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Ecological and Botanical Diversity in *Haloxylon Persicum* Community at Al-Qassim Region in Kingdom of Saudi Arabia

Suliman Alghanem*

Department of Biology, College of Science, Tabuk University, Tabuk, Saudi Arabia
*Corresponding author: s-alghanem@ut.edu.sa

Abstract *Haloxylon persicum* is a vital species in desert environment. Not only does it play a role in stabilizing sand dunes, but also conserves soil and water and reduces the rate of desertification. However, the fact that the plant species is endangered poses serious consequences. *Haloxylon persicum* is native to northwestern China, Russia and the Middle East and can withstand extreme drought. This study was conducted in the Al-Qassim region of Saudi Arabia and the research areas were selected based on how they represent the ecological and botanical diversity of the *H. persicum* species. The researcher chose nine sites from the three areas. The researcher estimated the vegetation parameters like the species coverage, density and frequency. Moreover, soil analysis was also conducted in all the three selected areas of research. Physical tests to ascertain the soil types were conducted to find the electrical conductivity (EC) Mmoh / cm, pH, total dissolved salts (TDS) as parts per million (ppm), Sodium Ions, Potassium, and soil texture. The results show that soil factors play an important role in the survival and distribution of *H. persicum* species starting with the emergence as well as establishment of the seedlings. The researcher concludes that to protect the *H. persicum* community, it is important to stop overgrazing the plants and using it as the main source of wood for charcoal. It is critical that the Kingdom of Saudi Arabia and other nations in which *H. persicum* exists protect the species because of the role it plays to the desert topography.

Keywords: *Haloxylon persicum, diversity, soil analysis, reserve*

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1. Introduction

The aim of this research is to study the diversity, both botanical and ecological of the *H. persicum* community at Al-Qassim Region in Saudi Arabia. As an important plant in the Gulf of Arabia as shown above, the fact that the *H. persicum* species is endangered warrants a study to determine its distribution in the area, which also means looking at the underlying biological and environmental factors that affect the distribution. The findings and recommendations of this research will enable the concerned authorities to make policies that will help protect and restore the *H. persicum* species not in the areas where it once flourished.

The *Haloxylon persicum* species is an endangered edible species. It plays a very critical role in the stabilization of sand dunes, hinders soil desertification, conserves soil and water and improves the conditions within the environment [1]. *Haloxylon persicum* is a white saxual multipurpose plant that belongs to the Amaranthaceae family and is a short tree that is typical in the desert. These plants develop to heights that range between two and four meters, with large underground root systems. Also, these plants carry out photosynthesis through small photosynthetic branches [2].

H. persicum is a species common in northern Russia, northwestern China and the Middle East. In the Middle East, the species is found particularly in Egypt, the Sinai Peninsula and on the Arabian Peninsula in northwestern and central Saudi Arabia [3]. *H. persicum* is referred to as a super xerophyte because of its extreme tolerance to drought, enabling its survival in environments considered prohibitive. This explains why the *H. persicum* species is favored as the first plant during sand dune stabilization, preventing soil desertification, water and soil conservation and enhancement of the environment to favor wildlife in conditions that only a miniscule number of large shrubs can handle [4].

In addition, *H. persicum* can be eaten by livestock and it is an excellent plant species that helps in giving insight into the physiology of stress adaptation [26, 27]. Nevertheless, misuse of the rangelands and overgrazing have resulted in the loss of the useful *H. persicum* species, resulting in the dominance of inedible plants in most areas where it is distributed. According to [30], *H. persicum* loss is particularly felt towards the west of Asia. The seeds of this species are known to germinate well when freshly harvested, but they quickly lose their viability. To help in the mass production of genetically identical and physiologically uniform plants, micropropagation has more advantages than normal methods of propagation.

Micropropagated plants develop normally and without diseases [5]. Moreover, it is possible to acclimatize *H. persicum* in a short period and at a lower cost. Besides, micropropagation is more promising for the mass multiplication of important woody species that are close to extinction.

In conclusion, the *H. persicum* species is very important not only to the biodiversity in the regions where it is found, but also for the role it plays in the lives of human beings and animals living in the areas. The following is a literature review of the relevant past studies done with regard to the distribution of the *H. persicum* species not only in Saudi Arabia, but also in other areas that the plant grows. The literature review will help show the gaps that exist in literature and that this study aims to fill by contributing to the body of literature.

