Saudi Journal of Biological Sciences 27 (2020) 35–40

Contents lists available at ScienceDirect

Saudi Journal of Biological Sciences

journal homepage: www.sciencedirect.com

Original article

Ecological significance of floristic composition and life forms of Riyadh region, Central Saudi Arabia

Najla A. Al Shaye [a], Yahya S. Masrahi [b], Jacob Thomas [c]

[a] Department of Biology, Faculty of Science, Princess Nourah bint Abdulrahman University, Riyadh, Saudi Arabia
[b] Department of Biology, Faculty of Science, Jazan University, Jazan, Saudi Arabia
[c] Department of Botany and Microbiology, Faculty of Science, King Saud University, Riyadh, Saudi Arabia

ARTICLE INFO

Article history:
Received 13 February 2019
Revised 5 April 2019
Accepted 9 April 2019
Available online 17 April 2019

Keywords:
Riyadh region
Floristic composition
Life forms
Adaptation
Phytoclimate
Saudi Arabia

ABSTRACT

Riyadh region is one of the hardest habitats in Saudi Arabia with a hyper-arid climate. This study was conducted to investigate floristic composition and plant life forms of Riyadh region and their ecological significance. Work aimed to determine the prevailing plant families and biological spectrum of their components that reflects the phytoclimate and adaptation to hyper-arid conditions of the region. Work involved field surveys of different locations in Riyadh region where plant specimens were collected and identified. Collected plant species were then listed according to their families and data were used to assess the contribution of different plant families to the flora of the region. Study of life forms was conducted to classify recorded floristic elements into categories that reflect environmental conditions prevailing in the region. Prevailing plant families were Asteraceae (17.4%), Poaceae (11%), Brassicaceae (9.9%), and Fabaceae (7%). These percentages reflect wide ecological ranges especially for Asteraceae and Poaceae. High presence of species belonging to Astreaceae and Poaceae can be attributed to their adaptation to harsh conditions as well as to effective wind dispersal strategies of their diaspores. While the most frequent life form classes were therophytes with 52%, and chamaephytes with 30%, phanerophytes and hemicryptophytes represented 9% and 8%, respectively. Predominance of therophytes and chamaephytes over other life forms is a response to hyper arid climate with insufficient rainfall and the nature of region of few available microhabitats that can support high percentage of perennials.

1. Introduction

Saudi Arabia is a country with vast area occupying about 80% of the area of Arabian Peninsula. However, most of this area is barren deserts except southwestern highlands with ample rainfall and mild climate that supports plant life (Masrahi, 2012).

Riyadh region represents the central part of Saudi Arabia (Central Region) occupying the eastern part of Najd Plateau (as a part of platform, Fig. 1), covering an area of about 38,0000 km^2. It is located between latitudes 19° 29′ and 27° 28′N and longitudes 41° 48′ and 48° 14′E (Fig. 1). Geomorphological features of Riyadh region include rocky formations of Tuwaiq Mountains with altitudes of 1062 m, scattered areas of sand dunes between escarpments of the plateau and in northern and southern parts of the region (Edgell, 2006). Most of the rocky formations are sedimentary belonging largely to limestone and sandstone (Al-Refeai and Al-Ghamdy, 1994). Climate is characterized by high summer temperatures of 33–37 °C, moderate winter temperatures of 14–17 °C, and humidity of 17% and 47% for summer and winter, respectively. Total annual precipitation is 90–137 mm (Sagga, 1998) falling basically in winter (December–February). Rainfall in the region is generally considered a rare event (Kumar et al., 2015). Of these characters of climate, Riyadh region represent a hyper arid area (Kumar et al.,2015).

