursery's premises to assure the presence of diverse populations and genetic pool variation among mother plants. For the germination assays and the production of large number of seedlings, seeds were harvested from PAAF mother plants, washed, thoroughly dried, and stored in a cold (5°C) and dry environment until sowing. The chosen species are distinguished by their capacity to withstand extreme arid environments such as high temperatures, limited water supply, and high salinity tolerance. Moreover, fully developed plants provide ecological services such as sand stability, erosion control, and fodder for animals. Table (1) and Figure (2A-E) provides information and illustration on each species' morphology, phenology, ecological and economic uses.

Planting phases

Schematic diagrams illustrating the planting phases carried by PAAF are shown in Figure (3). The germination process underwent three major phases summarized below:

Phase 1

Greenhouse: germinating seeds and establishing seedlings inside the greenhouse under a controlled environment (25.0 ± 2 °C, under 10/14 hrs of light/dark photoperiod, and relative humidity ranged between 40-60%).

Phase 2

Green shaded area: seedlings transfer from seedling trays, medium sized pots and shift to a green shaded net area outside the greenhouse (the net lowers the temperature, and avoid direct sunlight, allowing plants to adapt to the outer environmental factors).

Phase 3

Re-vegetation site: the seedling pots are transported to the re-vegetation sites and planted during favorable environmental conditions around 25 °C (between October-December).

Germination assays

The germination process was studied using trays containing 50 cells each (measuring 54 cm x 28 cm x 5.7 cm) in a greenhouse at Al-Abdali Public Authority for Agriculture Affairs and Fish Resources (PAAF) nurseries from September to November 2020. Prior to seed sowing, the trays were filled with a potting soil mixture comprising peat moss and sandy soil in a 1:1 ratio. Seeds were then placed into each cell, sown approximately 1 cm deep and covered with soil. A total of fifty planting trays, containing 2,500 seedling inserts, were examined, with each species treatment replicated in 10 trays, totaling 500 counts for each species.

In the greenhouse, the trays were positioned on tables within a controlled setting, with periodic watering to prevent soil desiccation. The irrigation was facilitated using a mixture of desalinated seawater and brackish groundwater. The germination assays were carried out under constant conditions: a temperature of 25°C± 2°C, a light period of 10 hrs followed by a dark period of 14 hours, and a relative humidity maintained between 40-60%. These specific parameters were selected to mimic the natural climatic conditions of Kuwait's environment, particularly during the period from February to April. Conspicuously, no treatments were applied to the seed coatings to induce dormancy breakage in this study.

Data analysis

The total germination percentage was recorded when no more seeds germinated for each treatment. One-way analysis of variance (ANOVA) was used to evaluate seedling germination means and investigate if there were any significant differences across species. In addition, to test the relationship between the seedlings of different species pairwise comparisons were applied using the least square difference (LSD) method.

Figure (2): The photomicrograph represents the following five plant species: (A) *Rhanterium epapposum* Oliv; (B) *Farsetia aegyptia* Turra; (C) *Panicum turgidum* Forssk; (D) *Calligonum comosum* L'Herit., and (E) *Pennisetum divisum* (Forssk. ex J.F.Gmel.) Henrard. *(Photo Credit: Modhi Al-Dosari).*

Table (1): Description of the studied five native plants: scientific names, families, morphology, phenology, ecological, and economic uses.