2. Literature Review

Haloxylon persicum is among the well-known trees in Central Asia, Afghanistan, Iran, and North West China and near the eastern deserts. The plant is an Irano-Turanian species purported to have originated in Central Asia where it forms a critical component of the desert vegetation. Generally, *H. persicum* belongs to the sandy habitats in the shallow depressions found along dune slopes. The tree is a well-known source of firewood and in several deserts in Central Asia, it produces as much as fifty tons of charcoal per hectare [1].

According to Liu et al. [6], the *H. persicum* tree is one of the trees that have dominion in the sandy deserts that occupy a large area in a region that at most receives 25 mm of rainfall per annum. The species exhibits very high tolerance to temperature extremes as well as water and light availability. Other than cutting the trees down to acquire charcoal and firewood, these plant species are overgrazed by livestock [7]. The destructive use of biological resources in this region of the world has caused the extinction of many species, endangered many and also, harmfully damaged the biodiversity as a whole.

It is important to understand how to regulate the population as well as growth so as to understand the structure and dynamics of the economics. The goal of this paper is to analyze the *H. persicum* distribution in the Arabian Peninsula [8]. This study also tries to understand the phonological events under the desert climate of the Peninsula. Finally, the paper looks at the reasons behind the poor germination in the natural habitats.

The Arabian Peninsula occupies an area that stretches as far as 2254 km, running from the Gulf of Aqaba towards the north as well as the Gulf of Aden towards the south [9]. The span between the northern part of the Red Sea and the Arabian Gulf is approximately 1200 km southwards and the distance between the Gulf of Oman and the Red Sea is approximately1930 km. The expansiveness of the Arabian Peninsula consists of many habitats like rocky deserts, sand, mountains, wadis, hillocks, lava areas and salt pans. The Peninsula consists of arid and extremely arid areas, apart from the high elevations towards the southwest and a small region close to the Gulf of Oman [10]. Approximately a third of the land area is made up of sand that resembles sea sand. This expansive sandy area offers adequate room for the luxuriant development of several range plants such as *H. persicum*.

Previous records of this plant can be found in Zohary [11] as they appeared in previous works on the deserts of Arabia. Large populations of *H. persicum* were reported in Wadi Arabia, which is the valley that separates the Dead Sea and the Red Sea. Other than Zohary [11,12], a few other plant explorers and botanists have delved into the elements of flowers within the Arabian Peninsula and the mention of the presence of *H. persicum* has been common in this region. The vernacular name given for this species in most parts is “Ghada.” Before Zohary [11], the plant was known as *Euphorbia Haloxylon articalatum* or *Arthrocnemum fruticosum*.

Based on the gatherings from the deserts of Syria and earlier works, Zohary [11] attested that the Ghada tree was *Haloxylon persicum*. Saudi Arabia shares 80% of its land surface those 2.23 million square kilometers. The country lies 15^0 45' and 34^0 34' northern latitude and 34^0 40' and 55^0 45' eastern longitude. The phytogeographical map of Saudi Arabia shows nine different regions. There are three main geographical areas such as Dahna, Summan and Tihama were initially not merged or marked with adjacent regions. The Tihama region, which lies close to the Red Sea and extends for 72.5 km in width and narrows to 48 km close to Jizan, narrowing down to 16 km till it reaches the Gulf of Aqaba [13].

The Dahna region is crescent shaped and connects Nafud towards the north and the great Rub Al-Khali that lies southwards. Some scholars treat Dahna as Nafud’s extension containing unique types of vegetation that are distinct from other bodies of sand such as that found at Rub Al-Khali and Nafud [14,15]. Another area that is parallel to Dahna is Summan towards the east and is characterized by topography that is gently sloping. However, there are regions that are deeply sloping and have loamy shallow soil.

The three bodies of sand together with their extensions play a critical role in the distribution of *Haloxylon persicum*. Towards the north, there are sand dunes, hills and wadis among others. Deep sands along the hill slopes and the wadis support *Haloxylon persicum* growth. There are also psammophytes Hummocks of drifting sand in the coastal regions towards the east that have small populations of the *Haloxylon persicum*. The great Nafud is towards the north and the massive sand dunes in these areas offer the *Haloxylon persicum* habitat on the slopes while the top contains relative species, *Calligonum comosum* [16,17].

