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Floristic Diversity of Jabal Al-Ward, Southwest Tabuk Region, Kingdom of Saudi Arabia

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Abstract: Jabal Al-Ward is one of the Hijazi mountains situated between Al-Ulā and Al-Wajh, southwest Tabuk Province, Saudi Arabia's northwesterly border region. It is considered the highest mountain in this area and is enriched in wildlife. For the first time, the present research aimed to investigate the floristic composition, phytogeographical distribution, and plant diversity in Jabal Al-Ward. One hundred ninety-eight species representing 47 plant families have been identified. The Asteraceae, Poaceae, and Fabaceae represented more than a third of the region's floristic composition. The perennial species (53.5%) were dominant over the annuals (46.46%). This is a prominent feature in Jabal Al-Ward, where the perennial species may be more tolerant of climatic changeability than the annuals. Seven life form categories were found; therophytes (46.46%) showed to be the most common life form. In addition, there were four main phytogeographical groups: Mono-regional, Bi-regional, Pluri-regional, and Worldwide. The Mono-regional and Bi-regional categories had the highest participation, with 38.5% and 37.4%, respectively. Thirty-six species (18.2%) were found to be native to the Saharo-Arabian region. The Saharo-Arabian region was combined with eight more regions, including Saharo-Arabian/Sudano-Zambesian (12.6%), Irano-Turanian/Saharo-Arabian (9.1%), Mediterranean/Saharo-Arabian (5.6%), Irano-Turanian/Mediterranean/Saharo-Arabian (4.5%), Irano-Turanian/Saharo-Arabian/Sudano-Zambesian (2%), Euro-Siberian/Irano-Turanian/Mediterranean/Saharo-Arabian and Saharo-Arabian/Sudanian (1% each), Mediterranean/Saharo-Arabian/Sudano-Zambesian, and Irano-Turanian/Mediterranean/Saharo-Arabian/Saharo-Zambesian (0.5% each). The current study demonstrated the highest species richness compared to earlier research on various locations in Tabuk Province. In future work, the species and endemic richness along elevation gradients should be studied in Jabal Al-Ward. As well as the IUCN status of each taxon, the DNA barcoding of endangered species will be of great significance if applied in the surveyed area.

Keywords: Arabian Peninsula; chorology; flora of Saudi Arabia; flora of West Asia; Hijazi Mountains; Jabal Al-Ward; Tabuk; Saudi Arabia

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1. Introduction

The Kingdom of Saudi Arabia's total area is around 2,250,000 km^2. This vast area holds diverse heterogenic landscapes. It is considered an arid or semi-arid region, where the xerophytic plants represent the highest proportion of Saudi Arabian flora [1]. The country's topography reflects the diversified flora explored by Collenette [2] and Chaudhary [3–5]. The flora of Saudi Arabia is one of the wealthiest biodiversity areas in the Arabian Peninsula, with substantial crops and medicinal plants [6]. Saudi Arabia contained 2223 species and 816 genera assigned to 129 families, with about 147 endemic species [5]. The flora's taxa

are of combined origin; North African, East African, Mediterranean, and Irano-Turanian plants [7,8].

The Tabuk region occupies approximately 146,072 km^2 and is situated in the northwestern part of Saudi Arabia, with diverse ecosystems and habitats [9,10]. One of the most important agricultural areas in Saudi Arabia is the Tabuk region, which produces about a quarter of the country's olive and dates. A floristic survey was conducted in eight discrete regions of Tabuk by Rajasab [11] to reveal 198 plant species belonging to 52 families. Eighty-two species representing 30 families were recognized by Moawed and Ansari [12] in the coastal areas of the Red Sea (from Ras Hemaid to Umluj road across Al Wajh and Dhiba regions) in Tabuk province. Al-Mutairi et al. [13] recorded ninety-six species exemplifying thirty-eight families at four localities in Tabuk (Sharma, Alqan, Al-Lwaz Mountains, and Alzetah). A total of 102 species belonging to 34 families were recorded in the Alaqan region by Moawed [14]. At the Harrat ArRahah, a volcanic field in South Tabuk, 135 species represent 34 families by Fakhry and Al-Kenany [15]. In addition, Alghanem et al. [16] identified 30 perennial species (15 families) at Al-Wadi Al-akhder. At the same time, 69 weed species representing 20 families were detected in farms of the Tabuk region [17]. Al Mutairi [9] reported one hundred and sixty-three species assigned to forty-one families at five sites (Aldesah, Alzetah, Alawz, Harra and Sharma). Ansari et al. [18] have estimated the identified species cited in the different studies of Tabuk and mentioned two hundred twenty-seven species in their comprehensive review. These species belonged to 157 genera and 45 angiosperms' families, including 12 endangered species. However, *Astragalus collenettiae* Hedge & Podlech was the only endemic species recorded by Fakhry & Kenany [15] in the Harrat ArRahah.

Achillea fragrantissima (Forssk.) Sch.Bip., *Artemisia judaica* L., *Ochradenus baccatus* Delile and *Rhazya stricta* Decne. Were mentioned to have potent anti-microbial activity against nosocomial pathogens [19]. Al-Mutairi et al. [13] and Moawed [14] reported that the dominant plant families were: Asteraceae, Brassicaceae, Chenopodiaceae, Fabaceae, Lamiaceae, Poaceae, Resedaceae, and Zygophyllaceae. Moreover, the plant life form categories, phytogeographical affinities, and the economic importance of the vegetation in this area have been studied [9,13,14,20].

Al-Mutairi et al. [13] highlighted the importance of exploring floristic compositions for analyzing socioeconomic and vegetation in this unique area. Moreover, Al-Mutairi et al. [9,13] stated that Tabuk is a biodiversity hot spot region and should be subjected to a conservation program to protect its natural resources. Assessing the floristic composition in a particular area provides insights into species, habitats, or ecosystem diversity. Thus, suitable conservation strategies should be implemented to save the threatened taxa and their habitats [21]. In addition, studies on regional floras are crucial to perform cross-biome comparisons. These studies also serve as the basis for further analyses of the plant communities' function, structure, and evolution in order to better understand the delimitation and mapping of biomes [22,23].

Jabal Al-Ward is one of the Hijazi mountains located between Al-Ulā and Al-Wajh, southwest Tabuk province, where this region is about 900 and 1600 m asl. However, Jabal Al-Ward is regarded as the highest mountain in this region, with up to 2096 m asl [24]. Generally, Jabal Al-Ward is enriched in wildlife, including flora, amphibians, and reptiles [25,26]. This region mainly consists of some valleys that cut across the mountains and act as large natural drainages [24].

Despite the previous trials to describe the floristic composition of the Tabuk region [9,11–17,19,20], Jabal Al-Ward has remained unsatisfactorily studied. Therefore, the present study contributed to investigating and evaluating the floristic composition, phytogeographical distribution, and plant diversity of the wild plant taxa growing in the Jabal Al-Ward region, southwest Tabuk, Saudi Arabia, for the first time.