Scientific name	Family	Morphology/ Phenology	Ecological/ Economical uses
Rhanterium epapposum Oliv.	Asteraceae	Dwarf-shrub, perennial, height reaches 80 cm, leaves: small greyish-green feathery, flowers: yellow daisy-like, stem: woody to herbaceous; root: deep taproot system. Seeds: capitulum contains 6-8 seeds, Flowering duration: February-May.	Fodder, sand stabilizer, medicinal (Demirci, *et al*., 2017; El-Keblawy *et al*., 2009)
Farsetia aegyptia Turra.	Brassicaceae	Sub-shrub, perennial, height not exceeding 50 cm, leaves: covered with tiny white hair alternate 4-5 cm long, flowers: numerous each with 4 white free petals, stem: very thin, root: taproot system. Seeds: at maturity pods split open release seeds. Flowering duration: March-April.	Fodder, sand stabilizer, medicinal (AbdElAal et al., 2015; Bidak *et al*., 2015
Calligonum comosum L'Herit	Polygonaceae	Shrub, perennial, height 1-2 m, leaves: reduced and inconspicuous, flowers: white with pink stamens, stem: numerous, slender, and intricately branched (modified stems: cladodes), root: deep root system. Seeds: winged capsule containing seeds, Flowering duration: March-April.	Fodder, fuel (wood), tanning, medicinal, sand stabilizer, drought resistant, shading, wind break (Rathore *et al*., 2015).
Panicum turgidum Forssk.	Poaceae	Perennial grass, height 1 m, leaves: linear, lanceolate, or narrowly ovate in shape, stem: culms are densely tufted with swollen nodes. Seeds: flowers develop into seeds within the spikelet. Flowering duration: March-May	Fodder (grazed pastures), edible, sand stabilizer, soil fertility, shading (Bhatt *et al*., 2020)
Pennisetum divisum (Forssk. ex J.F.Gmel.) Henrard	Poaceae	Perennial grass, height 1-1.5 m, leaves: linear, narrow, and can be up to 50 cm long, stem: erect, slender culms that arise from a central point, Inflorescence: feathery, cylindrical spike-like structure, each spikelet contains both male and female flowers. Flowering duration: February-April.	Fodder (grazed pastures), sand stabilizer, soil fertility (Bhatt *et al*., 2020)

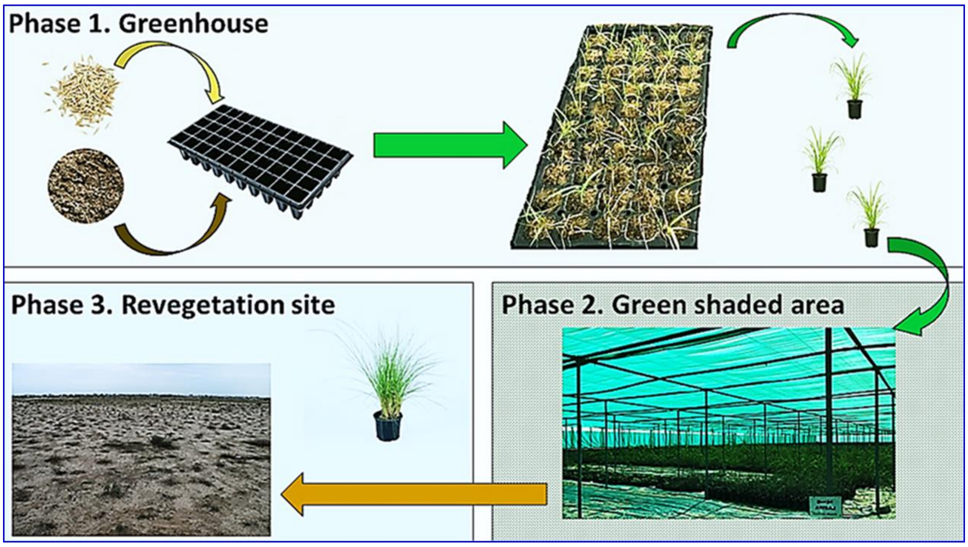

Figure (3): Three phases of the planting process: Phase 1 preparation and seeding germination inside the greenhouse, Phase 2 seedlings transfer to green shaded net area for adaptation with outer climate, and Phase 3 seedling pots transportation to re-vegetation sites.

Significance was set to $p \leq 0.05$ for all pairwise comparisons. The statistical analysis ANOVA and LSD method were conducted using JMP® statistical analysis software (SAS Institute, Inc., Cary, NC, version 17.2.0, 2023).

