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INFLUENCE OF SELECTED SOIL PHYSICAL AND CHEMICAL VARIABLES ON DISTRIBUTION OF PERENNIAL PLANT SPECIES IN DIFFERENT PLANT COMMUNITIES OF RAWDHAT AL MASODI, SAUDI ARABIA

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Abstract

The present study aimed to investigate the dominance of perennial plant communities in Rawdhat Al Masodi in Saudi Arabia and the effect of soil physical and chemical variables on the species distribution. A total of 51 plant species representing 25 families were reported from the study site in which 19 perennial species were reported that composite 7 plant communities. The soil physical and chemical variables showed significant differences among plant communities (ANOVA, $p<0.05$) except for pH. The identified plant communities (C1-C7) were dominated by *Rhazya stricta*, *Calotropis procera*, *Acacia gerrardii*, *Acacia ehrenbergiana*, *Pulicaria undulate*, *Zilla spinosa* and *Teucrium oliverianum*, respectively. The CCA model between species composition and soil physical and chemical variables was significant (Monte-Carlo test, 499 permutations, $p<0.05$) and explained 51.15 % of the total variation in species composition. The CCA identified strong factors structuring the perennial plant species in Rawdhat Al Masodisuch as organic matter (OM), total dissolved salts (TDS), phosphate (PO_4), carbonate (CO_3) and bicarbonate (HCO_3) contents. In conclusion, there was remarkable diversity in plant communities in Rawdhat Al Masodi with remarkable variation in their physical and chemical properties of soil. The floristic diversity in this area is threatened by several factors including occasional recreational activities, woodcutting and development. Further ecological studies should be conducted to better understanding the factors influencing the plant community in this area. The government should design immediate and effective conservation programs to protect the floristic diversity in this area from future deterioration.

Key words: Plant communities, Arid ecosystem, Saudi Arabia, CCA, Diversity.

Introduction

Due to intensive several anthropogenic activities, industrial development and urbanization, the vegetation cover and floral diversity of arid ecosystems including those in Arabian Peninsula are threatening (Barakat *et al*., 2014; Al-Mutairi *et al*., 2015; Hatim *et al*., 2016; Al-Mutairi, 2017). Meanwhile, launching efficient conservation programs still need assessment of the current status of the floral biodiversity and better understanding the complex relationships between species abundance and/or diversity and environmental settings (Shaltout *et al*., 2016). Arid and semi-arid ecosystems comprise a large portion of the entire terrestrial ecosystem. Despite that, the distribution and diversity of plant species in the arid and semi-arid regions is still not fully understood. Most importantly, the interaction between the soil environmental variables and plant species diversity and the dominance of certain species in a specific community require intensive research efforts (Al-Mutairi, 2017).

Saudi Arabia is situated in the Arabian Peninsula (32º34` N – 16º83` N, 34º36` E – 56` E) covers a total area of more than 2 million km^2. The arid environment is the predominant regime with very low annual rainfall (0-200 mm/year) (Al-Nafie, 2008; El-Sheikh *et al*., 2013). Therefore, the xerophytes are the dominant plant life form (Al-Nafie, 2008) in the region. Saudi Arabia is characterized with remarkable floristic diversity due to the diversity of the habitats (Collenette, 1999). The total number of plant species reported from Saudi Arabia is 2253 species representing 132 families and the rare plant species represent 20% of the total flora (Collenette, 1999). Biogeographically, the flora of Saudi Arabia showed strong relationships with those in the North Africa, East Africa and The Mediterranean and Irano-Turanian countries (Alfarhan, 1999; Al-Mutairi *et al*., 2016).