2. Materials and Methods

2.1. Study Area

This study was performed in the Jabal Al-Ward region (Figure 1) during most plant species' active growing seasons.

Figure 1. Map of the Kingdom of Saudi Arabia showing the study area's location. The red rectangle refers to Jabal Al-Ward region.

The excursions were conducted during the growing seasons of 2019 and 2020. The eremic vegetation was surveyed in 25 localities, in the mountain ridges, distributed to cover the study area, and their elevations ranged from 1435 m to 1807 m asl. The geographical coordinates were recorded for each locality (Table 1). Each locality was visited at least three times to ensure that the required field data was entirely recorded. Sampling surveys using quadrats of 50 m × 50 m is recommended for arid habitats [27,28]; however, the quadrate size 10 m × 10 m was suitable for the current study, as the species number was constant in the latter quadrate size.

The quadrate was randomly distributed at each site to record the vegetation of the studied area. Species included in the quadrate's border were counted in the sampling. The plants with their vegetative branches spreading over the quadrate's sides were also considered, even though their roots were anchored outside the borders.

The study area lies within the eremic subtropical dry zone, characterized by hot summers and warm winters [29]. The Tabuk region had 33.5 mm of annual precipitation on average from 1978 to 2013, which is less than the 250 mm worldwide average for arid regions [30]. Data concerning monthly climatology of min-, mean- and max-temperature, and precipitation during the period of 1991–2020 at Tabuk, Saudi Arabia, were obtained from the Climate Change Knowledge Portal [31]. The average annual rainfall from 1991 to 2020 was 5.725 mm, and the minimum was detected in August and September (0.42 and 0.4 mm, respectively), while the maximum was in November (14.95 mm). The average monthly minimum temperature was 6.9 °C in January, whereas the average maximum was 37.81 °C in August (Figure 2).

Table 1. Coordinates of 25 sampling sites in Jabal Al-Ward.

Locations	Coordinates	
	Latitude (N)	Longitude (E)
1	26°26′52.7″	37°15′51.9″
2	26°26′53.7″	37°15′52.7″
3	26°26′54.5″	37°15′53.3″
4	26°26′54.9″	37°15′54.2″
5	26°26′55.1″	37°15′55.1″
6	26°26′55.5″	37°15′56.1″
7	26°26′56.4″	37°15′56.5″
8	26°26′57.3″	37°15′57.2″
9	26°26′57.2″	37°15′58.2″
10	26°26′56.9″	37°15′59.4″
11	26°26′56.4″	37°16′00.8″
12	26°26′56.0″	37°16′02.4″
13	26°26′55.6″	37°16′03.5″
14	26°26′55.7″	37°16′04.7″
15	26°26′56.4″	37°16′05.2″
16	26°26′57.3″	37°16′05.3″
17	26°26′58.2″	37°16′05.6″
18	26°26′58.9″	37°16′06.1″
19	26°26′58.6″	37°16′07.1″
20	26°26′57.9″	37°16′07.9″
21	26°26′57.4″	37°16′08.5″
22	26°26′56.6″	37°16′09.1″
23	26°26′56.0″	37°16′09.8″
24	26°26′55.5″	37°16′10.7″
25	26°26′55.2″	37°16′11.8″

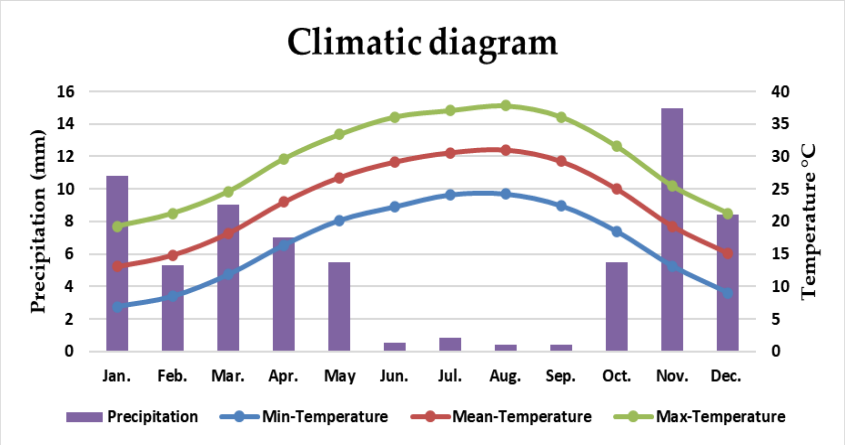

Figure 2. Climatic diagram showing min-, mean- and max-temperature, and precipitation during (1991–2020) in Tabuk, Saudi Arabia. The chart is based on the Climate Change Knowledge Portal data (CCKP 2021).

2.2. Plant Collection and Species Identification

Identification of the collected taxa followed Collenette [2], Cope [32], Mighaid [33], and Chaudhary [3–5]. Nomenclature was revised for accepted names through the Plants of the World Online (POWO) [34] and Taxonomic Name Resolution Service (TNRS) [35]. Voucher specimens were deposited in the herbarium of the Biology Department, College of Sciences, Taibah University Al-Ulā branch. Life form categories were recognized after Govaerts et al. [36], who updated Raunkiaer's [37] classification. Phytogeographical categories were distinguished based on Wickens [38], Zohary [39], and White and Léonard [40]. The generic coefficient (GC) was calculated according to Jaccard [41], which is the ratio of the total number of genera to the total number of species. The statistical analysis was performed using Microsoft Excel to create the charts and histograms.

3. Results

Floristic Composition

This study identified 198 vascular plant species in Jabal Al-Ward, and no gymnosperms were listed. The recorded taxa belonged to 152 genera in 47 plant families. The Dicotyledonous families accounted for 83%, while the Monocotyledonous represented 17% (Figure 3). The Monocotyledonous families are Asparagaceae, Asphodelaceae, Colchicaceae, Cyperaceae, Iridaceae, Liliaceae, and Poaceae. Perennial species constituted 53.54% (106 species); meanwhile, the annuals recorded 46.46% (92 species).