Towards the north of Dahna, there are large Ghada populations. *H. persicum* have been reported in the northwest parts of Rub Al-Khali. According to [31], the plant populations in these areas are not only conspicuous, but also clear cut. Moreover, one can find some sporadic populations from Najd region’s sandy formations towards central Saudi Arabia. *H. persicum* is reported in the Arabian Peninsula in the UAE and Oman. There is a large population of the species towards southern Abu Dhabi in the UAE, where the plants grow on sand dunes of medium sizes. Nevertheless, the species’ occurrence in Oman is yet to be confirmed. There have been erroneous reports of the existence of *H. persicum* in Bahrain but the illustrations and descriptions seem to match another popular species, known as *Haloxylon salicornicum* Bunge *ex.* Boiss.

The other area where there are reports of *H. persicum* outside the Arabian Peninsula are Egypt, and southwest Asia towards Pakistan, Central China and Central Asia. All the sighted populations are towards the north of the Tropic of Cancer as far as 50° northern latitudes [18]. As a popular source of firewood and fodder, *H. persicum* populations are threatened by overgrazing, destruction of the habitat and over collection of charcoal and wood. Moreover, the fact that the *H. persicum* have poor regeneration rates and high seedling mortality rates under natural conditions create problems for the growing populations.

A combination of manmade and natural obstacles has acted as natural barriers that reduce the size of the *H. persicum* population in the Arabian Peninsula in the course of the past few decades. *H. persicum* exists in a region that spans 300,000 km squared, going through Dahna, Nafud and the northwestern border of Rub Al-Khali as well as the UAE. While the species has a wide area of occurrence, the actual occupancy area falls below 30,000 km squared. For every 50 m squared, the average number of mature individuals is approximated to be around 23.93 ± 6.28. Considering the areas where *H. persicum* exists, with a good occupancy area and many plants that make up the population, this taxon is considered lower risk [15,19]. The main challenges facing the species include high seedling mortality, poor natural regeneration, habitat destruction and off-road recreational driving, causing a decline in the population of the species. It is, therefore, plausible that *H. persicum* species found in the Arabian Peninsula be given the status of 'near threatened.'

H. persicum produces aestival and vernal flowering, which is uncommon in Chenopodiaceae. Most *H. persicum* plants generate perfect flowers from branches from the previous year [20]. However, the normal flowering period occurs between March and April. At the beginning of winter, the plant appears yellowish and then has a dormant stage followed by the appearance of leaves and small shoots by the end of December. These small shoots are where the flower buds appear. Also, the aestival flowers that form on new shoots during summer are usually male or in minimal cases, polygamous [21].

After anthesis, these flowers dry up and wither and it is at this period that the frequency of insect attack is at the highest. This leads to the creation of fruit-like galls. Viable seeds are produced by vernal flowers found in the middle of white perianth lobes, which turn to dull-white and then transparent on maturity. Normally, fresh seeds gathered in the course of vernal flowering and stored under laboratory and refrigeration conditions have a 100 percent germination rate for up to three months [5]. After four hours of hydration, the seeds begin uncoiling after which it produces the straight radicle. The leaves of the cotyledon appear in 24 hours followed by the generation of tiny secondary roots within a few days. The seeds have an extremely thin seed coat that enables the absorption of moisture during sporadic rains that are usually a few hours long [1].

As a successful species in a sandy desert, the plant needs to take advantage of all favorable conditions. A study conducted by [32] carried out an experiment to measure the percentage of germination and concluded that the ideal seed germination temperature was around 20°C and that temperature increases lessen the percentage of germination. In this experiment, however, maximum germination was recorded at 25°C. Research on the longevity and storage conditions found that seeds stored at 2°C still remained viable after one year and nine months. Moreover, these seeds had an 88% germination rate unlike seeds stored under a shade without temperature control lost their viability after 15 months. Also, seeds under refrigeration had just as high germination percentage for 11 months, after which there was a decline in their viability [20].

Arabzadeh [5] and Al-Khalifahand Shanavaskhan [3] show that even seeds that were presoaked failed to germinate on the dry filter paper. However, seeds on moist filter paper recorded germination as high as 96%.

Therefore, the absence of enough moisture in the medium of germination is also a limiting factor in the regeneration in natural conditions. During winter, the sporadic rains that fall in the sandy areas to facilitate germination. However, the unavailability of water in the following days hampers further development. Seeds planted near the surface of the soil usually have a higher germination percentage than those planted at some depth under the soil [13]. This shows that when the seeds are buried deep by the drifting sand, the results are poor regeneration. *H. persicum* is normally found in the small depressions of sand dunes meaning that the likelihood of sand accumulation over the fallen seeds is very high [22].

