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Ecological and nutritional values of halophytes in the Al-Qunfudhah, Saudi Arabia

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ABSTRACT

The existence of coastal salt marshes along the Arabian Gulf and Red Sea shores and inland salt marshes led to many halophytes found in several regions of Saudi Arabia. Many grazing animals rely on marginal and neglected resources like halophytes. Consequently, the work objectives were to determine halophytic community diversity in this vital region and assess some halophytic species nutritional value in the studied area. Twelve plant species belonging to ten families were recorded in Al-Qunfudhah area from February 2018 to January 2020. Amaranthaceae was the dominant family, and chamaephyte was the predominant life form, which indicates a typical salt marches form. Among survived halophytic species, the highest importance value (IV) is found in Aeluropus lagopoides (87.02), Suaeda vermiculata (60.48); these plants are considered C4 pathway in protein biosynthesis. The results indicate that some halophytic species have high protein contents, fiber, and nitrogen-free extract, which render them an excellent source of forage. Such halophytic plant species may play an essential role in Saudi Arabia's welfare living in harsh arid regions by providing economic fodders throughout the year.

In addition, exploring solutions to preserve wildlife plants from extinction is an essential step in protecting our ecosystem.

1. Introduction

Salt marshes (sabkha) are a unique ecosystem, frequently saline, flat, forms along the Red Sea coast of Saudi Arabia [1]. Kinsman & Park described two main forms of sabkha landforms, inland, and coastal salt marshes [2]. Coastal sabkha (coastal salt marshes) are formed in the arid area of coastal regions where soil washing is marginal, high evaporation rate, poor soil drainage coupled with low precipitation [3].

Salt marshes are characterized by high saline content were particularly adapted plant species can grow. These plants, halophytes, such as seaweeds, mangroves, and many Amaranthaceae species, can complete their lifecycle under salt circumstances, where the salt levels are at least 200 mM NaCl [3]. Globally, halophytic species are found in about 500 genera, where about half belonged to 20 families [4].

Floristic studies show that Saudi Arabia contains over 100 species of halophytes distributed in 33 families. These species are either strictly halophytes or adapt to survive in wider ecological amplitude [5-6]. Sabkha habitats are constantly threatened throughout the tropics, particularly along the coast, due to their suitable location for recreation and summer resorts. [7]. In the last decades, increased human activities have degraded the habitat leading to a decline and reduction in floristic composition. The main reasons for the deterioration in plant vegetation are habitat fragmentation and urban development [6].

Halophytes have various economic uses, including food, fodder, fuelwood, oilseeds, medicines, chemicals, and landscape plants [8], which could meet the basic requirements of rapid human population growth, especially in underdeveloped countries. Halophytes can grow in highly saline soils and can tolerate many physiological and environmental mechanisms. These plants also grow in nonsaline soils, such as marshes, various deserts, slope retreats, and mangrove swamps. Therefore, halophytes and other plants that tolerate high salinity may be useful and important sources of food for livestock [9-10]

The first description of Western regions of Saudi Arabia's vegetation was given by Vesey-Fitzgerald, who noted various vegetation cover and common ecological types, such as coastal marshes, coastal desert plains, coastal foothills, highland ranges, and wadis. Conversely, extensive efforts have been made to understand the vegetation-environmental relations in sabkha ecosystems [11-12-13].

In the agricultural sector, livestock production is one of the central concerns that play a vital role in people's socio-economic for it provide meat, milk, and many products [14]. The efficiency of any feed to sustain animals' production depends on the quality of the feed consumed and the degree to which the feed meets the demand for energy, protein, minerals, and vitamins [15]. Seasonal changes significantly affect the nutritional value of pasture and range. For example, during dry conditions, plants' crude protein, moisture content, total soluble sugars decline, and plants tend to be fibrous with high ash content and relatively low nutritional value [16]. Saudi Arabia is characterized by a dry climate and suffers from the scarcity of rainfall around the year, affecting the quantity and quality of feedstock to ruminant animals.

Consequently, the economic sustainability of pasture resources in Saudi Arabia depends of using marginal and long-neglected resources. Halophytic plants are one of such resources. However, little information about halophytes' nutritional value in Saudi Arabia is known.

The work's objectives are to i) explores the floristic composition and distribution of halophytic species in Al Qunfudhah salt marches and ii) evaluate the nutritional value of some halophytic species as rangeland survived in the studied area. The observations of this work will be used to establish guidelines for conserving the coastal region in the study area.