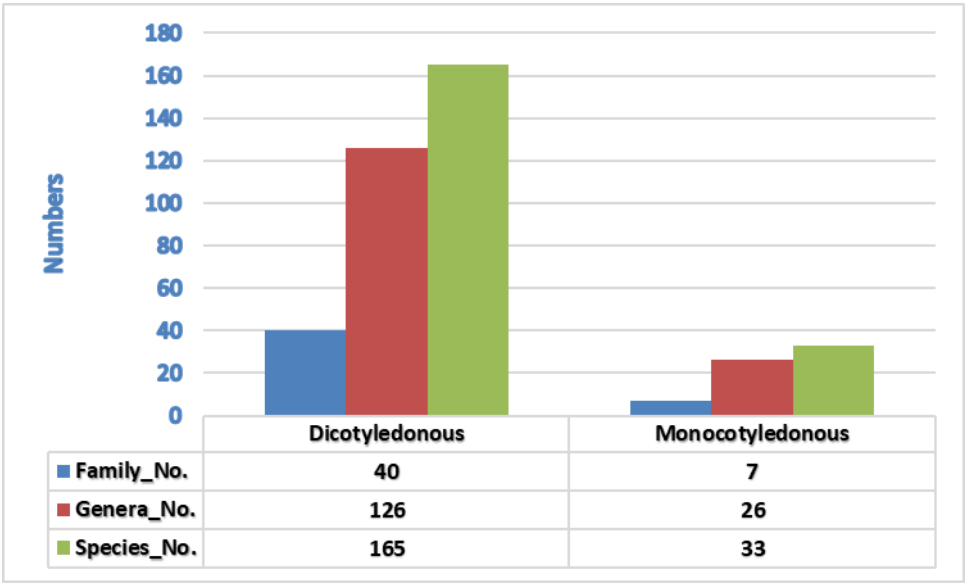

Figure 3. Histogram of the family, genera, and species number based on class Dicotyledonous and Monocotyledonous in Jabal Al-Ward.

The floristic analysis of the Jabal Al-Ward region revealed the presence of the following families: Asteraceae (29 species), Poaceae (25 species), Fabaceae (23 species), and Brassicaceae (14 species); they account for (14.57%, 12.56%, 11.55%, and 7.53%) of the total flora of the study area respectively. Amaranthaceae, Lamiaceae, Solanaceae, and Zygophyllaceae were represented by 9–7 species, accounting for 8% of the entire flora. Apocynaceae, Boraginaceae, and Euphorbiaceae were represented by 6–5 species. Caryophyllaceae, Geraniaceae, Plantaginaceae, and Resedaceae were represented by four species. Two to three species represented ten plant families, while twenty-two plant families were represented by at least one plant species (Table 2, Figure 4). The species richness in Jabal Al-Ward accounted for 8.9%, genera 18.6%, and families 36.43% of the total flora of Saudi Arabia. The generic coefficient (%) is 76.8% in the study area, while Saudi Arabia accounted for 36.7%. *Anthemis scrobicularis* Yavin was the only endemic species recognized in the study area.

Table 2. List of plant taxa recorded in Jabal Al-Ward. Life span: Annual (ANN), Perennial (PER). Life form: Chamaephytes (CH), Cryptophytes (CR), Helophytes (HEL), Hemicryptophytes (HEM), Parasites (PA), Phanerophytes (PH), Therophytes (TH). Chorotypes: American (AM), Cosmopolitan (COSM), Euro-Siberian (ES), Irano-Turanian (IT), Mediterranean (ME), Neotropical (NEO), Paleotropical (PAL), Pantropical (PAN), Saharo-Arabian (SA), Sudano-Zambesian (SZ), and Sudanian (SUD).

Plant Family	Taxa	Life Form	Chorology	Life Span
Acanthaceae	*Blepharis edulis* (Forssk.) Pers.	CH	IT + SA + SZ	PER
	Hygrophila auriculata (Schumach.) Heine	TH	PAN	ANN
Aizoaceae	*Aizoon canariense* L.	TH	SZ	ANN
Amaranthaceae	*Aerva javanica* (Burm.f.) Juss. ex Schult.	CH	PAL	PER
	Alternanthera pungens Kunth	TH	NEO	ANN
	Amaranthus hybridus L.	TH	PAN	ANN
	Bassia muricata (L.) Asch.	TH	IT + SA	ANN
	Bassia eriophora (Schrad.) Asch.	CH	IT + SA	PER
	Chenopodium murale L.	TH	COSM	ANN
	Halocnemum strobilaceum (Pall.) M.Bieb.	CH	IT + ME + SA	PER
	Haloxylon salicornicum (Moq.) Bunge ex Boiss.	CH	SA	PER
	Caroxylon imbricatum (Forssk.) Moq. Syn. *Salsola imbricata* Forssk.	PH	SZ	PER
Apiaceae	*Deverra tortuosa* (Desf.) DC.	CH	SA	PER
	Ferula sinaica Boiss.	HEM	IT	PER
Apocynaceae	*Calotropis procera* (Aiton) Dryand.	PH	SA + SZ	PER
	Apteranthes europaea (Guss.) Murb. Syn. *Caralluma europaea* (Guss.) N.E.Br.	CH	ME + SA	PER
	Leptadenia pyrotechnica (Forssk.) Decne.	PH	SA	PER
	Marsdenia tenacissima (Roxb.) Moon Syn. *Pergularia tomentosa* L.	CH	SA + SZ	PER
	Rhazya stricta Decne.	CH	SA + SZ	PER
	Solenostemma oleifolium (Nectoux) Bullock & E.A.Bruce ex Maire Syn. *Solenostemma argel* (Delile) Hayne	CH	SA	PER
Asparagaceae	*Bellevalia flexuosa* Boiss.	CR	ME	PER
Asphodelaceae	*Asphodelus tenuifolius* Cav.	CR	SA + SZ	PER
Asteraceae	*Achillea fragrantissima* (Forssk.) Sch.Bip.	CH	IT + SA	PER
	Achillea falcata L.	CH	IT	PER
	Anthemis scrobicularis Yavin	TH	IT + ME + SA	ANN
	Anthemis melampodina (Boiss.) Eig subsp. *deserti*	TH	ME + SA	ANN
	Artemisia herba-alba Asso	CH	SA	PER
	Artemisia judaica L.	CH	SA	PER
	Atractylis carduus (Forssk.) C. Chr.	TH	ME	ANN
	Calendula tripterocarpa Rupr.	TH	PAN	ANN
	Centaurea procurrens Sieber ex Spreng.	CH	ME	PER
	Centaurea sinaica DC.	TH	ES + IT	ANN
	Echinops glaberrimus DC.	HEM	SA	PER
	Echinops spinosissimus Turra	CH	IT + SA	PER