Vegetation is the major component determining nature of ecosystems (Orshan, 1986). Low vegetation cover represents one of the main indications of climatically arid lands (Brovkin, 2002). The form and structure of vegetation units can be recognized by classifying the floristic elements implicated in groups reflecting environmental conditions (Saxena et al., 1982). Since plant life form is the growth form that represents adaptation to specific

Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

https://doi.org/10.1016/j.sjbs.2019.04.009
1319-562X/

Fig. 1. Map of Saudi Arabia with geomorphological characters. Riyadh is located in the platform, surrounded by areas of sand dune. Area indicated by dots represents area of field survey.

ecological conditions (Mera et al., 1999), this trait reflects the climatic adaptability and then the whole vegetation in particular area would be an expression of the prevailing climate (Batalha and Martins, 2002). The most widely used classification system for life forms is that proposed by Raunkiaer (1934). This classification divided the plant life forms depending on situation and degree of protection of the buds or other renewing organs (seeds, tubers, rhizomes) in relation to protection from unfavorable seasons. According to this classification plant life forms can be classified into five main groups, namely; phanerophytes, chamaephytes, hemicryptophytes, cryptophytes (geophytes), and therophytes. The percentage of each life form put together in the flora of specific vegetation is called biological spectrum (Raunkiaer, 1934) and constructs a "normal spectrum" which represent a null type versus which life form spectra could be compared. Normal spectrum regards the distribution of all plant life forms together in the global scale. Raunkiaer (1934) stated that the essential patterns of climates are characterized by the fact that one or few life-forms are, relatively or absolutely, dominant. Any deviation in biological spectrum of particular area from the normal spectrum determines the phytoclimate of the area. Therefore, the main aim of the present work is to investigate the floristic composition and plant life forms of Riyadh region to determine the prevailing plant families and biological spectrum which reflect together the phytoclimate and adaptation to hyper arid conditions of the region.

2. Materials and methods

Three field surveys were carried out in the Riyadh region during the period of 2017–2018 to collect plant specimens for floristic composition studies. Voucher specimens of each species are kept at the Princess Noura University Herbarium (PNUH). Other specimens of old collections from the region that are kept in PNUH were compiled and taken into account. The plant specimens were identified according to relevant flora literature (Collenette, 1999; Chaudhary,1999–2001). Life form categories were identified according to Raunkiaer classification (Raunkiaer, 1934).

3. Results

A total of 172 plant species belonging to 130 genera and 37 families were reported in the present study (Table 1). Among reported families the species recorded included 30 species from Asteraceae and 19 species from Poaceae representing 17.4% and 11% of total number of recorded species, respectively. In addition, 17 species from Brassicaceae and 12 species from Fabaceae were also recorded, representing 9.9% and 7% of total number of recorded species, respectively. Each of the other 33 families reported were represented by less than 9 species constituting less than 6% of total number of recorded species (Table. 1, Fig. 2).

The most frequent life form classes observed were therophytes and chamaephytes with 52% and 30%, respectively. Phanerophytes and hemicryptophytes were represented by 9% and 8%, respectively. The least frequent life form was geophytes with only 1% (Fig. 3). Frequency of presence of different life forms compared using Raunkiaer's normal spectrum indicated that the study site showed high proportions of therophytes, followed by chamaephytes, while phanerophytes, hemicryptophytes, and geophytes were less than Raunkiaer's normal spectrum (Fig. 3).

4. Discussion

Despite its vast area, Riyadh region has low floristic richness compared to other regions of Saudi Arabia (Chaudhary and Al-Jowaid, 1999). Asteraceae, Poaceae, Brassicaceae and Fabaceae represent the largest families. Asteraceae and Poaceae not only represent the largest families in Riyadh region and the whole Arabian Peninsula, but they are also among the largest and most widespread families of flowering plants in the world (Jeffrey, 1978; Clayton, 1978). These two families are particularly well repre-

Table 1
List of families, species and life forms.