RESULTS

Seedlings germination assays

In each of the five wild populations evaluated, different percentages of seeds germinated, with highest seed germination rate was represented by *Farsetia aegyptia*, 95.4%, while the lowest germination rate was *Pennisetum divisum*, 78.2%. A summary of each species is given below and represented in Table (2).

In detail, the germination percentage of *Rhanterium* epapposum seedlings fluctuated between 72% and 90% *within* 37 days of germination, with a mean germination rate of 84.6%. For *Farsetia aegyptia*, the germination rate ranged from 88% to 100% after 55 days, with a mean germination rate of 95.4%. *Calligonum comosum* exhibited a germination range of 78% to 98% after 30 days, with an average germination rate of 86.4%. *Panicum turgidum* showed a germination percentage between 76% and 98% after 47 days, with a mean germination rate of 88.2%. Lastly, *Pennisetum divisum* had a germination range of 60% to 96%, with a mean germination rate of 78.2% (Table 2).

Seedlings germination variation

The results from one-way ANOVA showed significant variation between germination mean and variation within the species, represented by F-value 6.07, and a highly significant value of $p \leq 0.0005$ (Figure 4). The most significant germination variation was represented by *Farsetia aegyptia* followed by *Rhanterium epapposum* seedlings and the least significant variation was represented by *Pennisetum divisum* seedlings (Figure 4).

The mean differences in total seed germination and the number of days treated using a pairwise least square difference (LSD) were also compared. For LSD comparison, no significant differences were found between the germination mean of *Rhanterium epapposum* and *Pennisetum divisum*, and *Calligonum comosum* and *Panicum turgidum* while significant difference was found for *Farsetia aegyptia*, $p \leq 0.05$.

DISCUSSION

Planting seedlings for revegetation

Understanding the variation in species germination is critical for developing efficient revegetation and restoration strategies (Lázaro-González *et al*., 2023; Marty and Kettenring, 2017). Our findings show that if time and logistics is not an obstacle, transplanting seedlings technique to revegetation sites is recommended over seed scattering technique. Our results showed that native seeds of various species yield high germination

Table (2): Germination performance of studied plant species

Measured parameter	Studied plants				
	Rhanterium epapposum	***Farsetia aegyptia***	***Calligonum comosum***	***Panicum turgidum***	***Pennisetum divisum***
Germinated seeds/Total seed number†	423/ 500	477/ 500	432/ 500	441/ 500	391/ 500
Germination mean (±SE)	42.3 ±2.98 [b]	47.7 ±1.89 [a]	43.2 ±3.42 [ab]	44.1 ±4.12 [b]	39.1 ±6.19 [b]
Mean Germination (%)	84.6	95.4	86.4	88.2	78.2
Germination period (day)	37	55	30	47	47

†10 tray, contained 50 seeds, were used per each plant species

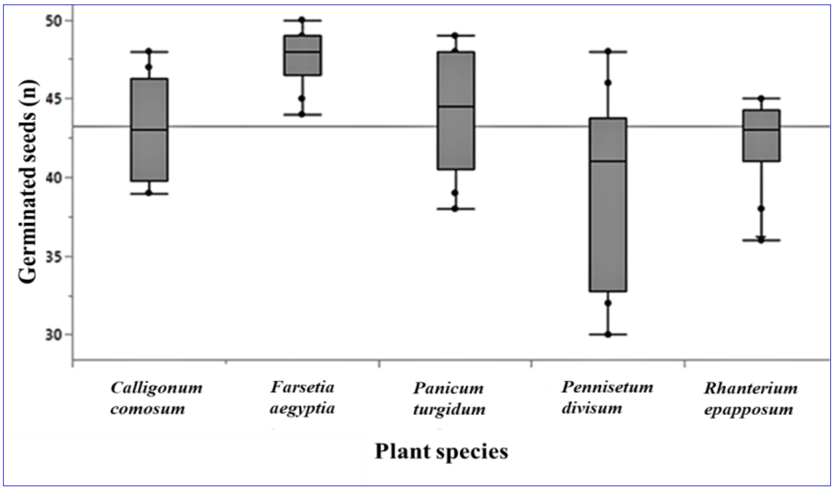

Figure (4): Histogram showing the germinated number of seeds for five native species.