Table 2. *Cont.*

Plant Family	Taxa	Life Form	Chorology	Life Span
	Filago desertorum Pomel	TH	IT + SA	ANN
	Helichrysum stoechas (Ten.) Nyman subsp. *barrelieri*	HEM	ME	PER
	Ifloga spicata (Forssk.) Sch.Bip.	TH	SA	ANN
	Ifloga spicata (Forssk.) Sch. Bip. subsp. *albescens Chrtek*	TH	ME + SA	ANN
	Lactuca serriola L.	TH	IT	ANN
	Pseudognaphalium luteoalbum (L.) Hilliard & B.L.Burtt Syn. *Laphangium luteoalbum* (L.) Tzvelev	HEL	IT + ME + SA	PER
	Launaea procumbens (Roxb.) Ramayya & Rajagopal	TH	SA	ANN
	Launaea spinosa (Forsk.) Sch.Bip. ex Kuntze	CH	SA	PER
	Onopordum boissierianum Raab-Straube & Greuter Syn. *Onopordum sibthorpianum* Boiss. & Heldr.	HEM	ME + SA	PER
	Picris cyanocarpa Boiss.	TH	SA	ANN
	Pulicaria incisa (Lam.) DC.	CH	SA + SZ	PER
	Pulicaria undulata (L.) C.A.Mey.	CH	SA + SZ	PER
	Ramaliella tortuosissima (Boiss.) Zaika, Sukhor. & N.Kilian Syn. *Scorzonera tortuosissima* Boiss.	CH	IT + SA	PER
	Senecio glaucus L.	TH	IT + SA	ANN
	Sonchus oleraceus (L.) L.	TH	COSM	ANN
	Tanacetum sinaicum (Fresen.) Delile ex K.Bremer & Humphries	CH	IT	PER
	Urospermum picroides (L.) Scop. ex F.W.Schmidt	TH	IT + ME	ANN
Boraginaceae	*Alkanna orientalis* (L.) Boiss.	CH	IT + ME	PER
	Arnebia hispidissima (Lehm.) A.DC.	TH	SA + SZ	ANN
	Echium horridum Batt.	TH	ME + SA	ANN
	Gastrocotyle hispida (Forssk.) Bunge	TH	IT + SA	ANN
	Trichodesma africanum (L.) Sm.	TH	SA + SZ	ANN
Heliotropiaceae	*Heliotropium bacciferum* Forssk.	CH	SA + SUD	PER
	Heliotropium crispum Desf.	HEM	IT + SA	PER
	Heliotropium europaeum L.	TH	ES + IT + ME	ANN
Brassicaceae	*Coincya tournefortii* (Gouan) Alcaraz, T.E.Díaz, Rivas Mart. & Sánchez-Gómez Syn. *Brassica tournefortii* Gouan	TH	ME + SA	ANN
	Diplotaxis harra (Forssk.) Boiss.	TH	IT + SA	ANN
	Diplotaxis acris (Forssk.) Boiss.	TH	IT + ME	ANN
	Enarthrocarpus strangulatus Boiss.	TH	SA	ANN
	Eremobium aegyptiacum (Spreng.) Asch. ex Boiss.	HEM	SA	PER
	Eremobium aegyptiacum var. *lineare* (Delile) Zohary	HEM	SA	PER
	Farsetia aegyptia Turra	CH	SA + SZ	PER
	Lepidium didymum L.	TH	SA	ANN
	Matthiola arabica Boiss.	TH	SA	ANN
	Morettia canescens Boiss.	CH	ME	PER
	Morettia parviflora Boiss.	TH	SZ	ANN

Table 2. *Cont.*

Plant Family	Taxa	Life Form	Chorology	Life Span
	Rhamphospermum arvense (L.) Andrz. ex Besser Syn. *Sinapis arvensis* L.	TH	ME	ANN
	Sisymbrium irio L.	TH	ES + IT + ME + SA	ANN
	Zilla spinosa (L.) Prantl subsp. *spinosa*	CH	ES + IT + ME + SA	PER
Caryophyllaceae	*Gymnocarpos decandrus* Forssk.	CH	SA	PER
	Gypsophila viscosa Murray	TH	IT	ANN
	Polycarpaea robbairea (Kuntze) Greuter & Burdet	CH	SA + SZ	PER
	Silene villosa Forssk.	TH	SA	ANN
Cistaceae	*Helianthemum lippii* (L.) Dum.Cours.	CH	SA + SZ	PER
Cleomaceae	*Cleome amblyocarpa* Barratte & Murb.	TH	SA + SZ	ANN
	Cleome arabica L.	CH	SUD	PER
Colchicaceae	*Colchicum ritchii* R.Br.	CR	SA	PER
	Colchicum tunicatum Feinbrun	CR	IT	PER
Convolvulaceae	*Convolvulus arvensis* L.	CR	PAL	PER
Crassulaceae	*Umbilicus intermedius* Boiss.	CR	IT + ME	PER
Cucurbitaceae	*Citrullus colocynthis* (L.) Schrad.	HEM	IT + ME + SA + SZ	PER
	Cucumis prophetarum L.	HEM	SA	PER
Cyperaceae	*Cyperus rotundus* L.	CR	COSM	PER
Ephedraceae	*Ephedra aphylla* Forssk.	PH	SA	PER
Euphorbiaceae	*Chrozophora oblongifolia* (Delile) A.Juss. ex Spreng.	CH	SZ	PER
	Euphorbia granulata Forssk.	TH	SZ	ANN
	Euphorbia peplus L.	TH	COSM	ANN
	Euphorbia prostrata Aiton	TH	COSM	ANN
	Euphorbia retusa Forssk.	TH	COSM	ANN
Fabaceae	*Vachellia tortilis* (Forssk.) Galasso & Banfi Syn. *Acacia tortilis* (Forssk.) Hayne	PH	SZ	PER
	Alhagi graecorum Boiss.	CH	IT + ME	PER
	Astragalus eremophilus Boiss.	TH	IT + ME + SA	ANN
	Astragalus palaestinus Eig	TH	ME	ANN
	Astragalus spinosus (Forssk.) Muschl.	CH	IT + SA	PER
	Astragalus tribuloides Delile	TH	IT + SA	ANN
	Crotalaria aegyptiaca Benth.	HE	SZ	PER
	Hippocrepis cyclocarpa Murb.	TH	ME	ANN
	Hippocrepis unisiliquosa L.	TH	IT + SA	ANN
	Lotus corniculatus L.	HEM	COSM	PER
	Lotus glinoides Delile	TH	SZ	ANN
	Lotus lanuginosus Vent.	HEM	SA	PER
	Medicago laciniata (L.) Mill.	TH	SA	ANN
	Medicago polymorpha L.	TH	COSM	ANN
	Melilotus indicus(L.) All.	TH	PAL	ANN
	Onobrychis ptolemaica (Delile) DC.	HEM	IT	PER
	Ononis natrix L.	CH	ME	PER
	Retama raetam (Forssk.) Webb	PH	SA	PER
	Senna italica Mill.	CH	SZ	PER
	Tephrosia purpurea (L.) Pers.	CH	SA + SZ	PER
	Trigonella anguina Delile	TH	SA	ANN