Family	Species	Life Form Th	Ch	Ph	H	G
Acanthaceae	*Blepharis edulis* (Forssk.) Pers.	+	–	–	–	–
Aizoaceae	*Aizoon canariense* L.	+	–	–	–	–
Amaranthaceae	*Aerva javanica* (Burm.F.) Juss	–	+	–	–	–
	Alternanthera sessilis (L.) R.Br. ex DC.	+	–	–	–	–
	Amaranthus lividus L.	+	–	–	–	–
	A. viridis L.	+	–	–	–	–
Apocynaceae	*Rhazya stricta* Decne.	–	+	–	–	–
	Calotropis procera L	–	–	+	–	–
	Pergularia tomentosa L.	–	+	–	–	–
	Glossonema varians (Stocks) Benth. ex Hook.f.	–	+	–	–	–
Boraginaceae	*Arnebia decumbens* (Vent.) Coss. & Kralik	+	–	–	–	–
	A. hispidissima (Lehm.) A.DC.	+	–	–	–	–
	A. linearifolia A.DC.	+	–	–	–	–
	Echium rauwolfii Delile	+	–	–	–	–
	Heliotropium bacciferum Forssk.	–	+	–	–	–
	H. luteum Poir.	–	+	–	–	–
	Trichodesma africanum (L.) Sm.	+	–	–	–	–
Capparaceae	*Capparis sinaica* Veill.	–	–	+	–	–
	C. decidua (Forssk.) Edgew.	–	–	+	–	–
	Cleome amblyocarpa Barratte & Murb.	+	–	–	–	–
	C. arabica L.	–	+	–	–	–
Caryophyllaceae	*Paronychia arabica* (L.) DC.	+	–	–	–	–
	Pteranthus dichotomus Forssk.	+	–	–	–	–
	Gymnocarpos sclerocephalus (Decne.) Dahlgren & Thulin	+	–	–	–	–
Chenopodiaceae	*Anabasis setifera* Moq.	–	+	–	–	–
	Atriplex leucoclada Boiss.	–	+	–	–	–
	Bassia eriophora (Schrad.) Asch.	+	–	–	–	–
	B. muricata (L.) Asch.	+	–	–	–	–
	Chenopodium murale L.	+	–	–	–	–
	Cornulaca aucheri Moq.	+	–	–	–	–
	Haloxylon salicornicum (Moq.) Bunge ex Boiss.	–	+	–	–	–
	Salsola imbricata Forssk.	–	+	–	–	–
Cistaceae	*Helianthemum lippii* (L.) Dum.Cours.	–	+	–	–	–
Asteraceae	*Anthemis melampodina* subsp. *deserti* (Boiss.) Eig	+	–	–	–	–
	A. melampodina Delile	+	–	–	–	–
	Anvillea garcinii (Burm.f.) DC.	–	+	–	–	–
	Artemisia monosperma Delile	–	+	–	–	–
	Atractylis mernephthae "Asch., Sch. & Leto.	+	–	–	–	–
	Calendula arvensis M.Bieb.	+	–	–	–	–
	Carthamus oxyacantha M.Bieb.	+	–	–	–	–
	Chrysanthemum coronarium L.	+	–	–	–	–
	Centaurea pseudosinaica Czerep.	+	–	–	–	–
	Conyza bonariensis (L.) Cronq.	+	–	–	–	–
	Echinops spinosissimus Turra	–	+	–	–	–
	Ifloga spicata (Forssk.) Sch.Bip.	+	–	–	–	–
	Koelpinia linearis Pall.	+	–	–	–	–
	Lactuca serriola L.	+	–	–	–	–
	Launaea angustifolia (Desf.) Kuntze	+	–	–	–	–
	L. capitata (Spreng.) Dandy	+	–	–	–	–
	L. mucronata (Forssk.) Muschl.	+	–	–	–	–
	L. nudicaulis (L.) Hook.f.	–	+	–	–	–
	Leontodon laciniatus (Bertol.) Widder	+	–	–	–	–
	Picris babylonica Hand.-Mazz.	+	–	–	–	–
	Pulicaria crispa Sch.Bip.	–	+	–	–	–
	P. glutinosa (Boiss.) Jaub. & Spach	–	+	–	–	–
	Rhanterium epapposum Oliv.	–	+	–	–	–
	Scorzonera acanthoclada Franch.	+	–	–	–	–
	Senecio flavus (Decne.)Sch.Bip.	+	–	–	–	–
	S. glaucus L.	+	–	–	–	–
	Sonchus oleraceus (L.).	+	–	–	–	–
	S. tenerrimus L.	+	–	–	–	–
	Tripleurospermum auriculatum (Boiss.) Rech.f.	+	–	–	–	–
	Verbesina encelioides (Cav.) Benth. & Hook.f. ex A.Gray	+	–	–	–	–
Convolvulaceae	*Convolvuls arvensis* L	–	+	–	–	–
	C. austroaegyptiacus Abd. & Saad	–	+	–	–	–
	C. glomeratus Choisy	–	+	–	–	–
	C. oxyphyllus ssp. oxycladus	–	+	–	–	–
	C. pilosellifolius	–	+	–	–	–
	Cressa cretica L.	+	–	–	–	–
Brassicaceae	*Anastatica hierochuntica* L	+	–	–	–	–
	Cakile arabica Velen.	+	–	–	–	–
	Diplotaxis acris (Forssk.) Boiss.	–	+	–	–	–
	D. harra (Forssk.) Boiss.	+	–	–	–	–