percentages without interfering with dormancy-breaking techniques. Within 30-55 days, the succession rate ranged from 88.2% (*Pennisetum divisum*) to 95.4% (*Farsetia aegyptia*). Furthermore, the three shrubs (*Rhanterium epapposum*, *Farsetia aegyptia*, and *Calligonum comosum*) germinated into seedlings within 30-55 days, while the two grasses (*Pennisetum divisum* and *Panicum turgidum*) germ-inated into seedlings within 47 days. Given that dormancy levels may fluctuate widely among native plant populations due to a variety of reasons, including environmental and genetic changes, the data on the germination of the five wild seeds should be regarded as preliminary (Duncan *et al*., 2019; Bhatt *et al*., 2020). Given this, people interested in learning more about the germination technique of these species may find our research to be of great assistance.

Similar studies on native plants of Kuwait showed that untreated seeds of *Haloxylon salicornicum* resulted in the highest germination rate (86 %) compared to the treated ones (using Gibberellic acid and heat methods), which varied in germination (44-76 %) (Almulla, 2014). Additionally, in agreement with our findings, *Nitraria retusa*, a native perennial shrub, demonstrated that untreated seeds needed 55 days to achieve 79% of germination, whereas treatments considerably quicker (Gibberellic acid) allowed them to achieve 91% of germination in just 20 days (Suleiman *et al*., 2008). On the other hand, some untreated native seeds resulted in very low germination (55 %) due to the deep-dormancy cycles (Suleiman *et al*. 2011a). Furthermore, Bhatt *et al*. (2020) research demonstrated that seed germination variation between different populations of the same species of *Panicum turgidum* and *Pennisetum divisum* occurred, showing inter-population variabilities.

Revegetation planning strategies

Decision-makers should consider choosing a healthy ecosystem for a higher succession rate of seedling adaptation and revegetation success. The revegetation and restoration areas should have sufficient nutrients for plant growth and development (Mashaly *et al*., 2015; Salama *et al.*, 2018).

Signs of good restoration sites could be explored in the field using the concept of green water areas. According to Yang *et al.* (2015), a green water area is defined by vegetation and soils that aid in water absorption, infiltration, and storage. As a result, green water areas significantly impact plant biomass growth (Simiyu *et al*., 2022). Furthermore, Abdullah *et al.* (2021b) study observed that soil characteristics improved in northern regions of Kuwait due to the presence of high annual plant coverage (conserving soil moisture), high levels of phosphorus present, and soils rich in organic matter.

Therefore, green water areas with high annual density and coverage could be ideal revegetation sites for introducing seedlings of perennial shrubs (Nafea, 2015). In addition, the floristic composition at the site should be investigated for any possibilities of adaptation or competition with the introduced seed-lings. Also, it is crucial to remember that sometimes, using seedlings or applying plant seeds is not the most effective option. Direct sowing with seedling supplementation, a combination of the two strategies, is frequently used in practice to maximize the restoration efforts since it optimizes the benefits of each option (St. Clair *et al*., 2020; Lázaro-González *et al*., 2023).

For the choice of revegetation sites, maps of possible green water areas in Kuwait should be employed. Abdullah *et al.* (2022) and Asadalla *et al.* (2021) established maps for large-scale revegetation and restoration planning, by combining remote sensing techniques and GIS (Geographic Information System) with the Maxent model, that identifies green water areas and hotspot locations through the analysis of numerous environmental variables related to veget-ation coverage. Furthermore, it is important to assess and monitor the biodiversity changes occurring at the revegetation sites in order to follow the progress and study the vegetation succession rate. Monitoring methods have been employed lately in Kuwait using remote sensing techniques, GIS, and Unmanned Aerial Vehicles (UAVs) to capture and analyse high-resolution imagery and monitor the progress level of each revegetation site (Abdullah *et al*., 2021a; Asadalla *et al*., 2021; Abdullah *et al*., 2022).