2. Materials and Methods

2.1. Study area

Al Qunfudhah governorate is situated on the southwestern edge of the Makkah province. The governorate region is estimated at 5195

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km²; it is also one of the huge seaports of KSA on the Red Sea (Figure 1).

The climate in the investigated region is dry subtropical and is characterized by hot summer and mild winter seasons [17]. Data obtained from the website:

https://www.meteoblue.com/en/weather/historyclimate/climatemodelled/al-qunfudhah_saudi-arabia_108896, from 1998 to 2019 showed that an average annual temperature is 31.2°C; January and February are the coldest winter months with the maximum average temperature (26.48°C), whereas June and July are the hottest months with the maximum average temperature (35.95°C) (Figure 2). Rainfall is irregular and scarce, with an average of 191 mm/year, with a monthly mean that ranges between 7 mm in July and 29 mm in January.

2.2. *Vegetation measurements*

A total of 30 sample plots from three different locations were selected along the Red Sea shore in Al Qunfudhah governorate. The sampling was carried out from February 2018 to January 2020 to represent the flora during different seasons. The representative plots were 5 m X 5 m, and the sampling was carried out during the active plant growth stage when most species were expected to be blooming. The placentation of the quadrates was chosen randomly at each location. All the plant species were recorded in each plot. Plant species and families were recognized and named referring to [18-19], and scientific names were updated by the flora of Saudi Arabia checklist [20].

The collected samples were preserved at The Biology Department Herbarium, Faculty of Applied Science, Umm Al-Qura. The life form of the species was determined, rendering to Raunkiaer [21]. Phytogeographical affinities were made to determine the listed species in world geographical collections, according to Eig [22].

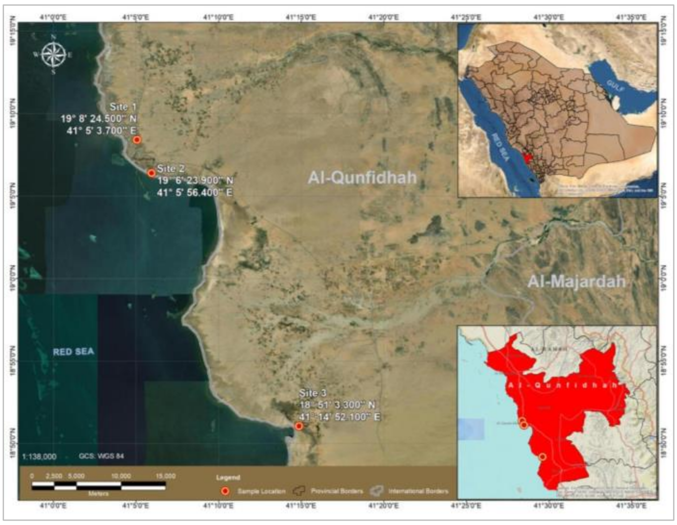

Figure 1. Map of the Kingdom of Saudi Arabia showing the study area.

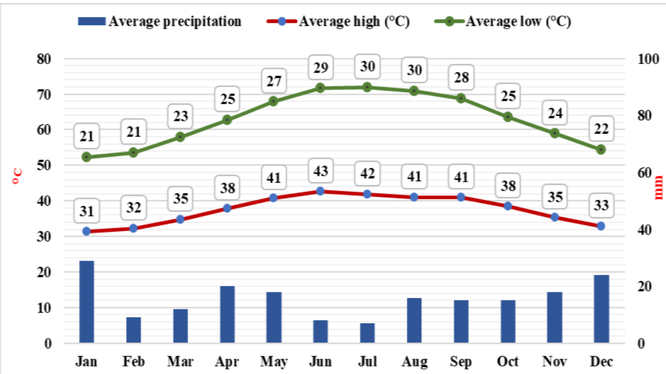

Figure 2. Climate chart showing the average annual range of temperatures and precipitation in Al-Qunfudhah (1998-2019)

Vegetation measurements were determined to evaluate the vegetation characteristics [23] as follows:

1. $\textbf{Density} = \frac{\text{(number of individual species)}}{\text{(area sampled)}}$
2. $\textit{Relative density} = \frac{(\textit{density for a species})}{(\textit{total density for all species})} \times 100$
3. $\textit{Frequency} = \frac{(\textit{number of sampled quadrates in which species occurs})}{(\textit{total number of quadrates sampled})}$
4. $\textit{Relative frequency} = \frac{(\textit{frequency value for a species})}{(\textit{total quadrate area})} \times 100$
5. $\textit{Cover} = \frac{(\textit{the area occupied by the species})}{(\textit{the whole investigated area})}$
6. $\textit{Relative cover} = \frac{(\textit{total of quadrate area for a species})}{(\textit{total of quadrate area for all species})} \times 100$
7. $\textit{Importance value}(IV) = \textit{Relative density} + \textit{Relative frequency} + \textit{Relative cover}$