Also, when seeds are deeply buried in the soil, they experience retarded germination and growth. Despite the fact that the *H. persicum* produces many seeds, the authors were only able to find a couple of seedlings within the natural habitat. The initial stages of development following germination are critical for the growth, survival as well as reproduction of *H. persicum* within deserts [23]. Without an endosperm, young *H. persicum* seeds rely on cotyledon photosynthesis as the source of food for the seedling as it develops. Past research shows that *H. persicum* cotyledons have an isolateral mesophyll structure that lacks the Kranz anatomy [17].

Therefore, the likelihood of some features such as C3 photosynthesis in cotyledons and C4 mechanism in developing shoots is hypothesized. It is normal within a plant to find that all of the photosynthetic tissue follows the same photosynthetic pathway [16]. Nevertheless, deviations are known to exist in leaf cells of the epidermis and reproductive tissue. The fact that *Haloxylon* cotyledons exhibit C3 photosynthesis in the cotyledons of a C4 species is very unusual. The existence of C3 photosynthesis in *Haloxylon* cotyledons may have important evolutionary and ecological significance [14].

Photosynthesis by the cotyledon from saxual seeds that lack an endosperm is the only source of energy required for plant growth. In the deserts of Central Asia, cotyledons become evident towards the end of April when soil moisture content is high with low temperatures after the rains that fall during winter and spring [24]. These conditions favor C3 rather than C4 photosynthesis. Winter begins in November in the Arabian Peninsula, which is the period when sporadic rains are expected. With such favorable conditions, *H. persicum* produce vernal flowers that produce viable seeds that is very instrumental in their perpetuation during the normal flowering season that runs from March to April. At this time, the climatic conditions do not favor C3 seedlings meaning that the plants only produce sterile flowers [25].

In natural ecosystems, the heterogeneity of soil resources is considered normal. Such differences in soil resources are some of the primary drivers of biological processes and a key factor in plant interactions that are either competitive or facilitative [4,5]. As such, the differences in oil resources may account for landscape patterns with the most effect on the biological, geological and chemical cycles in most ecosystems. Differences are usually marked in desert ecosystems that are dominated by shrubs because of the various species and the irregular vegetation distribution and the topographical differences [21].

In conclusion, the above literature review section shows the diversity and distribution of the *H. persicum* species in the Gulf of Arabia based on past studies. The review shows that the apart from the reduced precipitation received in the area, the *H. persicum* species is affected by human activities such as being cut down for firewood, feeding animals and charcoal. The other important factor that affects the distribution of the *H. persicum* species is its own implicit biological makeup such as the fact that its seeds can only germinate at a certain depth beneath the soil, past which the seeds die. Based on the above literature review, it is apparent that more research is needed to determine the soil composition and climatic conditions that favor the growth of the *H. persicum*. This is the purpose of the following methodology section.

3. Methods and Materials

The researcher conducted a quantitative analysis of the *H. persicum* species in the Al-Qassim region between 2015 and 2016. So as to identify the *H. persicum* species in the region, the researcher used stratified random sampling. Three research areas were selected for the study in a manner that represents the botanical and ecological diversity in *H. persicum* community. The three areas are Rawdhat Salasel, Ghada Park and Nafud al-‘Urayq Reserve. The researcher selected nine sites from the three areas; meaning that there were three sites from each area. List-count quadrat sampling method was used in the study [33,34]. Every site was divided into three squares and the dimensions of each square were 10m by 10m. The researcher then counted all the plant species grown at the research site during the spring season between March and May 2016.

Besides, the study also estimated the vegetation parameters such as species density, species coverage and species frequency. The present study estimated these vegetative parameters through the following mathematical equations [34]:

1. Species Density in a sector (plant/square) = Number of plants in three squares/3.
2. Species Density in a sector (plant/m2) = Plant density (Plant/square)/Square area.
3. Relative species density in a sector (%) = [Density (Plant/square)/Sum of plant densities of all species] × 100.
4. Species Frequency (%) = [(Number of square in which a plant species in a sector appeared/the total number of squares in the sector] × 100.
5. Relative Frequency of species in a sector (%) = [Species frequency/ sum of frequencies of all species in the sector] × 100.
6. Species Coverage (%) = Sum of coverage in all square in a sectors/number of square.
7. Relative Coverage in a sector (%) = [(Species coverage/ Sum of coverage of all species)] ×100.
8. Relative Importance of a species in a sector (%) =Relative density + Relative frequency+ Relative coverage.