In terms of the vegetational surveys, there are numerous studies dealing with the floral diversity of Saudi Arabia. For comprehensive description of the flora of Saudi Arabia, see Migahid (1996), Collenette (1999) and Chaudhary (2001). In the same context, there is quite high number of reports studying the plant species diversity in several parts of Saudi Arabia. For instance, Al-Mutairi *et al*., (2016) investigated the diversity of plant species in four locations of Tabuk region, is located in the North-western part of Saudi Arabia. Other studies were conducted such as Hosni & Hegazy (1996) on Asir region and Al-Turki (1997) on Al-Qassim region, and Al-Turki & Al-Olyan (2003) and El-Ghanim *et al*., (2010) on Hail region.

Unfortunately, the floristic diversity in Saudi Arabia is at high risk due to various irresponsible anthropogenic activities including urbanization, industrialization and woodcutting (Khalik *et al*., 2013; Al-Mutairi *et al*., 2015). During the last few decades, several ecological efforts were made to understand the effect of soil physical and chemical properties on the floristic diversity and species distribution and composition in various parts of Saudi Arabia (Al-Nafie, 2008; Alharbi, 2010; Rajasab, 2011; Alsherif *et al*., 2013; Al-Mutairi *et al*., 2016).

Plant communities are important components in the arid ecosystems and being involved in future sustainable management and conservation programs (Kandi *et al*., 2011). This is due the fact that plant species also provide continuous food and raw materials for pharmaceutical products (Shehata & Galal, 2014). The ultimate objective in most recent floristic studies was to explain the patterns of plant diversity and distribution in relation to certain physical, chemical, geographical variables (Fried *et al*., 2008; Barakat *et al*., 2014; Shaltout *et al*., 2016).

The present study aimed to investigate the influence of soil physical and chemical variables on the diversity and distribution of the perennial plant species in seven dominant plant communities in Rawdhat Al Masodi, Saudi Arabia.

Materials and Methods

Study sites: The present study was conducted in Rawdhat Al Masodi (25.12ºN and 47.28ºE) which is located at Al Armah valley away from the capital Riyadh about 120 km in the Eastern-north direction (Fig. 1). The temperature in the study site varies from approximately 43ºC during the summer to 5ºC during winter. The annual rainfall of the study site is low (less than 200mm/year).

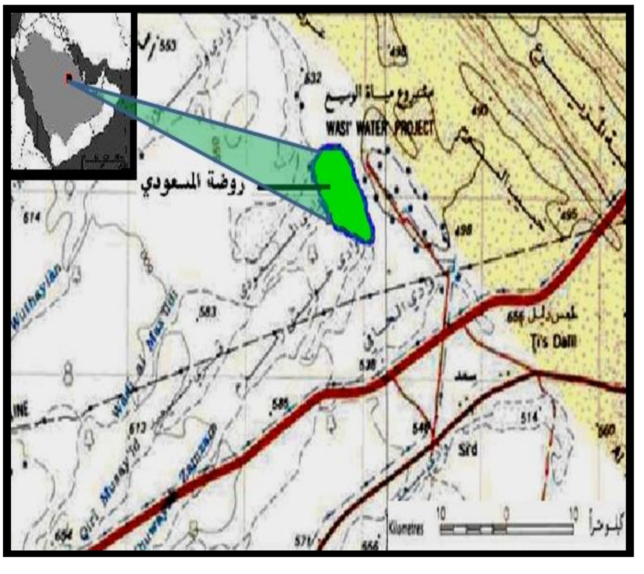

Fig. 1. Map showing the study location of Rawdhat Al Masodi, Riyadh, Saudi Arabia.

Sampling of plant species: The plant species were studied using 10×10m stand following the standard procedures. Briefly, the stand was distributed randomly and the vascular plants located in each stand were recorded. The perennial plant species in the dominant plant communities were reported and their vegetation percentage cover was calculated (Kent & Coker, 1992). The recorded plant species in each community were identified using available taxonomical keys of Chaudhary (2001) and Collenette (1999).