The importance value (IV) was defined according to Ludwig & Reynolds [24]

2.3. *Chemical composition*

Samples of survived halophytic species were dried at 65 °C to a steady weight [25]. For chemical analysis, the dried sample was ground into a fine powder. Nitrogen was estimated using modified Micro-Kjeldahl [26] and then multiplied by 6.25 to estimate the crude protein (CP) value. Crude fiber (CF %) was estimated using the filtration method, according to [25]. Ash content was detected according to [25]. The ether extract (EE %) was determined using petroleum ether at 60-80ºC in Soxhelt apparatus [25]. Nitrogen free extract (NFE) was calculated as follows: NFE% = 100 - (CP% + CF% + EE% + ash %).

Forage Quality: The digestible crude protein (DCP % in DM) was measured by using equation (1) [27].

$$\text{DCP (\% in DM)} = 0.929\ \text{CP} - 3.52. \qquad (1)$$

Total digestible nutrients (TDN%, in DM) were evaluated by using equation (2), where EE is % of ether extract, and CP is % of crude protein [28].

$$\text{TDN (\% in DM)} = 0.623\ (100 + 1.25\ \text{EE}) - \text{CP}\ 0.72 \qquad (2)$$

Gross energy (GE kcal 100 g^{-1}) was calculated by using equation (3), where CP is crude protein, EE is ether extract, CF is crude fiber, and NFE is a nitrogen-free extract [29].

$$\text{GE (kcal 100 g}^{-1}) = 5.72\ \text{CP \%} + 9.5\ \text{EE\%} + 4.79\ \text{CF\%} + 4.03\ \text{NFE\%} \qquad (3)$$

Digestible energy (DE Mcal kg^{-1}) was estimated by equation (4) [29].

$$\text{DE (Mcal kg}^{-1}) = 0.0504\ \text{CP \%} + 0.077\ \text{EE\%} + 0.02\ \text{CF\%} + 0.000377\ (\text{NFE})^2 + 0.011\ \text{NFE\%} - 0.152 \qquad (4)$$

Metabolized energy (ME) was calculated by using equation (5), where DE is digestible energy [30].

$$\text{ME (Mcal kg-1)} = 0.82 \times \text{DE} \qquad (5)$$

Net energy (NE) was determined by using equation (6), where ME is metabolized energy [31].

$$\text{NE (Mcal kg}^{-1}) = 0.5 * \text{ME} \qquad (6)$$

2.4. *Soil sampling and analyses*

Three soil samples were collected randomly from the selected site at 60 cm in depth. All samples from the same sub-plot were pooled into one composite sample for physical and chemical analysis for a given layer. Chemical determinations of the soil extract (Table 1) were conducted referring to Jackson [32].

Table 1. Mean chemical and physical properties of soil at three sites at Al Qunfudhah salt marshes (n=10)

Sites	pH	EC	TDS	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	Texture
				dS/m		mg/l			meq/l			
Site I	7.82	34.58	20726.00	69.66	31.88	241.31	2.24	0.12	1.37	51.57	304.00	Sandy loam
Site II	8.25	34.52	21038.14	67.80	79.18	192.28	4.47	0.55	1.99	115.21	239.79	Sandy loam
Site III	7.80	40.26	24239.90	124.25	52.46	231.31	1.24	0.26	1.73	69.84	347.57	Sandy loam

3. Results and discussion

3.1. Floristic composition

The data in Table 2 indicated that twelve plant species belonging to ten families (Acanthaceae, Aizoaceae, Amaranthaceae, Boraginaceae, Capparaceae, Convolvulaceae, Juncaceae, Poaceae, Tamaricaceae, and Zygophyllaceae) were reported in the study area from February 2018 to January 2020. The most representative family was Amaranthaceae and Aizoaceae. Each of them achieved 17% of the plants found in the study areas. Each family was represented by *Suaeda monoica* and *Suaeda vermiculata* of the Amaranthaceae family, and *Sesuvium verrucosum* Raf. and *Trianthema portulacastrum* L. of the Aizoaceae family. These results are consistent with those obtained by [33, 34, 35].