(continued on next page)

Table 1 (*continued*)

Family	Species	Life Form				
		Th	Ch	Ph	H	G
	Eremobium aegyptiacum ssp. *lineare*	+	–	–	–	–
	Eruca vesicaria (L.) Cav.	–	+	–	–	–
	Farsetia aegyptia Turra	–	+	–	–	–
	F. burtonae Oliv.	–	+	–	–	–
	F. stylosa R.Br.	+	–	–	–	–
	Horwoodia dicksoniae Turrill	+	–	–	–	–
	Lepidium aucheri Boiss	+	–	–	–	–
	L. sativum L.	–	+	–	–	–
	Moricandia sinaica (Boiss.) Boiss.	+	–	–	–	–
	Savignya parviflora (Delile) Webb	+	–	–	–	–
	Schimpera arabica Hochst. & Steud.	+	–	–	–	–
	Sisymbrium irio L.	–	+	–	–	–
	Zilla spinosa (L.) Prantl	–	+	–	–	–
Cucurbitaceae	*Citrullus colocynthis* (L.) Schrad	–	–	–	+	–
Cyperaceae	*Cyperus alternifolius* L.	–	–	–	+	–
	C. conglomeratus Rottb.	+	–	–	–	–
Dipsacaceae	*Lomelosia olivieri* (Coult.) Greuter & Burdet	–	+	–	–	–
Euphorbiaceae	*Chrozophora oblongifolia* (Del.) A. Juss. exSpreng.	+	–	–	–	–
	C. tinctoria (L.) A.Juss.	–	+	–	–	–
	Euphorbia exigua L.	–	+	–	–	–
	Ricinus communis L.	–	–	+	–	–
Fabaceae	*Acacia gerrardii* Benth.	–	–	+	–	–
	A. ehrenbergiana Hayne	–	–	+	–	–
	A. tortilis (Forssk.) Hayne	–	+	–	–	–
	Astragalus sieberi DC.	–	+	–	–	–
	Astragalus spinosus(Forssk.)Muschl.	+	–	–	–	–
	Melilotus indica (L.) All.	–	+	–	–	–
	Onobrychis ptolemaica DC.	–	–	+	–	–
	Prosopis farcta (Banks & Sol.) J.F.Macbr.	–	–	+	–	–
	Prosopis juliflora (Sw.)DC.	+	–	–	–	–
	Trigonella hamosa Del.Ex.Smith	+	–	–	–	–
	Senna occidentalis (L.) Link	–	+	–	–	–
	S. italica Mill.	–	–	–	+	–
Geraniaceae	*Erodium glaucophyllum* (L.)Her.	+	–	–	–	–
	E. laciniatum(Cav.)Willd.	+	–	–	–	–
	Monsonia nivea(Decne.)Webb	–	–	–	+	–
Poaceae	*Cenchrus ciliaris* L.	–	–	–	+	–
	Cynodon dactylon L.	+	–	–	–	–
	Echinochloa colona (L.) Link.	+	–	–	–	–
	Elusine indica (L.) Gaertn.	+	–	–	–	–
	Eragrositis barrelieri Day.	–	–	–	+	–
	Lasiurus scindicus Henrard	+	–	–	–	–
	Lolium rigidum Gaudin	–	–	–	+	–
	Panicum coloratum L.	–	–	–	+	–
	P. turgidum Forssk.	–	–	–	+	–
	Pennisetum setaceum (Forssk.) Chiov.	+	–	–	–	–
	Phalaris minor Retz	–	–	–	+	–
	Phragmites australis (Cav.)Trin. ex Steud.	+	–	–	–	–
	Polypogon monspeliensis (L.) Desf.	+	–	–	–	–
	Schismus arabicus Nees	+	–	–	–	–
	Setaria verticillata (L.) P. Beauv.	–	–	–	+	–
	Sorghum halepense (L.) P. Beauv.	+	–	–	–	–
	Stipa capensis Thunb	–	–	–	+	–
	Stipagrostis plumose Munro ex.T.Anderson	+	–	–	–	–
	Rostraria pumila (Desf.) Tzvelev	–	+	–	–	–
Lamiaceae	*Lavandula pubescens* Decne.	–	+	–	–	–
	Salvia aegyptiaca L.	–	+	–	–	–
	S. spinosa L.	–	+	–	–	–
	Teucrium oliverianum Ging ex.Benth.	–	–	–	–	+
Iridaceae	*Moraea sisyrinchium* (L.) Ker Gawl.	+	–	–	–	–
Malvaceae	*Alcea acaulis* (Cav.) Alef.	+	–	–	–	–
	Malva parviflora L.	+	–	–	–	–
Neuradaceae	*Neurada procumbens* L.	+	–	–	–	–
Plantaginaceae	*Plantago amplexicaulis* Cav.	+	–	–	–	–
	P. boissieri Hausskn. & Bornm.	+	–	–	–	–
	P. ciliate Desf.	–	–	–	+	–
	P. lanceolata L.	+	–	–	–	–
	P. ovate Forssk.	–	–	+	–	–
Polygonaceae	*Calligonum comosum* L Her	+	–	–	–	–
	Polygonum argyrocoleum Kom	+	–	–	–	–
	Rumex vesicarius L.	–	–	–	+	–
	R. conglomeratus Murray	+	–	–	–	–
Portulacaceae	*Portulaca oleracea* L.	+	–	–	–	–
Primulaceae	*Anagallis arvensis* L.	+	–	–	–	–