Measuring the soil physical and chemical properties: Several physical and chemical variables of the soil in the study sites were measured. Four samples of soils were collected from each plant community up to 50 cm depth. These samples were labeled and saved in plastic bags. In the laboratory, the soil suspension was prepared with a ratio of 1:5 in distilled water. This soil suspension was used to measure; pH, electrical conductivity (EC), Organic Matter (OM), total dissolved salts (TDS), Nitrogen (N), Sodium (Na), Potassium (K), Calcium (Ca), Magnesium (Mg), Phosphate (P), Chloride (Cl) Carbonate (CO_3) and Bicarbonate (HCO_3) following the procedures of Jacson (1965), Allen *et al*., (1986) and Alyamani & Alddosoqi (2006).

Statistical analysis: The soil physical and chemical variables were analyzed for the mean and standard deviation. The one-way ANOVA analysis (at $p<0.05$) of SPSS (version 22.0) was applied to examine the significant differences between the means of soil physical and chemical variables in different plant communities. The multivariate analysis of Canonical Correspondence Analysis (CCA) (CANOCO program 4.5 version) (ter Braak, 1989) was employed to determine the relationship between plant species in different communities versus the soil physical and chemical variables. The effectiveness of the produced CCA model was examined using Monte-Carlo test (499 iterations at $p<0.05$). The sum of all eigenvalues and the total inertia values were produced. Therefore, the total variance explained (TVE) was calculated to determine the amount of variance in the species composition explained by the selected soil physical and chemical variables.

The diversity measure of species richness (which can be considered as alpha diversity), Shannon-Weiner (H'), Simpson (1-D) and Evenness indices were calculated using Species Diversity and Richness (SDR) software package (Pisces Conservation Group). The Cluster Analysis based on Bray-Curtis distance measure was used to investigate the relation between different plant communities based on presence/absence of species data. The cluster dendrogram was produced using MultiVariate Statistical Package (MVSP version 3.13d) (Kovach Computing Services).

Results

The measured soil properties showed variation among the sites. The average values of the variables are shown in Table 1. All soil chemical and physical variables showed significant differences (except soil pH) among the seven studied sites (one-way ANOVA, $p<0.05$).

In total, 51 annual and perennial plant species belonging to 25 families were recorded from Rawdhat Al Masodi. About 19 perennial plant species belonging to 13families were reported from the seven different communities in the study site. The perennial species are those live for more than two years. The complete list of recorded plant species is provided in Appendix 1. The number of perennial species represented by each family is shown in Figure 2. The families of Fabaceae, Poaceae and Asteraceae had the highest number of species (3 species of each family). The other families were represented by single species except of Apocynaceae which had two species.

Table 2 presents the diversity measure of the seven plant communities. The list of plant species is shown in Table 3. The highest number of species (8) was recorded in *Acacia ehrenbergiana* community (C4) followed by C1 (*Rhazya stricta*) and C6 (*Zilla spinosa*) communities with species richness of 7 for each. However, the lowest number of species was reported in *Teucrium oliverianum* community (C7) with only 3 plant species reported. The highest value of the diversity measure of Shannon-Weiner (H') of 1.001 was reported in *Zilla spinosa* community (C6), meanwhile the lowest value of H' (0.118) was reported in *Pulicaria undulata* community (C5). Simpson (1-D) index showed slightly different results in various plant communities. The highest value of Simpson was recorded in C3 community (*Acacia gerrardii*) and the lowest value of Simpson index was observed in *Calotropis procera* community (C2).

Table 1. The soil physical and chemical variables (mean±SD) in Rawdhat Al Masodi, Saudi Arabia. The ANOVA results comparing means of the soil variables among the seven studied communities. The significant different values (one-way ANOVA, $p<0.05$) are marked with asterisk.