Table 2. *Cont.*

Plant Family	Taxa	Life Form	Chorology	Life Span
	Trigonella glabra Thunb. subsp. *glabra* Syn. *Trigonella hamosa* Del. ex Smith	TH	ME + SA	ANN
	Trigonella stellata Forssk.	TH	IT + SA	ANN
Geraniaceae	*Erodium laciniatum* (Cav.) Willd.	TH	SA	ANN
	Erodium oxyrhinchum M.Bieb.	TH	SA + SZ	ANN
	Erodium oxyrhinchum (Boiss.) Schönb.-Tem.subsp. *bryoniifolium*	TH	IT	ANN
	Monsonia nivea (Decne.) Webb	CR	SA + SZ	PER
Iridaceae	*Moraea sisyrinchium* (L.) Ker Gawl.	CR	IT + ME	PER
Lamiaceae	*Pseudodictamnus undulatus* (Benth.) Salmaki & Siadati Syn. *Ballota undulata* (Sieber ex Fresen.) Benth.	CH	ME	PER
	Lavandula coronopifolia Poir.	CH	SA + SZ	PER
	Lavandula pubescens Decne.	CH	SA + SZ	PER
	Mentha longifolia (L.) Huds.	CH	PAL	PER
	Mentha longifolia (Briq.) Harley subsp. *typhoides*	HEM	PAL	PER
	Otostegia fruticosa (Forssk.) Schweinf. ex Penzig	CH	SA	PER
	Stachys aegyptiaca Pers.	CH	ME + SA	PER
	Teucrium polium L.	CH	IT + ME	PER
Liliaceae	*Gagea commutata* K. Koch	CR	IT	PER
	Gagea reticulata (Pall.) Schult. & Schult.f.	CR	IT	PER
Malvaceae	*Malva neglecta* Wallr.	TH	ES + IT	ANN
	Malva parviflora L.	TH	IT + ME	ANN
Molluginaceae	*Glinus lotoides* L.	TH	PAL	ANN
Moraceae	*Ficus palmata Forssk.*	PH	SUD	PER
Nitrariaceae	*Peganum harmala* L.	HEM	IT + ME + SA	PER
Nyctaginaceae	*Boerhavia repens* L.	CH	PAL	PER
Orobanchaceae	*Cistanche tubulosa* (Schenk) Wight	PA	IT + SA + SZ	PER
Papaveraceae	*Fumaria parviflora* Lam.	TH	COSM	ANN
Plantaginaceae	*Kickxia floribunda* (Boiss.) Täckh. & Boulos	CH	SA	PER
	Nanorrhinum hastatum (R.Br. ex Benth.) Ghebr.	CH	SA + SUD	PER
	Plantago ciliata Desf.	TH	IT + ME + SA	ANN
	Plantago lanceolata L.	TH	IT + ME + SA	ANN
Poaceae	*Avena barbata* Pott ex Link	TH	ME	ANN
	Bromus scoparius L.	TH	IT + ME + SA	ANN
	Bromus danthoniae Trin.	TH	IT	ANN
	Bromus madritensis L.	HEM	IT + ME	PER
	Cenchrus echinatus L.	TH	AM	ANN
	Centropodia fragilis (Guinet & Sauvage) Cope	TH	ME + SA	ANN
	Cutandia memphitica (Spreng.) Benth.	TH	IT + ME	ANN
	Cynodon dactylon (L.) Pers.	CR	PAN	PER
	Enneapogon desvauxii P.Beauv.	HEM	IT + SA	PER
	Eragrostis aegyptiaca (Willd.) Delile	TH	SZ	ANN
	Eremopyrum bonaepartis (Spreng.) Nevski	TH	IT	ANN
	Lamarckia aurea (L.) Moench	TH	IT + ME	ANN
	Lolium perenne L.	HEM	COSM	PER
	Panicum turgidum Forssk.	CR	SA + SZ	PER
	Parapholis incurva (L.) C.E.Hubb.	TH	IT + ME	ANN

Table 2. *Cont.*

Plant Family	Taxa	Life Form	Chorology	Life Span
	Phalaris minor Retz.	TH	IT + ME	ANN
	Phalaris paradoxa L.	TH	IT + ME	ANN
	Poa annua L.	TH	ES + IT + ME	ANN
	Polypogon monspeliensis (L.) Desf.	TH	IT + ME + SA	ANN
	Rostraria pumila (Desf.) Tzvelev	TH	ME + SA	ANN
	Schismus barbatus (L.) Thell.	TH	IT + SA	ANN
	Stipellula capensis (Thunb.) Röser &Hamasha Syn. *Stipa capensis* Thunb.	TH	IT + SA	ANN
	Stipa lagascae Roem. & Schult.	HEM	IT + ME	PER
	Stipa obtusa (Nees & Meyen) Hitchc.	HEM	SA + SZ	PER
	Stipagrostis ciliata (Desf.) De Winter	HEM	IT + SA + SZ	PER
Polygonaceae	*Rumex spinosus* L. Syn. *Emex spinosa* (L.) Campd.	TH	PAN	ANN
	Rumex vesicarius L.	TH	ME + SA + SZ	ANN
Portulacaceae	*Portulaca oleracea* L.	TH	ME + SA	ANN
Primulaceae	*Anagallis arvensis* L.	TH	ES + IT + ME	ANN
Rhamnaceae	*Ziziphus spina-christi* (L.) Desf.	PH	SA + SZ	PER
Resedaceae	*Caylusea hexagyna* (Forssk.) M.L.Green	TH	SA + SZ	ANN
	Ochradenus baccatus Delile	PH	SA	PER
	Reseda muricata C. Presl	CH	SA	PER
	Reseda sphenocleoides Deflers	CH	SA + SZ	PER
Rubiaceae	*Galium spurium* L.	TH	ES + IT + ME	ANN
Scrophulariaceae	*Verbascum sinaiticum* Benth.	HEM	IT + SA	PER
Solanaceae	*Datura innoxia* Mill.	TH	COSM	ANN
	Hyoscyamus desertorum (Asch. ex Boiss.) Täckh.	TH	SA	ANN
	Hyoscyamus pusillus L.	TH	IT	ANN
	Lycium depressum Stocks	PH	IT	PER
	Lycium shawii Roem. & Schult.	PH	SA + SZ	PER
	Solanum incanum L.	CH	SUD	PER
	Solanum americanum Mill.	HEM	ES + IT + ME	PER
	Withania somnifera (L.) Dunal	CH	IT + ME	PER
Tamaricaceae	*Tamarix aphylla* (L.) H.Karst.	PH	IT + SA + SZ	PER
Typhaceae	*Typha domingensis* Pers.	HEL	PAN	PER
Urticaceae	*Forsskaolea tenacissima* L.	CH	SA + SZ	PER
	Parietaria alsinifolia Delile	TH	SA	ANN
Zygophyllaceae	*Fagonia arabica* L.	CH	SA	PER
	Fagonia bruguieri DC.	CH	SA	PER
	Fagonia glutinosa Delile	CH	SA	PER
	Fagonia mollis Delile	CH	SA	PER
	Seetzenia lanata (Willd.) Bullock	TH	SUD	ANN
	Tetraena simplex (L.) Beier & Thulin	TH	SA + SZ	ANN
	Tribulus terrestris L.	TH	ES + IT + ME	ANN