Table 1 (*continued*)

Family	Species	Life Form				
		Th	Ch	Ph	H	G
Resedaeae	*Caylusea hexagyna* (Forssk.) M.L.Green	–	+	–	–	–
	Ochradenus arabicus Hillcoat &.Miller	–	–	+	–	–
	O. baccatus Del. *Oligomeris linifolia* J.F.Macbr.	+	–	–	–	–
	Reseda Arabica Boiss.	+	–	–	–	–
	R. muricata C.Presl	–	+	–	–	–
Rhamnaceae	*Ziziphus spina-christi* (L.) Desf.	–	–	+	–	–
	Z. nummularia (Burm.f.)Wight & Arn	–	–	+	–	–
Rutaceae	*Haplophyllum tuberculatum* Forssk.	–	+	–	–	–
Salvadoraceae	*Salvadora persica* L.	–	–	+	–	–
Scrophulariaceae	*Scrophularia deserti* Delile	–	+	–	–	–
Solanaceae	*Lycium shawii* Roem. & Schult.	–	–	+	–	–
	Datura innoxia Mill.	+	–	–	–	–
	Solanum nigrum L.	+	–	–	–	–
	Withania somnifera (L.) Dunal	–	+	–	–	–
Tamaricaceae	*Tamarix aphylla* (L.) H. Karst.	–	–	+	–	–
	T. nilotica (Ehrenb.) Bunge.	–	–	+	–	–
Urticaceae	*Forsskaolea tenacissima* L.	–	+	–	–	–
Apiaceae	*Anisosciadium lanatum* Boiss	+	–	–	–	–
	Ducrosia anethifolia (DC.) Boiss	+	–	–	–	–
Zygophyllaceae	*Fagonia bruguieri* DC.	–	+	–	–	–
	F indica Burm.F.	–	+	–	–	–
	Peganum harmala L.	–	+	–	–	–
	Tribulus terrestris L.	+	–	–	–	–
	Seetzenia lanata (Willd.) Bullock	+	–	–	–	–