CONCLUSION

To restore Kuwait's damaged desert ecosystem, effective restoration projects and revegetation activities are required. If money and logistics are not an issue, the seedling technique evaluated in this study is recommended for large-scale revegetation projects in Kuwait. As a result, increasing seedling establishment rates will aid in the implementation of revegetation projects. It is also critical to explore seed collection from diverse populations and locations of the same species to boost the gene pool variation of the seedlings. Kuwait can improve its biodiversity, restore ecosystem services, and reduce the environmental impact of human activities by expanding the knowledge of ecological dynamics and implementing effective revegetation and restoration measures. The effectiveness of restoration programs is dependent on continuing investigations, long-term monitoring, and, most crucially, stakeholder participation.

REFERENCES

ABDELAAL, M., EL-SHORA, H. AND KADHIM, O. 2015. Community associates of the medicinal *Farsetia aegyptia* Turra. and its soil correlates in the North-Eastern Desert of Egypt. Mansoura Journal of Biology 40(8): 53-66.

ABDULLAH, M.M., ASADALLA, N., GHARABI, Y., MOHAN, M., AL NAABI, S., SRINIVASAN, S., AL AWADHI, T. 2022. The Use of Annual Plants as Ecological Indicators to Identify Locations with High Levels of Green Water in Arid Ecosystems Using Remote Sensing and Maxent Modeling. Social Science Research Network (SSRN) 1-18. http://dx.doi.org/10.2139/ssrn.4286772.

ABDULLAH M.M., AL-ALI, Z.M., ABDULLAH, M.T., AL-ANZI B. 2021a. The Use of Very-High-Resolution Aerial Imagery to Estimate the Structure and Distribution of the *Rhanterium epapposum* Community for Long-Term Monitoring in Desert Ecosystems. Plants 10(5):977. https://doi.org/10.3390/plants10050977.

ABDULLAH, M.M., AL-ALI, Z.M., ABDULLAH, M.T., SRINIVASAN, S., ASSI, A.T., AL ATIQI, S. 2021b. Investigating the applicability of UAVs in characterizing desert shrub biomass and developing biological indicators for the selection of suitable revegetation sites, Journal of Environmental Management (288):112416. https://doi.org/10.1016/j.jenvman.2021.112416.

ABELLA, S.R., CRAIG, D.J., AND SUAZO, A.A. 2012. Out planting but not seeding establishes native desert perennials. Native Plants 13(2):81-89.

AL-AWADHI, J.M., MISAK, R.F. & OMAR, S.S. 2003. Causes and consequences of desertification in Kuwait: a case study of land degradation. Bulletin of Engineering Geology and the Environment 62, 107–115. https://doi.org/10.1007/s10064-002-0175-0.

AL-AWADHI, J.M. 2001. Impact of gravel quarrying on the desert environment of Kuwait. Environmental Geology 41, 365–371. https://doi.org/10.1007/s002540100398

AL-DOUSARI, A.M. AND AL-AWADHI, J.M. 2012. Dust Fallout in Northern Kuwait, Major Sources and Characteristics. Kuwait Journal of Science 39, 171-187.

ALMULLA L, SULEIMAN M.K., BHAT N.R., JACOB S., AND ISLAM M.A. 2017. Propagation studies on selected keystone plant species for use in restoration projects in Kuwait. International Journal of Agricultural Science 2:27−31.

ALMULLA, L. 2014. Comparative germination studies in mature seeds of *Haloxylon salicornicum*. Proceedings of the 2014 International Conference on Energy and Environment (ICEE 2014), June 26-27, Beijing, China.

ASADALLA, N., ABDULLAH, M.M., AL-ALI, Z.M. AND ABDULLAH, M.T. 2021. Vegetation restoration targeting approach to identify the optimum environmental conditions for the restoration of native desert plants using remote sensing and MaxEnt modeling. Restoration Ecology 29: e13425. https://doi.org/10.1111/rec.13425.