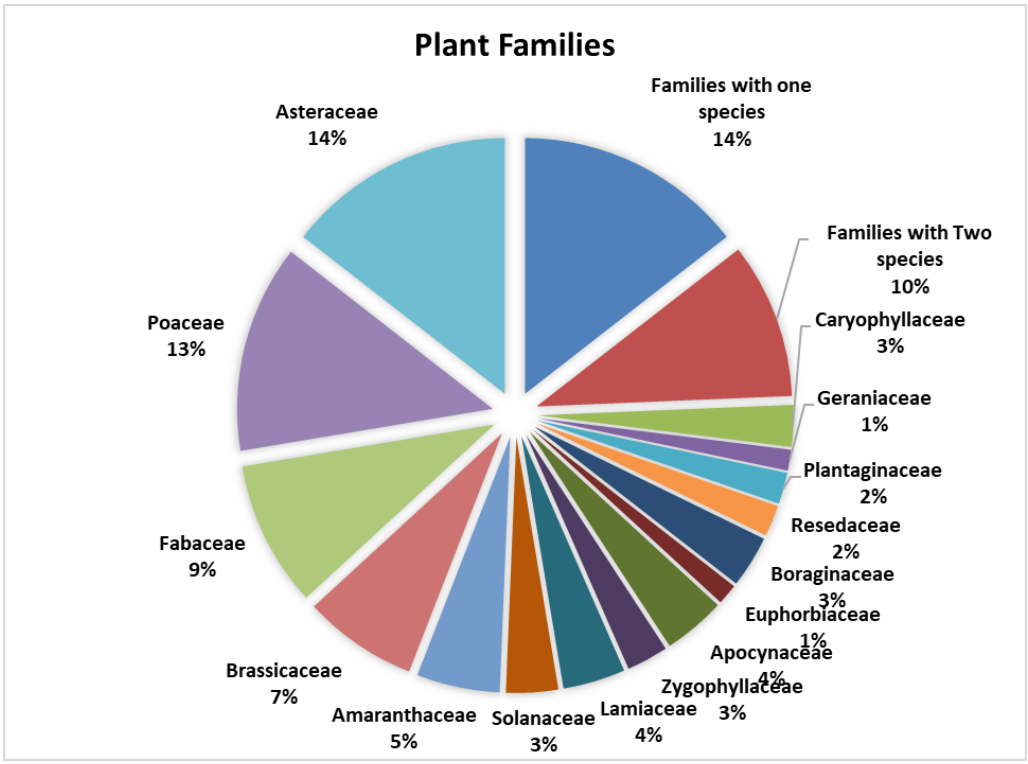

Figure 4. The proportional contribution of plant families in Jabal Al-Ward.

Seven life form categories were observed in the current study. The most frequent group was the therophytes, with 92 species, followed by chamaephytes, which were identified as 55 different species. There were 22 species of hemicryptophytes. Thirteen species were cryptophytes and twelve species were identified as phanerophytes. Three species were helophytes and one parasitic species was recorded in the Jabal Al-Ward area. Percentages of each life form relevant to the total number of species are illustrated in Figure 5.

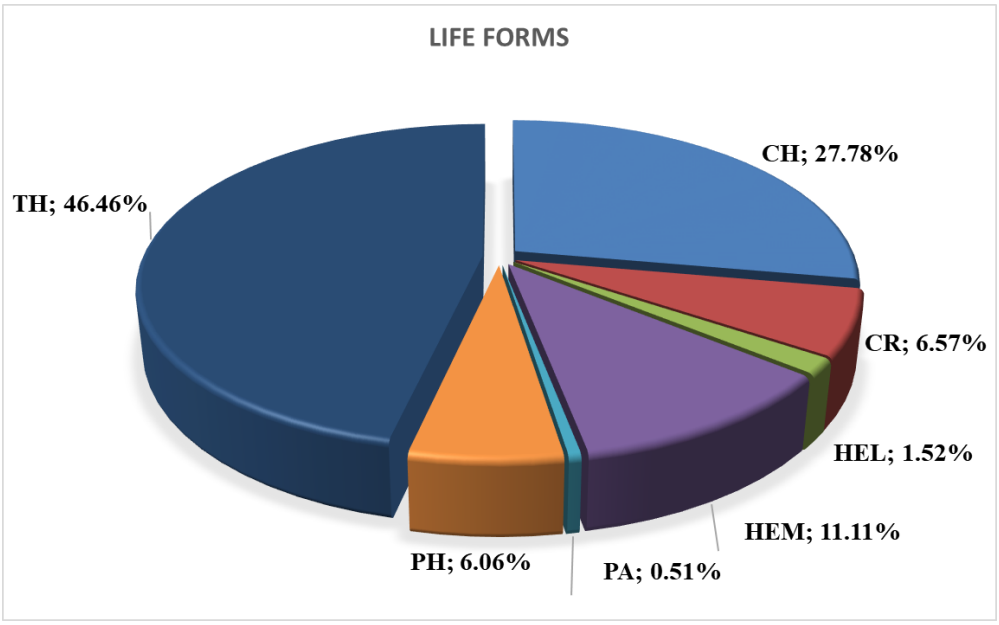

Figure 5. Life form spectrum of the recorded species in Jabal Al-Ward region. TH = Therophytes, CH = Chamaephytes, HEM = Hemicryptophytes, PH = Phanerophytes, GE = Geophytes, CR = Cryptophytes, HEL = Helophytes, PA = Parasites.

The chorological analysis of Jabal Al-Ward vegetation showed that the Mono-regional group was represented by the highest number of taxa 76 (38.5%). It comprised seven chorotypes; Saharo-Arabian (18.2%) with 36 species accounted for the highest representation. The Saharo-Arabian region was combined with eight more regions, including Saharo-Arabian/Sudano-Zambesian (12.6%), Irano-Turanian/Saharo-Arabian (9.1%), Mediterranean/Saharo-Sindian (5.6%), Irano-Turanian/Mediterranean/Saharo-Arabian (4.5%), Irano-Turanian/Saharo-Arabian/Sudano-Zambesian (2%), Euro-Siberian/Irano-Turanian/Mediterranean/Saharo-Arabian, and Saharo-Arabian/Sudanian (1% each), Mediterranean/Saharo-Arabian/Sudano-Zambesian, and Irano-Turanian/Mediterranean/Saharo-Arabian/Sudano-Zambesian (0.5% each).