Abbreviations: Th = Therophyte, Ch = Chamaephyte, Ph = Phanerophyte, H = Hemicryptophyte, G = Geophyte.

sented in arid and semi-arid regions (Jeffrey, 1978; Clayton, 1978,) Wide ecological range of Asteraceae and Poaceae can be attributed to their adaptation to harsh conditions as well as effective wind dispersal strategies of their diaspores (van Rheede van Oudtshoorn and van Rooyen, 1999) (see Fig. 4).

Poaceae species have adaptations that allows them to endure and even benefit from grazing stress and drought. This adaptation pertains to an ample network of shallow highly ramified roots

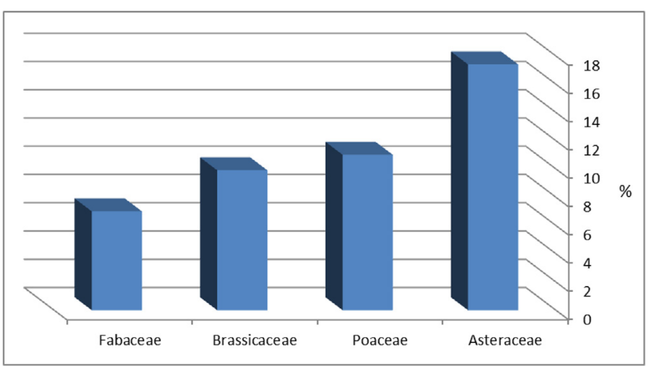

Fig. 2. Percentages of most prevailing plant families in the study area. Other plant families represent less than 6% (not shown).

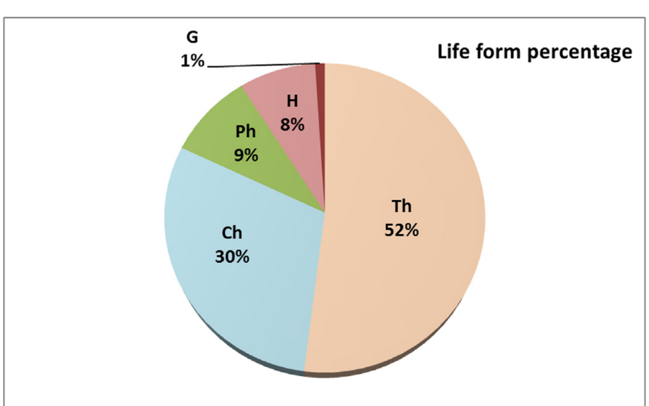

Fig. 3. Life form percentage of Riyadh region.