3.1. Soil Analysis Methods

After the division of study area into botanical communities, soil samples were collected from each community using the following method: The researcher dug a hole at each of the nine selected sites in the three areas at a depth of (1 m). Soil samples were placed in sealed plastic boxes. The samples were prepared for analysis as stated in (35) as follows:

1- Soil samples got dried in an oven at a temperature (105° C) for a period of not less than 24 hours to get rid of moisture.

2- Disintegration of samples using a plastic hammer followed.

3- Samples were passed through a sieve; the diameter of its openings is (2 mm) to get rid of gravel and impurities.

Next, the study performed physical tests to estimate the lists of soil, and chemical analyses to estimate the values of each of the following: Electrical conductivity (EC) Mmoh / cm, pH, total dissolved salts (TDS) as parts per million (ppm), Sodium Ions, Potassium, and soil texture. In order to measure the relative composition of sand, silt and clay in the collected samples, sieves were used to collect the soil particles with the least size clay particles followed by sieves to collect medium-sized silt particles. The remaining soil was sand. The relative proportions of the sand, silt and clay were measured on a weight balance and the percentages calculated based on the weight of the original sample collected from the various areas of the study.

In order to measure the pH of the soil samples, the researcher used a meter and a litmus paper. The reason why the researcher chose this method is because it is a less expensive and simpler way to measure the pH of the soil. This method uses special strips of paper that change color based on the pH of the sample soil mixture. Moreover, the litmus strips can measure a difference in pH at an accuracy of between 0.2 and 0.3. The litmus paper changes color based on whether it is basic or acidic. The researcher placed a droplet of the sample on the paper as opposed to dipping the litmus paper into the sample in order to avoid contaminating the sample. Then, the researcher observed the color change on the paper and comparing it to the standards displayed on the pH charts. After measuring the pH of the soil samples acquired from the area of study, the researcher recorded the outcomes in a table.

So as to measure the electrical conductivity, the researcher used a meter and a probe. The probe used had a pair of metallic electrodes separated by a distance of one centimeter. The researcher then applied a constant voltage across the electrodes to initiate the flow of an electrical current within the soil sample containing water. The current that flows through the water is proportional to the concentration of the dissolved ions inside the water, the probe can measure the electrical conductivity of the water. Conventionally, the more the concentration of the dissolved ions in the soil-water mixture, the more conductive it is and the higher the electrical conductivity reading. The electrical conductivity readings were recorded in the table shown in the Results section of this research.

4. Results

Table 1 show that the highest number of *H. persicum* plants in the Rawdhat Salasel region per square meter was one plant, while the lowest density per square meter was 0.44. With regards to the relative density, the *Lycium shawii* subspecies was the lowest at 0.27 while the highest was the *Teucrium oliverianum* at 2.66. The *Panicum turgidum* subspecies had the highest percentage frequency at 80% while *Atractylis carduus* had the lowest frequency of occurrence at 20%. The *Lycium shawii* sub-species had the highest percentage coverage at 1.1% while the *Atractylis carduus* subspecies was the lowest at 0.22%. A noteworthy result is that the *Cynodon dactylon* plant, which has the highest relative importance of 10.99% has a 0.5% coverage.

In the Nafud al-‘Urayq Reserve region of the study, the *Haloxylon salicornicum* subspecies had the highest relative importance and had a frequency of 60%, which was second only to the *Stipagrostis plumosa* subspecies at 68.89% frequency. The plant with the lowest coverage in the area was *Rhanterium epapposum* at 0.001%. *Stipagrostis plumosa* had the highest density per square meter 9.166, followed by *Haloxylon salicornicum* at 2.633. Compared to the Rawdhat Salasel region whose results are shown in Table 1, the *H. persicum* community at the Nafud al-‘Urayq Reserve is higher, showing that the plants here have not been used as much as in the Rawdhat Salasel region.

Except for the *Moltkiopsis ciliata* and *Cynodon dactylon* subspecies which have a relative importance of 20.59% and 12.55% respectively, all the other plants found in Ghada Park have a relative importance beneath 4%. The *Atractylis carduus* has the lowest coverage at 0.002% while the *Moltkiopsis ciliate* subspecies has the highest relative coverage at 0.048% but with the highest density at 10.07% and the highest frequency 73.33%. The *H. persicum* community at Ghada Park is healthier than at Rawdhat Salasel, but comes second to the plant population at the Nafud al-‘Urayq Reserve region.