Variable	C1	C2	C3	C4	C5	C6	C7	ANOVA $F_{6,21}$
pH	8.430±0.049	8.360±0.077	8.318±0.011	8.230±0.105	8.305±0.096	8.338±0.029	8.410±0.092	2.503
Electronic conductivity (EC) mmhos/cm	0.393±0.048	0.425±0.079	0.698±0.008	0.465±0.036	0.485±0.038	0.425±0.017	0.413±0.080	12.667*
Organic Matter (OM) %	0.330±0.025	0.385±0.067	1.185±0.132	0.538±0.078	0.540±0.071	0.463±0.008	0.350±0.047	51.181*
TDS mg/L	256.125±26.298	279.625±20.096	451.100±11.388	304.950±17.252	315.175±13.515	296.050±8.864	271.075±23.490	38.202*
Nitrogen (N) ppm	0.183±0.008	0.223±0.044	0.280±0.016	0.298±0.035	0.288±0.050	0.248±0.025	0.208±0.043	4.825*
Sodium (Na) ppm	0.310±0.012	0.360±0.052	0.803±0.008	0.473±0.054	0.493±0.048	0.435±0.033	0.330±0.035	56.000*
Potassium (K) ppm	9.225±0.334	9.900±1.105	16.775±0.303	11.550±0.477	11.700±0.510	10.875±0.319	9.475±0.955	47.806*
Calcium (Ca) ppm	1.898±0.276	2.438±0.726	4.663±0.409	3.273±0.128	3.298±0.132	3.115±0.030	2.165±0.606	15.418*
Magnesium (Mg) ppm	2.225±0.178	2.808±0.437	3.758±0.244	3.358±0.104	3.168±0.450	3.265±0.021	2.565±0.384	8.835*
Phosphate (P) ppm	6.158±0.285	7.560±1.529	12.620±0.617	10.560±1.515	10.433±1.673	9.018±0.057	6.878±1.304	11.754*
Chloride (Cl) ppm	0.068±0.008	0.098±0.015	0.145±0.011	0.120±0.025	0.118±0.026	0.108±0.016	0.085±0.11	6.335*
Carbonate (CO3) %	1.198±0.023	1.138±0.063	3.115±0.017	1.623±0.538	1.850±0.436	1.118±0.054	1.173±0.54	22.513*
Bicarbonate (HCO3) %	0.190±0.024	0.213±0.008	0.430±0.051	0.270±0.046	0.280±0.034	0.230±0.007	0.205±0.11	20.855*

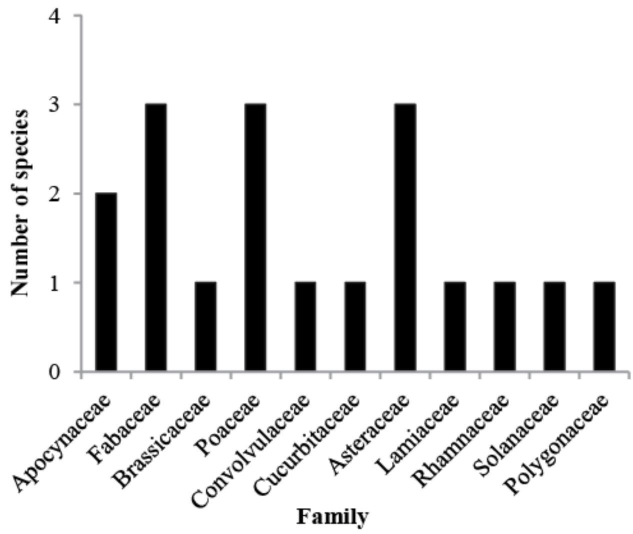

Fig. 2. The representation of the families by the perennial plant species in the seven communities in Rawdhat Al Masodi, Saudi Arabia.