Table 2. Floristic composition recorded in Al-Qunfudah salt marshes during February 2018 to January 2020.

Family name	Scientific name	Vernacular name	Vegetation type	Palatability	*P. P	Life form	Floristic categories
Acanthaceae	*Avicennia marina* (Forssk.) Vierh.	Mangrove	Per	P	C3	Ch	SA
Aizoaceae	*Sesuvium verrucosum* Raf.	alregra albahria	per	Up	C3-C4	Ch	NEO
	Trianthema portulacastrum L.	Laani	Ann	P	C3	Ch	PAN
Amaranthaceae	*Suaeda monoica* Forssk.	Suaeda	Per	P	C4	Ch	SU
	Suaeda vermiculata Forssk.	Suaeda	Per	P	C4	Ch	SA
Boraginaceae	*Heliotropium pterocarpum* (Hochst. & Steud.) Jaub. & Spach.	Remram	Ann	Up	C3	Ch	SA + S-Z
Capparaceae	*Dipterygium glaucum* Decne	Saffer	Per	P	C3	Ch	S-Z
Convolulaceae	*Cressa cretica* L.	Molleih	Per	P	C3	Ch	ME+ IR-TR
Juncaceae	*Juncus rigidus* Desf.	Janakas	Per	Up	C3	Ch	SA+ IR-TR
Poaceae	*Aeluropus lagopoides* (L.) Trin.	Akrash	Per	P	C4	Cr	SA-SI
Tamaricaceae	*Tamarix nilotica* (Ehrenb.) Bunge	Athl	Per	P	C3	Ph	ME + SA + S-Z
Zygophyllaceae	*Tetraena coccinea* (L.) Beier & Thulin	Mulaih	Per	Up	C3	Ch	SA

*P.P = photosynthetic pathway, Annual =Ann, Perennial = Per.; palatability; Palatable= P, Unpalatable= Up, photosynthetic pathway, and life forms; Ch = Chameophyte, Ph = Phanerophyte,Cr = Cryptophyte and Floristic categories (Chorotypes): SA. = SaharoArabian, NEO: Neotropical, ME. = Mediterranean, PAN. = Pantropical, SA-SI. = Saharo-Sindian, S-Z. = Sudano-Zambesian, SU = Sudanian. IR-TR: Irano-Turanian

Amaranthaceae and Aizoaceae families are considered as fugitive species of a salt wetland of arid and semiarid regions and have the capability to support a high level of salinity through osmoregulation processes [36-37-38]. Ten plant species were perennials in respect to vegetation type, while *Trianthema portulacastrum* L. and *Heliotropium pterocarpum (*Hochst. & Steud.) Jaub. & Spach. are annual, it could result from overgrazing for a long time, which led to eliminating the most highly palatable annual plants [38]. Also, it could indicate the dry climate prevailing in the study area.

Among twelve plant species (Table 2), eight species are considered palatable (Avicennia marina (Forssk.) Vierh., Trianthema portulacastrum L., Suaeda monoica Forssk., Suaeda vermiculata Forssk., Dipterygium glaucum Decne, Cressa cretica L., Aeluropus lagopoides L. Trin., Tamarix nilotica (Ehrenb.) Bunge). Otherwise, the remaining species are unpalatable (Sesuvium verrucosum Raf., Heliotropium pterocarpum (Hochst. & Steud.) Jaub. & Spach., Juncus rigidus Desf., Tetraena coccinea (L.) Beier & Thulin.

In general, halophytes shrubs show some degree of a slight palatable food intake, and they are usually grazed during the summer and autumn seasons. Due to the significant lack of food, poor or unpalatable bushes are attributed to the possibility of a high ash content, which is a characteristic of these plants. Salts and nitrate, and nitrite complexes may exist in some or others that contain anti-trophic agents such as tannins, glycosides, phenolic compounds, saponins, oxalates, alkaloids, etc. The presence of such plant secondary metabolites makes halophytes less or unpalatable to animals. Furthermore, their palatability enhanced when dried or mixed with other forages. Consequently, these plants should be considered a precious resource for pasture production, particularly during the dry seasons [38- 39].