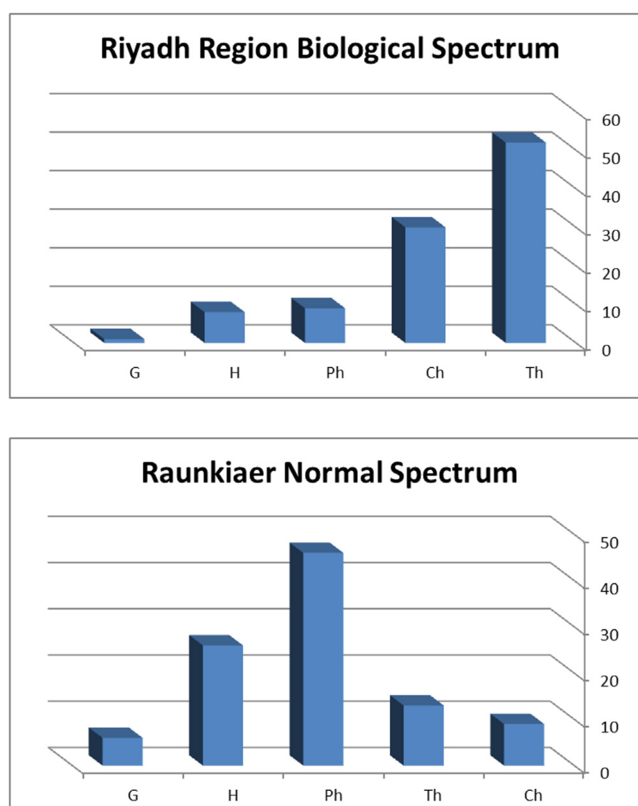

Fig. 4. Riyadh region biological spectrum (above) comparing with Raunkiaer normal spectrum (below).

allowing them to efficiently absorb moisture from the soil (Stanley, 1999). Moreover, many Brassicaceae species have fruits with pericarp characters that mechanically inhibits germination of fresh seeds and enhance germination of non-dormant seeds (Zhou et al., 2015). This attribute seems to be vantage against the risk linked with germination in a temporally unforeseeable environment. Additionally, most species of Brassicaceae are Therophytes (Khan and Shah, 2013).

Furthermore, Raunkiaer (1934) stated that the essential patterns of climates are characterized by the fact that one or few life-forms are, relatively or absolutely, dominant. This can be expressed numerically as the phytoclimate can be characterized by statistical survey of the life-forms (Raunkiaer, 1934). The life form composition of the community is the aspect of adaptations of its constituent species to climatic condition (Jamir and Pandey, 2003). Therefore, the climates and the major associated soil types can be reflected by life forms (Cain, 1950). When compared with Raunkiaer's normal spectrum, therophytes in Riyadh region are four times higher than that of the normal spectrum (Fig. 3). High percentage of therophytes in any specific region indicated that this region have arid climate and disturbed habitats (Cain, 1950; Ricklefs, 1979; Smith, 1980). On the other hand, chamaephytes indicate a temperate phytoclimate (Meher-Homji, 1964). Therefore, the observed dominance of therophytes followed by chamaephytes over other life forms in Riyadh region appears to be a response to the arid climate with insufficient rainfall and few microhabitats available to support high percentage of perennials. It also reflects anthropogenic and livestock impacts on the region. Moreover, phanerophytes are less than that of normal spectrum by about five times (Fig. 3). Since phanerophytes pertain to warm humid regions such as tropical zones (Raunkiaer, 1934) arid conditions prevailing in Riyadh region were unfavorable for such life form. High percentage of therophytes and low percentage of phanerophytes are, collectively, indicative arid climate and disturbed habitats. Compared to other reported life forms hemicryptophytes and geophytes show lower percentage than the normal spectrum, indicating the effects of biotic factors on the vegetation (Rana et al., 2002).

5. Conclusion

According to its climatic characteristics and geomorphological features, Riyadh region represents a hyper-arid habitat of low floristic diversity. Only few plant families can thrive in such harsh hyper-arid conditions, of which Asteraceae and Poaceae are most prevailing families reflecting their high adaptability to such harsh conditions and effective dispersal of their diaspores. It can also be concluded that high percentage of therophytes followed by chamaephytes over other life forms pertains to the hyper-arid phytoclimate with few available microhabitats to support high percentage of perennials.

Acknowledgements

We are grateful to Deanship of Scientific Research, Princess Nourah bint Abdulrahman University, Riyadh, for funding this work through grant number (38 – RFP - 224). We are also grateful to Mr. Khalid Alfanikh and Mr. Saleh AlShaye for assistance in field trips. Also many thanks to: Asma Charbaji, Salma Alghamdi, Ohud Alsufyani and Ebtesam Alqhtani for valuable assistance in herbarium works.