BABY, S., NATHAWAT, M.S., AL-SARAWI, M.A. 2014. Major Impacts from Anthropogenic Activities on Landscape Carrying Capacity of Kuwaiti Coast. Polish Journal of Environmental Studies 23(1):7–17.

BHATT, A., AND PÉREZ-GARCÍA, F. 2016. Seed dormancy of *Ochradenus baccatus* (Resedaceae), a shrubby species from Arabian desert regions. Revista de Biologia Tropical 64:965−74.

BHATT, A., BHAT, N.R., AL-NASSER, A., CARÓN, M.M., AND SANTO, A. 2020. Inter-population variabilities in seed mass and germination of *Panicum turgidum* and *Pennisetum divisum* on the desert of Kuwait. Journal of Arid Land, Journal of Arid Land 12:144−153. https://doi.org/0.1007/s40333-019-0017-6.

BHATT, A.; BHAT, N.R.; SULEIMAN, M.K.; AL-MANSOUR, H. 2023. Prioritization of Potential Native Plants from Arabian Peninsula Based on Economic and Ecological Values: Implication for Restoration. Sustainability. 15, 6139. https://doi.org/10.3390/su15076139

BIDAK, L.M., KAMAL, S.A., HALMY, A.W., HENEIDY, S.Z. 2015. Goods and services provided by native plants in desert ecosystems: Examples from the northwestern coastal desert of Egypt. Global Ecology and Conservation (2) 3: 433-447. https://doi.org/10.1016/j.gecco.2015.02.001

DEMIRCI, B., YUSUFOGLU, H.S., TABANCA, N., TEMEL, H.E., BERNIERM U.R., AGRAMONTE, N.M., ALQASOUMI, S.I., AL-REHAILY, A.J., BAŞER, K.H.C., DEMIRCI, F. 2017. *Rhanterium epapposum* Oliv. Essential oil: Chemical composition and antimicrobial, insect-repellent and anticholinesterase activities. Saudi Pharmaceutical Journal 25(5):703-708.

DUNCAN, C., SCHULTZ, N., LEWANDROWSKI, W., GOOD, M.K., AND COOK, S. 2019. Lower dormancy with rapid germination is an important strategy for seeds in an arid zone with unpredictable rainfall. PLoS ONE 14(9): e0218421. https://doi.org/10.1371/journal.pone.0218421

EL-KEBLAWY, T. KSIKSI, AND H. EL ALQAMY. 2009. Camel grazing affects species diversity and community structure in the deserts of the UAE. Journal of Arid Environments 73(3):347-354. https://doi.org/10.1016/j.jaridenv.2008.10.004

GRANTZ, D.A., VAUGHN, D.L., FARBER, R.J., KIM, B., ASHBAUGH, L., BANCUREN, T., CAMPBELL, R., BAINBRIDGE, D., ZINK, T. 1998. Transplanting native plants to revegetate abandoned farmland in the Western Mojave Desert. Journal of Environmental Quality 27(4):960-967.

GRINA, R.H., QUORESHI, A.M., THOMAS, T.M., RAMADAN, A., AL-MULLA, L. 2014. Former Pit 30 Remediated Soil Vegetation Restoration and Irrigation Testing at the Wafra Oilfield. Technical Report. KISR 12470. Kuwait.

GROSSNICKLE, S.C., MACDONALD, J.E. 2018. Why seedlings grow: influence of plant attributes. New Forests 49, 1–34. https://doi.org/10.1007/s11056-017-9606-4

HAASE, D.L., BOUZZA, K., EMERTON, L., FRIDAY, J.B., LIEBERG, B., ALDRETE, A., AND DAVIS, A.S. 2021. The High Cost of The Low-Cost Polybag System: A Review Of Nursery Seedling Production Systems. Land 10, 826. https://doi.org/10.3390/land10080826

KHORDAGUI, H., AND AL-AJMI, D. 1993. Environmental impact of the Gulf War: An integrated preliminary assessment. Environmental Management 17, 557–562.