Followed by Irano-Turanian (7.10%), the latter chorotype was recorded by 14 species (7.10%). Additionally, it was found in eight different arrangements with other floristic regions, such as: Irano-Turanian/Saharo-Arabian (9.1%), Irano-Turanian/Mediterranean (8.10%), Irano-Turanian/Mediterranean/Saharo-Arabian (4.5%), Euro-Siberian/Irano-Turanian/Mediterranean (3%), Irano-Turanian/Saharo-Arabian/Sudano-Zambesian (2%), Euro-Siberian/Irano-Turanian and Euro-Siberian/Irano-Turanian/Mediterranean/Saharo-Arabian (1% each), and Irano-Turanian/Mediterranean/Saharo-Arabian/Sudano-Zambesian (0.5%). Fifteen species were documented to belong to the Mediterranean region and achieved 5.60% as a Mono-regional element. Furthermore, seven mixed regions were indicated, such as Irano-Turanian/Mediterranean (8.1%), Mediterranean/Saharo-Arabian (5.6%), Irano-Turanian/Mediterranean/Saharo-Arabian (4.5%), Euro-Siberian/Irano-Turan ian/Mediterranean (3%), Euro-Siberian/Irano-Turanian/Mediterranean/Saharo-Arabian (1% each) and Mediterranean/Saharo-Arabian/Sudano-Zambesian and, Irano-Turanian/Mediterranean/Saharo-Arabian/Sudano-Zambesian (0.5% each). The Sudano-Zambesian chorotype has ten species representing 5.1% and it is found with four other mixed regions Finally, *Cenchrus echinatus* L. is an alien species representing the American type with 0.5%.

Afterward, the Bi-regional elements have six main chorotypes with 74 taxa (37.40%). The highest element was Saharo-Arabian/Sudano-Zambesian with 25 species representing 12.6%, followed by Irano-Turanian/Saharo-Arabian with 18 species (9.1%), Irano-Turanian/Mediterranean with 16 species (8.10%), then Mediterranean/Saharo-Arabian with 11 species (5.6%). Conversely, only 1% of the total number of species belonged to the Euro-Siberian/Irano-Turanian (*Centaurea sinaica* DC. and *Malva neglecta* Wallr.) and Saharo-Arabian/Sudanian (*Heliotropium bacciferum* Forssk. and *Nanorrhinum hastatum* (R.Br. ex Benth.) Ghebr.).

Subsequently, the Worldwide assemblage contained 25 species and occupied 12.60% of the recorded taxa. The Cosmopolitan types scored 5.60% for 11 species. The lowest scores were recorded for Paleotropical, Pantropical, and Neotropical at 3.50%, 3.0%, and 0.50%, respectively.

Finally, the Pluri-regional attained six chorotypes, accounting for 11.50% with 23 species. The Irano-Turanian/Mediterranean/Saharo-Arabian, Euro-Siberian/Irano-Turanian/Mediterranean, Euro-Siberian/Irano-Turanian/Mediterranean, and Irano-Turanian/Saharo-Arabian/Sudano-Zambesian exhibited 3.5%, 3%, and 2%, respectively. While one species was categorized for each of the following chorotypes: Mediterranean/Saharo-Arabian/Sudano-Zambesian (*Rumex vesicarius* L.) and Irano-Turanian/Mediterranean/Saharo-Arabian/Sudano-Zambesian (*Citrullus colocynthis* (L.) Schrad.) (Figure 6, Table 3).

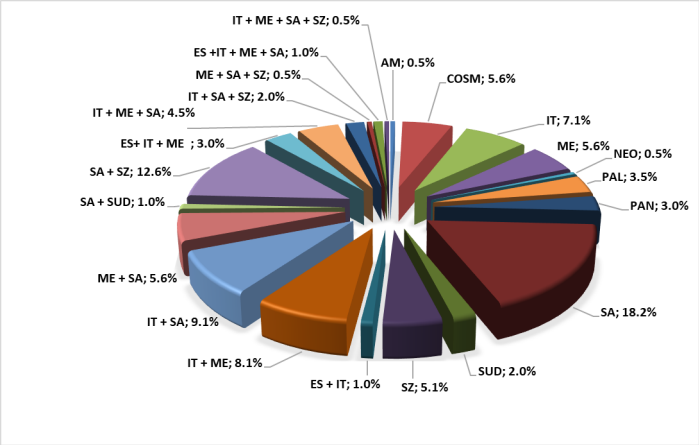

Figure 6. Floristic regions and chorotypes from the recorded taxa in Jabal Al-Ward. Note: American (AM), Cosmopolitan (COSM), Euro-Siberian (ES), Irano-Turanian (IT), Mediterranean (ME), Neotropical (NEO), Paleotropical (PAL), Pantropical (PAN), Saharo-Arabian (SA), Sudano-Zambesian (SZ), and Sudanian (SUD).

Table 3. The number of the recorded taxa belonging to the main floristic categories and their relevant percentages (%) in Jabal Al-Ward. American (AM), Cosmopolitan (COSM), Euro-Siberian (ES), Irano-Turanian (IT), Mediterranean (ME), Neotropical (NEO), Paleotropical (PAL), Pantropical (PAN), Saharo-Arabian (SA), Sudano-Zambesian (SZ), and Sudanian (SUD).

Chorotype	Number of Species	Percentage (%)
Mono-Regional		
AM	1	0.50%
IT	14	7.10%
ME	11	5.60%
SA	36	18.20%
SUD	4	2.00%
SZ	10	5.10%
Subtotal	76	38.50%
Bi-regional		
ES + IT	2	1.00%
IT + ME	16	8.10%
IT + SA	18	9.10%
ME + SA	11	5.60%
SA + SZ	25	12.60%
SA + SUD	2	1.00%
Subtotal	74	37.40%
Pluri-regional		
ES + IT + ME	6	3.00%
IT + ME + SA	9	4.50%
IT + SA + SZ	4	2.00%
ME + SA + SZ	1	0.50%
ES + IT + ME + SA	2	1.00%
IT + ME + SA + SZ	1	0.50%
Subtotal	23	11.50%
Worldwide		
COSM	11	5.60%
NEO	1	0.50%
PAL	7	3.50%
PAN	6	3.00%
Subtotal	25	12.60%
Total	198	100%

4. Discussion

Tabuk province is characterized by diverse habitats, including coastal plains, valleys, dunes, wadis, salt pans (sabkhas), and mountain ridges [42]. These habitats represent biogeographic units that guarantee a perfect distribution of this region's flora and fauna life regime [10]. Mountains are of great floristic and ecological importance in the Middle East. They provide a shelter for many species, which qualifies them as centers of species richness [43].

The Tabuk region has a high diversity of plants [9,20]. However, the present study demonstrates that the highest number of species (198 species representing 47 families) were recorded in one region, compared with the former studies performed in discrete areas of Tabuk [9,11–17].