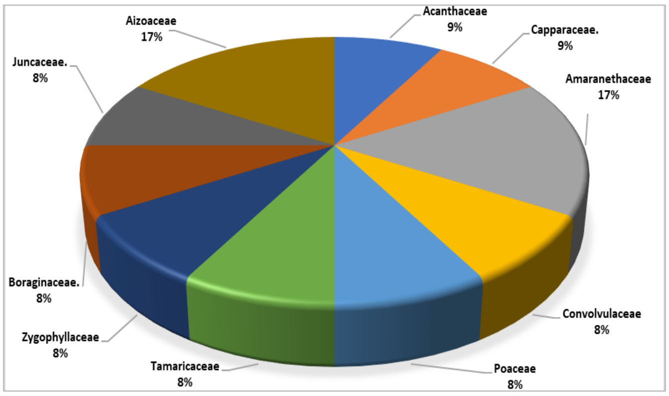

Figure 3. Plant families documented at Al-Qunfudhah salt marshes from February 2018 to January 2020.

According to the classification of Raunkiaer [21], as improved by Govaerts et al. [40], three life forms were recorded (Figure 3). The most numerous life form and were chamaephyte (83.33%= 10 species), while, *Aeluropus lagopoides* is cryptophyte (cr), and *Tamarix nilotica* is phanerophyte (ph). Basahi, [41] detected the same finding on the plant vegetation at the coastal region of Aqaba Gulf. The high percentage of chamaephytes is characteristic of the climate of Sahara Arabian zone (arid zone) [41].

The chronological analysis of the floristic data indicated that the Saharo-Arabian chorotype (30%) forms the main constituent of the floristic structure in halophytic species found in Al-Qunfudah.

Table 3. Mean values of halophytes vegetation documented at Al-Qunfudhah salt marshes during February 2018 to January 2020.

Scientific name	D	RD	C	RC	F	RF	IV
	individual m^{-2}		%		%		
Avicennia marina (Forssk.) Vierh.	0.03	3.85	0.63	3.02	3.33	2.27	9.14
Sesuvium verrucosum Raf	0.01	1.28	0.12	0.56	3.33	2.27	4.11
Trianthema portulacastrum L.	0.01	1.28	0.10	0.48	3.33	2.27	4.03
Suaeda monoica Forrsk.	0.08	11.54	3.68	17.51	30.00	20.45	49.50
Suaeda vermiculata Forrsk.	0.08	12.82	5.23	24.93	33.33	22.73	60.48
Heliotropium pterocarpum (Hochst. & Steud.) Jaub. & Spach.	0.02	2.56	0.32	1.51	6.67	4.55	8.62
Dipterygium glaucum Decne	0.02	2.56	0.15	0.71	6.67	4.55	7.82
Cressa cretica L.	0.03	5.13	0.06	0.28	6.67	4.55	9.95
Juncus rigidus Desf.	0.05	7.69	2.14	10.20	13.33	9.09	26.99
Aeluropus lagopoides (L.) Trin.	0.29	44.87	5.51	26.24	23.33	15.91	87.02
Tamarix nilotica (Ehrenb.) Bunge	0.02	2.56	0.83	3.97	6.67	4.55	11.08
Tetraena coccinea (L.) Beier & Thulin	0.03	3.85	2.23	10.60	10.00	6.82	21.26
Total	0.65	100	20.99	100	146.67	100	300

D= density RD= relative density C= cover RC= relative cover F= frequency RF= relative frequency IV= Importance value

3.2. Vegetation description

The study of vegetation aims to give a clear picture of the current state of vegetation cover, its current state, and the possibility of improvement and conservation.

3.2.1. Plant density: Data in Table 3 indicate that halophytic species show significant plant density (individual m^{-2}). The highest value was recorded in *Aeluropus lagopoides* (0.29 individual m^{-2}). *Aeluropus lagopoides* are noticeable plants with several physiological mechanisms that make them adapted and tolerate high salt contents with different mechanisms, such as reducing salt entrance to plant cells and excluding salt [42-43]. Meanwhile, *Sesuvium verrucosum* Raf, and *Trianthema portulacastrum* L (0.01 individual m^{-2} for each) recorded the lowest value (Table 3). These results indicate that the spreading of plant per unit area depends mainly on the effect of the edaphic factors such as soil texture and soil depth; this could, in turn, reflect on more plant growth and number. These results are in agreement with those obtained by [33 -41].

3.2.2. Plant cover: is a critical component for assessing soil erosion rates and vulnerability to land degradation [24]. *Suaeda vermiculata,* and *Aeluropus lagopoides* achieved the highest coverage values (5.23 & 5.51 %, respectively). *Suaeda vermiculata* survive in salt marsh habitats; it could be due to anatomical structure adaptations and modifications [44]. Also, the abundance of C4 species was predominant in saline regions because they had water use efficiency and comparatively higher saline resistance [45]. On the other hand, *Cressa cretica* achieved the lowest value (0.06). The variation in plant cover could be attributed to more rainfall and soil depth react together to induce more plant growth and number [46].