LÁZARO-GONZÁLEZ, A., ANDIVIA, E., HAMPE, A., HASEGAWA, S., MARZANO, R., SANTOS, A., CASTRO, J., LEVERKUS, A. 2023. Revegetation through seeding or planting: A worldwide systematic map. Journal of Environmental Management. 337(1): 1-14. https://doi.org/10.1016/j.jenvman.2023.117713.

LEVERKUS, A.B., LÁZARO GONZÁLEZ, A., ANDIVIA, E., CASTRO, J., JIMÉNEZ, M.N. AND NAVARRO, F.B. 2021. Seeding or planting to revegetate the world's degraded land: systematic review and experimentation to address methodological issues. Restoration Ecology 29: e13372. https://doi.org/10.1111/rec.13372

MANGUEIRA, J.R.S.A., HOLL, K.D., AND RODRIGUES, R.R. 2019. Enrichment planting to restore degraded tropical forest fragments in Brazil. Ecosystem and People 15:3-10.

MARTY, J.E. AND KETTENRING, K.M. 2017. Seed Dormancy Break and Germination for Restoration of Three Globally Important Wetland Bulrushes. Ecological Restoration. 35 (2) 138-147. https://doi.org/10.3368/er.35.2.138

RATHORE, V.S., SINGH, J.P., BHARDWAJ, S., NATHAWAT, N.S., AND KUMAR, M. 2015. Potential of native shrubs *Haloxylon salicornicum* and C*alligonum polygonoides* for restoration of degraded lands in arid western Rajasthan, India. Environmental Management 55:205−16.

SIMIYU, A.M., GICHABA, C.M., AMWATA, D.A., AND OPERE, A. 2022. Factors influencing availability and conservation of green water for sustainable agricultural production and livelihoods in drylands of Kenya. Journal of Dryland Agriculture 8(1), 1-12. https://doi.org/10.5897/JODA2021.0071.

ST. CLAIR, A.B., DUNWIDDIE, P.W., FANT, J.B., KAYE, T.N. AND KRAMER, A.T. 2020. Mixing source populations increases genetic diversity of restored rare plant populations. Restoration Ecology 28: 583-593. https://doi.org/10.1111/rec.13131

SULEIMAN, M.K., BHAT, N., ABDAL, M., ZAMAN, S., THOMAS, R.., AND JACOB, S. 2008. Germination Studies in *Nitraria retusa* (Forssk.) Asch. Middle-East Journal of Scientific Research 3 (4): 211-213.

SULEIMAN, M.K., ZAMAN, S., AL-DOSSERY, S., THOMAS, R.R., AND JACOB, S. 2009. Germination studies in *Horwoodia dicksoniae* Turril. International Journal of Environmental Studies 66:221−225.

SULEIMAN, M.K., BHAT, N.R., JACOB, J., THOMAS, R.R. 2011a. Germination studies in *Ochradenus baccatus* Delile., *Peganum harmala* L. and *Gynandriris sisyrinchium* Parl. Research Journal of Seed Science 4:58−63.

SULEIMAN, M.K., BHAT, N.R., JACOB, S., AND THOMAS, R.R. 2011b. Germination studies in *Lycium shawii* Roem. and Schult. World Journal of Agricultural Sciences 7:26−28.

SULEIMAN, M.K., BHATT, A., MADOUH, T.A., ISLAM, M.A., JACOB, S., THOMAS, R.R., SIVADASAN, M.T. 2023. Effects of Salt Stress on Growth, Proline and Mineral Content in Native Desert Species. Sustainability 15(7):6232. https://doi.org/10.3390/su15076232

UNCC. 2005. United Nation Compensation Commission Decision 258 (8 December, 2005). (Retrieved from https://uncc.ch/sites/default/files/attachments/S-AC.26-DEC%20258%20%5B2005%5D.pdf)

UNEP. 1994. United Nations Convention to Combat Desertification: In Those Countries Experiencing Serious Drought and/or Desertification, Particularly In Africa.