Table 1. Characterization of *Haloxylon persicum* community in Rawdhat Salasel

Plant Species	Density (plant/m2)	Relative Density(%)	Frequency (%)	Relative Frequency(%)	Coverage (%)	Relative Coverage(%)	Relative Importance (%)
Lycium shawii	0.08	0.27	30	2.54	1.1	3.81	6.62
Panicum turgidum	0.52	1.73	80	6.78	0.26	0.90	9.41
Cynodon dactylon	1	3.32	70	5.93	0.5	1.73	10.99
Atractylis carduus	0.44	1.46	20	1.69	0.22	0.76	3.92
Teucrium oliverianum	0.8	2.66	30	2.54	0.7	2.42	7.62
Salsola imbricata	0.78	2.59	30	2.54	0.39	1.35	6.84

Table 2. Characterization of Haloxylon persicum community in Nafud al-‘Urayq Reserve

Plant Species	Density (plant/m^2)	Relative Density (%)	Frequency (%)	Relative Frequency (%)	Coverage (%)	Relative Coverag(%)	Relative Importance (%)
Haloxylon salicornicum	2.633	3.145	60	3.145	2.178	52.53	61.73
Stipagrostis plumosa	9.166	13.25	68.89	6.912	0.022	0.598	20.76
Calligonum comosum	0.311	0.45	18.89	1.895	0.103	2.768	5.113
Rhanterium epapposum	0.289	0.418	11.11	1.115	0.001	0.036	1.568

Table 3. Characterization of Haloxylon persicum community in Ghada Park

Plant Species	Density (plant/m^2)	Relative Density(%)	Frequency(%)	Relative Frequency(%)	Coverage(%)	Relative Coverage(%)	Relative Importance(%)
Centropodia forskalii	1.055	1.526	18.89	1.895	0.003	0.071	3.492
Cynodon dactylon	5.011	7.246	50	5.017	0.011	0.0286	12.55
Atractylis carduus	0.711	3.209	21.11	2.118	0.002	0.063	1.029
Moltkiopsis ciliata	10.07	12.02	73.33	7.407	0.048	1.16	20.59

Table 4. Soil physical and chemical characteristics of Haloxylon persicum community in the three areas (Rawdhat, Salasel, Ghada Park and Nafud al-‘Urayq Reserve) in al-Qassim

Soil Properties	Rawdhat Salasel			Ghada Park			Nafud al-‘Urayq Reserve		
	A	B	C	A	B	C	A	B	C
Sand%	94.64	97.05	94.28	90.97	93.65	97.05	96.51	98.92	93.65
Silt%	2.68	0.36	3.13	3.76	3.67	0.18	0.9	0.99	3.67
Clay%	2.68	2.59	2.59	5.27	2.68	2.77	2.59	5.09	2.68
Texture	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Sand
(TDS) Total Dissolved Salts (ppm)	2048.00	211.20	499.20	140.80	147.20	134.40	24320.00	256.00	166.40
pH	7.1	7.5	7.3	7.9	7.8	7.5	7.7	6.3	7.5
Electrical conductivity (EC) Mmoh/cm,	3.2	0.33	0.78	0.22	0.23	0.21	0.38	0.40	0.26
K (ppm)	30	60	260	60	80	70	110	200	310
Na (ppm)	380	32	68	26	30	25	15	35	30

Table 4 shows that the soil texture found in Rawdhat, Salasel, Ghada Park and Nafud al-‘Urayq Reserve are all sandy. The total dissolved salts were highest at the Nafud al-‘Urayq Reserve, particularly in sample A that had a total dissolved salts count of 24,320.00 ppm, which explains its high plant cover and density, because it means that the plants have access to nutrients that aid in their growth. Ghada Park had the least total dissolved salts, which explains the low population of plants in the region. Apart from sample B derived from Nafud al-‘Urayq Reserve which was slightly acidic at 6.3, the pH of all the other samples were slightly basic ranging from 7.1 in sample A from Rawdhat Salasel to 7.9 in sample A from Ghada Park. Potassium ions were highest at Nafud al-‘Urayq Reserve where they ranged from 110 ppm in sample A to 310 ppm in sample C. On the other hand, Sodium ions ranging from 32 ppm in sample B to 380 ppm in sample A.