3.2.3. Plant frequency: indicates the number of times that plant species have been found in a certain number of quadrats. *Suaeda vermiculata* and *Suaeda monoica* is the highest value (33.33 and 30.00%, respectively).

4.2.4. Importance value (IV): It provides the ability of species to tolerate environmental stress and their adaptation. The highest importance value (IV) was recorded in *Aeluropus lagopoides* (87.02), *Suaeda vermiculata* (60.48); these plants are biosynthesis of proteins in C4 pathway plants [45]. The C-4 plants have an additional photosynthetic pathway associated with adaptations to avoid drought stress, and C4 plants have an obvious advantage in desert environments and salt marsh systems [46].

Meanwhile, the low IV was recorded by *Trianthema portulacastrum* L. and *Sesuvium verrucosum* Raf (4.03 and 4.11, respectively). These species are halophytes due to their adaptability to the high content of soluble salts and the low to medium calcium carbonate content in the sabkhah soils [43].

3.3. Halophytes chemical composition

Grazing livestock production in natural pastures is influenced by the role that grazing plants play as a food component on which animals in arid and semi-arid regions depend mainly to produce meat, milk, and wool. For this purpose, the study of chemical analysis and pasture plants' nutritional values is considered one of the essential points of study for pastures [47].

3.3.1. Moisture content (%)

The moisture content of the studied plants ranged from the lowest (29.58%) in *Aeluropus lagopoides* to the highest (81.72%) in *Tetraena coccinea* (Table 4). The high moisture content of tested plant species could be due to their succulence ability to water as a means of osmotic adjustment to survive in their saline habitat [33].

Table 4. Mean of chemical composition of halophytic plants recorded in Al-Qunfudhah salt marshes during February 2018 to January 2020.

Scientific name	Moisture content	Crude protein	Ether extract	Ash	Crude fiber	Nitrogen free extract
	%					
Avicennia marina (Forssk.) Vierh.	52.28	5.60	7.09	14.27	23.58	49.46
Sesuvium verrucosum Raf.	76.18	8.11	7.00	35.53	19.40	29.96
Trianthema portulacastrum L.	66.28	8.14	9.01	19.46	18.52	44.87
Suaeda monoica Forrsk.	71.61	8.04	6.10	22.45	20.72	42.69
Suaeda vermiculata Forssk.	65.89	7.99	6.78	24.90	21.25	39.08
Heliotropium pterocarpum (Hochst. & Steud.) Jaub. & Spach.	71.97	5.93	10.62	23.47	24.84	35.14
Dipterygium glaucum Decne	62.50	5.44	6.95	19.19	25.16	43.26
Cressa cretica L.	42.19	4.17	8.30	35.45	23.18	28.90
Juncus rigidus Desf.	44.40	4.29	8.39	5.55	30.11	51.66
Aeluropus lagopoides (L.) Trin.	29.58	3.47	8.39	19.49	26.36	42.29
Tamarix nilotica (Ehrenb.) Bunge	52.47	4.96	6.34	21.04	23.10	44.56
Tetraena coccinea (L.) Beier & Thulin	81.72	3.88	11.99	28.79	29.34	26.00

3.3.2. Crude protein (CP %): Results from Table 4 indicated that *Trianthema portulacastrum* L. (8.14%) followed by *Sesuvium verrucosum* Raf (8.11%) were the highest in crude protein content, while the lowest percentage of crude protein was in *Aeluropus lagopoides* (3.47%).

Halophytic species may be incorporated as fodder to a wide range of animals due to its complementary crude protein (CP) and adequate nutritional content. Riasi et al. [48] evaluated the digestible quantity of crude protein interrelated to *Atriplex* was larger than the crude protein contained in meadow vegetation. Similarly, Abd El-Hack et al. [10] reported that CP content in *A. halimus* and *A. nummularia* ranged from 18–31.5%, respectively. Likewise, the CP content of halophytic species, viz., *Salicornia bigelovii*, *Suaeda fruticosa*, and *Kosteletzkya virginica* are 31, 11, 32 %, respectively ([49-50]. *Cressa cretica* is a short upright herb used as a feed, particularly for domestic desert animals.

3.3.3. Ether extract (EE %):

The highest percentage of the ether extract (Table 4) was found in a *Tetraena coccinea*, (11.99%) followed by *Heliotropium pterocarpum*, (10.62%), while *Suaeda monoica* achieved the lowest percentage (6.10%).