References

Al-Refeai, T., Al-Ghamdy, D., 1994. Geological and geotechnical aspects of Saudi Arabia. Geotech. Geol. Eng. 12, 253–276.
Batalha, M.A., Martins, F.R., 2002. Life-form spectra of Brazilian cerrado sites. Flora 197, 452–460.
Brovkin, V., 2002. Climate-vegetation interaction. J. Phys. IV 12, 57–72.
Cain, S.A., 1950. Life-form and phytoclimates. Bot. Rev. XVI (1), 1–32.
Chaudhary, S.A., Al-Jowaid, A.A., 1999. Vegetation of the Kingdom of Saudi Arabia. Ministry of Agriculture and Water, Riyadh, Saudi Arabia.
Chaudhary, S.A., 1999–2001.. Flora of the Kingdom of Saudi Arabia, vol. 3. Ministry of Agriculture and Water, Riyadh, Saudi Arabia.
Clayton, W.D., 1978. Poales. In: Heywood, V.H. (Ed.), Flowering Plants of the World. Oxford University Press.
Collenette, I.S., 1999. Wildflowers of Saudi Arabia. National Commission for Wildlife Conservation, Riyadh, Saudi Arabia.
Edgell, H.S., 2006. Arabian Deserts. Springer, Dordrecht.
Jamir, S.A., Pandey, H.N., 2003. Vascular plant diversity in the sacred groves of Jaintia Hills in northeast India. Biodivers. Conserv. 12, 1497–1510.
Jeffrey, C., 1978. Asterales, compositae. In: Dod, B. (Ed.), Flowering Plants of the World. Oxford University Press, Oxford, pp. 263–268.
Khan, N.A., Shah, M., 2013. Eco-taxonomic study of family Brassicaceae of District Mardan, Khyber Pukhtoon-Khwa, Pakistan. PJLS 1 (1), 28–35.
Kumar, K.N., Entekhabi, D., Molini, A., 2015. Hydrological extremes in hyperarid regions: a diagnostic characterization of intense precipitation over the Central Arabian Peninsula. J. Geophys. Res. Atm. 120 (5), 1637–1650.
Masrahi, Y.S., 2012. The Illustrated Guide to Wild Plants of Jazan Region. Al Sarawat Publisher, Jeddah.
Meher-Homji, V.M., 1964. Life forms and biological spectra as epharmonic criteria of aridity and humidity in tropics. J. Ind. Bot. Soc. 43 (3), 424–430.
Mera, A.G., Hagen, M.A., Orellana, J.A.V., 1999. Aerophyte, a new life form in Raunkiaer's classification? J. Veg. Sci. 10, 65–68.
Orshan, G., 1986. The deserts of the Middle East. In: Evenari, M., Noy-Meir, I., Goodall, D.W. (Eds.), Hot Deserts and Arid Shrublands, B. Elsevier, Amsterdam, pp. 1–28.
Rana, T.S., Datt, B., Rao, R.R., 2002. Life forms and biological spectrum of the flora of Tons valley, Garhwal Himalaya (Uttaranchal), India. Taiwania 47 (2), 164–169.
Raunkiaer, C., 1934. The Life Forms of Plants and Statistical Geography. Claredon, Oxford.
Ricklefs, R.D., 1979. Ecology. Thomas Nelson and Sons Ltd., London.
Sagga, A., 1998. Physical Geography of Saudi Arabia. Published by Author, Jeddah (in Arabic).
Saxena, A., Pandey, P., Singh, J., 1982. Biological spectrum and other structural functional attributes of the vegetation of Kumaun Himalaya. Vegetatio 49 (2), 111–119.
Smith, R.L., 1980. Ecology and Field Biology. Harper and Row Publishers, New York.
Stanley, K.E., 1999. Evolutionary trends in the grasses (Poaceae): a review. Mich. Bot. 38, 3–12.
van Rheede van Oudtshoorn, K., van Rooyen, M.W., 1999. Dispersal Biology of Desert Plants. Springer, Berlin.
Zhou, Y.M., Lu, J.J., Baskin, C.C., Baskin, J.M., 2015. Seed germination ecology of the cold desert annual *Isatis violascens* (Brassicaceae): two levels of physiological dormancy and role of the pericarp. PLoS One 10 (10), e0140983. https://doi.org/10.1371/journal.pone.0140983.