VIDAK, M., LAZAREVIĆ, B., JAVORNIK, T., ŠATOVIĆ, Z., AND CAROVIĆ-STANKO, K. 2022. Seed Water Absorption, Germination, Emergence and Seedling Phenotypic Characterization of the Common Bean Landraces Differing in Seed Size and Color. Seeds 1, 324-339. https://doi.org/10.3390/seeds1040027

YANG, L., ZHANG, L., LI, Y., WU, S. 2015. Water-related ecosystem services provided by urban green

space: A case study in Yixing City (China), Landscape and Urban Planning (136) 40-51. https://doi.org/10.1016/j.landurbplan.2014.11.016.
ZENG, X., FISCHER, G.A. 2021. Using multiple seedlots in restoration planting enhances genetic diversity compared to natural regeneration in fragmented tropical forests. Forest Ecology and Management 482(2):118819.

تقييم الشتلات للنباتات المعمرة المستوطنة لتنفيذ مشاريع إعادةالغطاء النبات على نطاق واسع في الأراضي الجافة

منصور عبدالله[1]، مشعل عبدالله[2]، زهراء العلي[3]، محمد الموسى[1]، ميدهون موهان[4]، نوف الهشاش[5]
[1] قسم العلوم، كلية التربية الأساسية، الهيئة العامة للتعليم التطبيقي والتدريب، العارضية ص.ب.23167، صفاة - الكويت.
[2] قسم الجغرافيا - كلية الفنون والعلوم الاجتماعية - جامعة السلطان قابوس – مسقط - ص.ب. 50 - عمان.
[3] مجموعة أبحاث النظم والتقنيات البيئية الطبيعية - الكويت.
[4] شركة إيكوريسولف - سان فرانسيسكو - كاليفورنيا 94105 - الولايات المتحدة الأمريكية.
[5] إدارة النباتات الفطرية - الهيئة العامة للزراعية والثروة السمكية – الرابيا - ص. ب. 21422 - صفاة الكويت.

الملخص العربي

إن مفهوم تطور الشتلات وزراعتها على نطاق واسع بهدف الانتاج أمر بالغ الأهمية وذلك تخطيطا لمبادرات ناجحة لإعادة الغطاء النباتي. نظرا للظروف البيئية المتغيرة، فإن مراقبة انتاج البذور، ونجاح الزراعة في البرية يمثل تحديا. تهدف هذه الدراسة إلى تحديد ظروف إنبات الشتلات لخمسة أنواع مختلفة من النباتات المعمرة التي تستخدم بشكل دوري في الكويت. ولذلك تم دراسة انبات البذور، موضوع الدراسة، في حضانات الهيئة العامة للزراعة والثروة السمكية في الكويت. اشتملت الدراسة على انبات بذور للنباتات المعمرة، والتي تم الحصول على بذورها مسبقا من الأمهات المعمرة، المجففة تماما، والمخزنة في بيئة باردة وجافة، وكان النباتات المختاره هي: *Calligonum comosum, Farsetia aegyptia, Rhanterium epapposum, Pennisetum divisum, Panicum turgidum*. أجريت عمليات إنبات البذور في ظل ظروف بيئية مستقرة داخل الحضانات. كما ان البذور تم انباتها دون معاجة لكسر مرحلة الكمون. واثبتت النتائج ان جميع بذورالأنواع الخمسة للنباتات المحتاره حققت معدل مرتفع من الإنبات، وتراوحت نسبة الشتلات التي ظهرت بين 37 و55 يوما من 78.2% *Pennisetum divisum* التي أنتجت أقل الشتلات، في حين أنتجت *Farsetia aegyptia* أكثر من 95.4%. توفر هذه الدراسة معلومات أساسية لأصحاب القرار من أجل تنفيذ الاستراتيجيات المناسبة وتحقيق نتائج جيدة لمشاريع ناجحة وواسعة النطاق. ومع ذلك هناك حاجة إلى تقنية حديثة للمراقبة البيئية لتحديد نمو الشتلات وتطورها في المواقع التي تم زراعتها.