3.3.4. Ash percentage

Ash is the mineral residue of burnt organic matter, which plays an essential role in promoting growth**.** However, ash is a measure of the feed's total mineral content, but it does not tell us how much of each mineral is present. Ash is not digestible by animals; the high ash content of feeds may dilute the number of nutrients available to the animal [10]. The highest ash content was in *Sesuvium verrucosum* Raf (35.45%) then *Cressa cretica (*35.45%*)*, meanwhile, the lowest is *Juncus rigidus* (5.55%). The high content of ash is observed as a typical characteristic of halophyte plants [36].

The fact that a high content of ash is a typical characteristic of halophytic forages has resulted in divisive concerns over the bioavailability of mineral contents of these forages. However, the mineral profiles of halophytic forages differ from those of traditional ones. These differences may due in part to [51] forage species, stage of growth, seasonality, the degree of soil and water salinity, etc. It appears that these forages could be a source of some minerals to meet ruminant animal requirements. In this context, the concentrations of these minerals may balance the deficiency that may result from in areas depending on grazing ranges e.g., desert and the coastal regions ([52]). Albert and Marianne, [53] and Gorham et al. [54] found that some ions are present in frequent patterns, especially in certain taxons. Sodium salts were found to accumulate in large concentrations in dicotyledons compared with sulfate salts. The ratio of K:Na in these plants was found to be less than one. Low salt concentrations are characteristic monocotyledons like Poaceae and that the K:Na ration is more than one.

3.3.5. Crude fiber (CF %)

The highest crude fiber percentage was found in a *Juncus rigidus* (30.11%) followed by *Tetraena coccinea* (29.34%), while *Trianthema portulacastrum* L. (18.52%) achieved the lowest content (Table 4). Crude fiber and ether extract contents increased in the species that contained less protein and decreased in the species with high protein content. Similar findings were reported in earlier studies by [52-55]. In general, there is an opposite relationship appeared between crude protein and crude fiber content. These results are consistent with [55].

Alghamdi , [56] found that crude fiber content of halophytic species detected in Ha'il , Saudi Arabia ranged from 4.1- 20 %. The highest content was detected in *Salsola imbricata*, *Aeluropus lagopoide*, and *Salicornia strobilacea, making them preferable* for grazing animals. Attia-Ismail, [50] reported that forage species with high fiber content are usually better accepted by cattle than by sheep and goats

3.3.6. Nitrogen free extract (NFE %): a vital part of animal feed evaluation. This is part of a rough analysis and is the only ingredient that has not been analyzed and focuses on the sugar and starch content in animal feedstuff. The maximum nitrogen-free extract content (Table 5) was in *Juncus rigidus* (51.66%) then *Avicennia marina* (49.46%), while the minimum was in *Tetraena coccinea (*26.00 %).

3.4. Nutritional value

The nutritional values of the forage plant are the outcome of the two major components: i) nutritive value and ii) voluntary intake by grazing animals (livestock) and palatability [31- 57]. In this experiment, the nutritional value of halophytic species survived in Al Qunfudhah was assessed according to calculated equations.

3.4.1. Gross energy (GE) could be defined as the overall energy value of the feed or diet, in which feedstuff supply is oxidized to water and CO_2. Gross energy ranged between 330.202 in *Cressa cretica* and 456.661 *Juncus rigidus* Desf Kcal 100 g^{-1} (Table 5).

3.4.2. Total digestible nutrients (TDN) consider significant indicators for forage quality assessment. TDN ranged from 61.26-68.84% (Table 6). The highest value was recorded in *Tetraena coccinea*, while the lowest value was detected in *Suaeda monoica*.

3.4.3. Digestible crude protein (DCP %) is expressed as the amount of CP absorbed by animals. In the current work, the content of DCP of the tested species is classified well as per the index recommended by [58]. The highest values were found in *Sesuvium verrucosum* Raf, and *Trianthema portulacastrum* L., while the lowest values were detected in *Tetraena coccinea* (Table 5).

Table 5. Nutritive value and forage quality of halophytic species growing in Al-Qunfudhah salt marshes during February 2018 to January 2020.