The most dominant families are the Asteraceae, Poaceae, and Fabaceae. They represented more than a third of Jabal Al-Ward's floristic composition. The dominance of these families over the others is attributed to their ability to seed dispersal efficiency of their taxa, leading to a high diversity and wide distribution [44]. Al-Mutairi [13] mentioned that the Asteraceae is dominant in a different area of the Tabuk region. Additionally, our findings concur with several floristic studies conducted at different Saudi Arabian localities [45–47]. However, fourteen percent of the total number of families were represented by only one species: Aizoaceae, Asparagaceae, Asphodelaceae, Cistaceae, Convolvulaceae, Crassulaceae, Cyperaceae, Ephedraceae, Iridaceae, Molluginaceae, Moraceae, Nitrariaceae, Nyctaginaceae, Orobanchaceae, Papaveraceae, Portulacaceae, Primulaceae, Rhamnaceae, Rubiaceae, Scrophulariaceae, Tamaricaceae, and Typhaceae. The three genera with the highest species richness are *Astragalus* (Fabaceae), *Euphorbia* (Euphorbiaceae), and *Fagonia* (Zygophyllaceae); four species have been reported for each genus. The generic coefficient is 76.8% in Jabal Al-Ward, which is more than twice that of Saudi Arabia. Based on the high percentage of generic coefficient, it can be concluded that there are more intergeneric competitions in the area [48]. Furthermore, Al-Nafie [49] mentioned that the existence of a certain number of species corresponding to different taxa is a salient characteristic of this region, showing high plant diversity. Members of the recognized families are also well known for their higher economic and medicinal potentiality [50–58]. *Anthemis scrobicularis* was the only endemic species recorded in the surveyed area [59]. Many studies also reported limited endemism in the various regions of the country [15,49,60–62].

In the current study, the perennial species were dominant over the annuals (53.54% to 46.46%). The perennial/annual ratio is affected by abiotic factors such as the aridity of the area and the amount of precipitation [62,63]. This is a notable characteristic of Jabal Al-Ward because perennial plants may be more tolerant of climatic changeability than annual plants [64]. The predominant life forms among the others are the therophytes (46.46%), followed by chamaephytes (27.78%) and phanerophytes (6.06%). These findings are in line with some research on desert ecosystems [13–15,44–47,60,65–67]. Thakur [48], Das, et al. [68] and Fadl et al. [60] reported that the dominance of the therophytic pattern and phanerophytes are associated with lower altitudes, warm-dry arid climate, and habitat disturbances. On the other hand, at higher altitudes, hemicryptophytes and cryptophytes overwhelm cold conditions. The relatively high occurrence of chamaephytes (27.78%) is also associated with the desert habitat, topography, and biotic factors [69]. However, floristic research documented the predominance of other life forms over therophytes in Jabal Fayfa, Mecca, and Taif [61,62,70]. Lower frequency was observed for the helophytes (1.52%) in the current study, as they are indicators of the wetlands [71,72]. *Cistanche tubulosa* (Schenk) Wight was the only parasitic species documented in Jabal Al-Ward, where it grows mainly on the root of the *Calotropis procera* (Aiton) Dryand. Tree, which is commonly distributed in some arid areas [73].

The identified species were classified into four major phytogeographical groups: Mono-regional, Bi-regional, Pluri-regional, and Worldwide. It was remarkable that the Mono-regional and Bi-regional groups achieved the highest representation at 38.5% and 37.4%, respectively. The presence of interzonal habitats contributes to the higher prevalence

of Bi-regional elements [39]. The abundance of Pluri-regional and global taxa is another feature of the Saudi Arabian flora [49]. The existence of species growing in many regions of the world, or the widely distributed plants indicates the relationship between the Arabian Peninsula and these regions (Euro-Siberian, Irano-Turanian, Mediterranean, Sudanian, and Sudano-Zambesian). The dispersal of these species in the Arabian Peninsula is influenced by climate change and the long-distance migration of people, animals, and birds [70].

Saudi Arabia's vegetation belongs to Saharo-Arabian region [39]. Thirty-six species belonged to the Saharo-Arabian region, with the best representation accounting for 18.2%. According to Zohary [74], Saharo-Sindian is corresponding to Saharo-Arabian. Abdel Khalik et al. [62] point out that the Saharo-Arabian and Sudano-Zambezian species are good indicators of desert habitats. This explains the present study's relatively high contribution of Saharo-Arabian/Sudano-Zambesian. The Saharo-Arabian taxa in Saudi Arabia were developed gradually and discontinuously from some adjoining regions under the aridity's effect, such as the Sudanian, Mediterranean, and Irano-Turanian regions [39]. Therefore, our findings are consistent with most studies carried out in the various Saudi Arabian provinces, especially Tabuk [12–14,45,65].

The Irano-Turanian chorotype was recorded by fourteen species (7.10%) and it was found in eight different arrangements with other floristic regions. The Irano-Turanian region is one of the world's largest and most diverse floristic regions and serves as a source forthe halophytes (such as *Halocnemum strobilaceum* (Pall.) M.Bieb., *Haloxylon salicornicum* (Moq.) Bunge ex Boiss., *Caroxylon imbricatum* (Forssk.) Moq., *Heliotropium bacciferum* Forssk., *H. crispum* Desf., *H. europaeum* L., *Tamarix aphylla* (L.) H.Karst.), and xerophytes (representing the rest of the studied taxa) for adjacent countries [75,76]. The region is also characterized by relatively low precipitation and a long dry season. The maximum temperature was measured in the summer, similar to the hottest spots in the Sahara, while the minimum winter temperatures were lower than those recorded in the Mediterranean region [77]. These characters make this region a transition between the Saharo-Arabian and the Mediterranean.

Fifteen species were documented to belong to the Mediterranean region and achieved 5.60% as a Mono-regional element. According to Abdel Khalik et al. [62], the survival of Mediterranean species in the study area indicates a more mesic environment.

Recent studies conducted in the Arabian Peninsula have relied on DNA barcode markers to assess genetic variation among taxa in various geographical regions [78,79]. Projects are ongoing worldwide to create DNA barcode libraries for vascular plant flora and make these data accessible to conserve and utilize biodiversity [80]. DNA barcodes are used to enhance our understanding of how species evolve and interact and how we can delay their extinction [81,82].

5. Conclusions

The current study demonstrated the highest species richness compared to former studies performed in separate locations in Tabuk Province. One hundred ninety-eight plant species belonging to forty-seven plant families were identified in Jabal Al-Ward. The Asteraceae, Poaceae, and Fabaceae represented more than a third of Jabal Al-Ward's floristic composition. Annual species (46.46% of the total) were subordinate to perennial species (53.54%). Perennial species may be more tolerant of climatic changeability than annuals. This is a prominent feature in Jabal Al-Ward. Therophytes (46.46%) exemplify the most predominant life forms over the others, as they are associated with lower altitudes, warm-dry arid climate, and habitat disturbances. The recorded plant species were classified into four phytogeographical categories, with the highest representations being for the Mono-regional and Bi-regional groups. The phytogeographical distribution of the species revealed that thirty-six species (18.2%) belonged to the Saharo-Arabian region. The Saharo-Arabian and Sudano-Zambezian species are reliable indicators of desert habitats, which explained the highest contribution of Saharo-Arabian Sudano-Zambesian in the present study. In

Saudi Arabia, the Saharo-Arabian taxa were developed gradually and discontinuously from some adjoining regions such as the Sudanian, Mediterranean, and Irano-Turanian regions.

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