5. Discussion and Conclusion

Some of the biological aspects investigated in the present study included the morphological traits, seedling recruitment and biomass allocation. This study focuses on the significance of soil factors that determine the typical distribution of plants in the habitat. The results indicate that selection favored the plants with more water stress tolerance and nutrient shortage tolerance. These characteristics are what adapt the *H. persicum* species on the top of the dunes. On the other hand, more tolerance to salinity adapted *H. ammodendron* to lowland regions that lie between the dunes [29].

In the study, reciprocal transplants were used in evaluating the effect of soil factors on seedling development and the significance of those factors to the distribution of dune-interdune species. The species used in this study had lower seedling densities when planted on soil substrates that they did not normally occupy than when placed on normal soil substrates. Species survival and seedling performance proved better on its own soil type compared to different soil types. The outcomes of this study show that soil factors affected the emergence of seedlings as well as their establishment. The fact that there is higher soil salinity between the dunes coupled with decreased germination and seedling survival rates due to increased NaCl concentration in the laboratory. Therefore, it is logical to conclude that soil salinity constrains the distribution of *H. persicum* on lowland areas found between the dunes [29].

Suo, Jia, Lu, Pan, Jin, Xu, Peng, Sunand Tao[24] report maximum root depth is imperative for maximum root depth for the survival of species during times of drought. Desert ecosystems facing drought were linked to the distribution of plants. In the case of *H. ammodendron*, low soil salinity in the dune may hamper seedling survival. A study conducted by [32] a hydroponic culture of *H. ammodendron* at approximately three months was subjected to NaCl solution of 0, 200, 400 and 600 mmol/kg. The study found that the survival was highest at 400 mmol/kg of NaCl.

Besides, the slower vertical extension speed of *H. ammodendron* likened to that of *H. persicum* in the seedling stage may result in higher seedling mortality on the dunes. The higher mortality of *H. ammodendron* on the dunes may be worsened by the reduced availability of water within the dunes than what is observed in the interdunes, which is their natural habitat. Selection was higher in germinating seedlings because of differences in soil water and salinity. The different ways in which these two species adapt to their environment determines their distribution patterns in adulthood.

The differences in germination and survival requirements in the two species during the recruitment stage resulted in preferential germination and seedling emergence in the soil substrate. Therefore, it appears that variations of regeneration in dune/interdune systems determine how the adult trees will be distributed.

The balance between phenotypic traits and patterns of allocation is crucial in maintaining how a plant adapts to the limiting factors within the environment. Besides, it determines the distribution of species. Smaller stature *H. persicum* allocate a large proportion of its biomass to the roots to ensure a larger root/shoot ratio and longer roots. Therefore, *H. persicum* is more adapted to nutrient deficiency and water shortage than *H. ammodendron*. These results are in line with the second hypothesis.

When comparing between common and rare species, [36] found the balance in the allocation of whole plant biomass and within root may be the cause of their adaptation to their environment. Such adaptation to one environment means that the plant will be poorly adapted to other environment. Nevertheless, the ratio between the roots and shoots is not fixed because it varies with the size of the plant, meaning that it may have to be followed for a long periods to observe the differences. The total length of the roots is a better predictor of the soil volume that the plant needs and, thus, the root capacity to absorb water and nutrients as opposed to using the absolute root mass.

Also, competition between congeneric species around the boundary is usually of greater intensity than between unrelated species. This accounts for most of the differences between the two species with regard to their habitats and geographical distribution. Therefore, competition has an important role to play in the distribution patterns of the species, and should therefore be focused on for better understanding.

The outcomes from this research indicate that the two species have different adaptations to the water conditions and salinity of the soil. The difference in adaptation also affects the germination and establishment of seedlings, thus, strongly influencing the distribution patterns of the two species. *H. ammodendron* and *H. persicum* had higher seedling densities at every recruitment stage in the native and adjacent habitats. Lower total dry biomass was observed in *H. persicum* growing on the dunes. However, *H. persicum* allocated a greater proportion of its biomass to roots and possessed a greater root area and root length by the specialization of phenotypic traits than *H. ammodendron*. The disparities in morphology and allocation enabled these species to thrive in their own environments.

Species with higher drought and bareness resistance were favored by selection. Therefore, *H. persicum’s* occupation of the dunes and *H. ammodendron’s* occupation of the lowland between the dunes is the outcome of selection.

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