Scientific Name	GE	TDN	DCP In DM	DE	ME	NE
	kcal 100 g^{-1}	%		Mcal Kg^{-1}		
Avicennia marina (Forssk.) Vierh.	*411.659*	63.789	1.682	2.614	2.144	1.072
Sesuvium verrucosum Raf.	326.554	61.912	4.014	1.852	1.518	0.759
Trianthema portulacastrum L.	401.693	63.456	4.042	2.575	2.112	1.056
Suaeda monoica Forrsk.	375.228	61.262	3.949	2.294	1.881	0.941
Suaeda vermiculata Forrsk.	369.393	61.827	3.903	2.203	1.807	0.903
Heliotropium pterocarpum (Hochst. & Steud.) Jaub. & Spach.	395.407	66.301	1.989	2.313	1.897	0.949
Dipterygium glaucum Decne	391.996	63.796	1.534	2.342	1.920	0.960
Cressa cretica L.	330.202	65.761	0.354	1.794	1.471	0.735
Juncus rigidus Desf.	456.661	65.745	0.465	2.887	2.367	1.184
Aeluropus lagopoides (L.) Trin.	396.247	66.335	0.296	2.336	1.915	0.958
Tamarix nilotica (Ehrenb.) Bunge	378.827	63.666	1.088	2.287	1.875	0.938
Tetraena coccinea (L.) Beier & Thulin	381.417	68.844	0.085	2.094	1.717	0.859

3.4.4. Digestible energy (DE Mcal Kg-1) and metabolized energy (ME Mcal Kg-1)

The maximum values of ME and DE were recorded in *Juncus rigidus* Desf, accounting for 2.36 and 2.88 Mcal Kg^{-1}, respectively. In contrast, the lowest value was detected in *Cressa cretica,* accounting for 1.47 and 1.79 Mcal Kg^{-1}, respectively. These data are in agreement with those reported by Heneidy, [57] and El-Shesheny et al. [59].

Attia-Ismail [52] documented that, the nutritive value of halophyte species such as metabolizable energy (ME) appears to depend strongly on plant maturity. Energy contents of both traditional forages and halophytic ones were found to be similar and had no significant differences.

3.4.5. Net Energy (Mcal Kg-1)

In the current work, NE fluctuated between 1.184 in *Juncus rigidus* Desf and *Cressa cretica* 0.735 Mcal kg^{-1} (Table 5). Alghamdi, [56] who detected some halophytic species, which survived in Hail (KSA), noticed the same finding and have high to reasonable contents of protein, fat, and fiber that make them potential resources as forages [56].

Correspondingly, more research findings and efficient governance are needed to sustain the grazing system and help make this system better without degradation.

4. Conclusions

Halophytic plants exist in several Saudi Arabia regions due to the presence of coastal saltmarshes along the Red Sea and inland saltmarshes (Sabkhas).

This study comprises a survey of the halophytic vegetation and their life form at Al-Qunfudhah governorate, Emirate of Makkah Province, KSA, during February 2018 to January 2020. Twelve plant species belonging to 10 families were detected. The Amaranthaceae and Aizoaceae were the dominant family, and chamaephyte (10 plant Species) was the predominant life form. Forage nutritional and quality parameters [Crude protein (CP), The digestible crude protein (DCP), Total digestible nutrients (TDN), Gross energy (GE), Digestible energy (DE), Metabolized energy (ME) and Net energy (NE)] were detected in survived plant species. The data revealed that some halophytic species could be considered a vital resource of ruminant animals, especially during harsh conditions. The number and size of plant species in Al-Qunfudhah are reduced due to human activities like development, overgrazing, and woodcutting.

Additionally, planting some halophytic species on saline soil and irrigated with brackish or saline water could be a valuable strategy for saving freshwater in poor regions of freshwater worldwide and providing high-quality fodders, and increasing animal products in such areas.

Avicennia marina (Forssk.) Vierh. - Acanthaceae

Heliotropium pterocarpum (Hochst. & Steud.) Jaub. & Spach. - Boraginaceae

Suaeda vermiculata Forssk.- Amaranthaceae

Suaeda monoica Forssk. - Amaranthaceae

Aeluropus lagopoides (L.) Trin. - Poaceae

Dipterygium glaucum Decne - Capparaceae

Cressa cretica L. - Convolulaceae

Tamarix nilotica (Ehrenb.) Bunge- Tamaricaceae

Sesuvium verrucosum Raf - Aizoaceae

Trianthema portulacastrum L. - Aizoaceae

Tetraena coccinea (Zygophyllum coccineum) (L.) Beier & Thulin.- Zygophyllaceae

Juncus rigidus Desf. - Juncaceae

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Conflicts of Interest:

The authors declare that they have no conflict of interest.

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