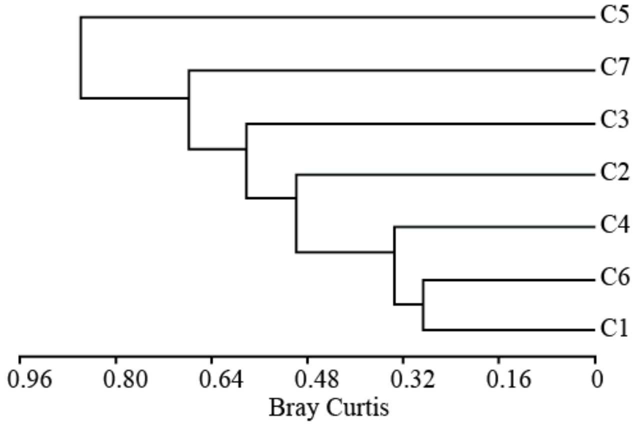

Fig. 3. Cluster analysis (based on Bray-Curtis distance measure) showing the similarity among the plant communities in the species composition collected from Rawdhat Al Masodi, Saudi Arabia.

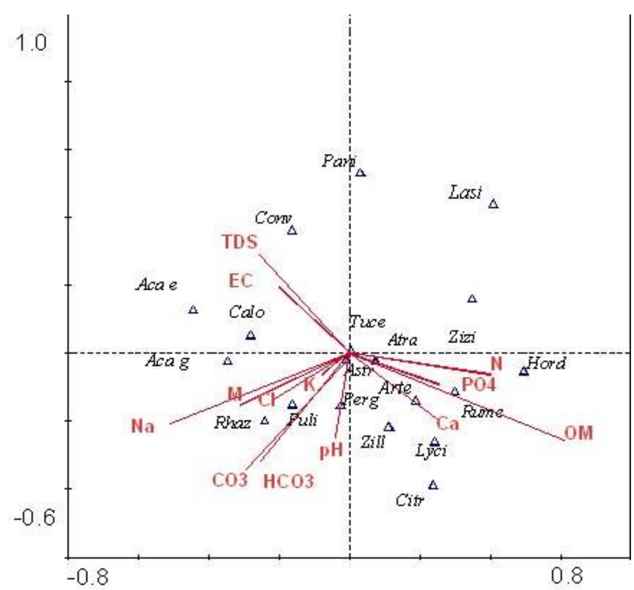

Fig. 4. The biplot of the canonical correspondence analysis (CCA) showing the relationship between the perennial plant species versus soil physical and chemical variables in Radhwat Al Masodi, Saudi Arabia. See the Appendix 1 for the full species names.

Table 2. Diversity measures of the perennial plant species in the seven plant communities in Rawdhat Al Masodi, Saudi Arabia.

	C1	C2	C3	C4	C5	C6	C7
Species Richness	7	6	6	8	5	7	3
Simpson (1-D)	0.231	0.221	0.527	0.449	0.0417	0.453	0.487
Shannon-Weiner (*H'*)	0.563	0.483	0.979	0.899	0.118	1.001	0.691
Evenness	0.251	0.270	0.444	0.307	0.225	0.389	0.665
Dominant species	*Rhazya stricta*	*Calotropis procera*	*Acacia gerrardii*	*Acacia ehrenbergiana*	*Pulicaria undulata*	*Zilla spinosa*	*Teucrium oliverianum*

Table 3. List of perennial plant species reported from Rawdhat Al Masodi, Saudi Arabia.

Family	Species	Abbreviated name	
Apocynaceae	*Rhazya stricta*	Rha	Perennial
Mimosaceae	*Acacia ehrenbergiana*	Acae	Perennial
Mimosaceae	*Acacia gerrardii*	Acag	Perennial
Asteraceae	*Artemisia monosperma*	Ast	Perennial
Papilonaceae	*Astragalus spinosus*	Art	Perennial
Asteraceae	*Atractylis carduus*	Atr	Perennial
Asclepiadaceae	*Calotropis procera*	Cal	Perennial
Cucurbitaceae	*Citrullus colocynthis*	Cit	Perennial
Conovolvulaceae	*Convolvulus pilosellifolius*	Con	Perennial
Poaceae	*Hordeum murinum*	Hor	Perennial
Poaceae	*Lasiurus scindicus*	Las	Perennial
Solanaceae	*Lycium shawii*	Lyc	Perennial
Poaceae	*Panicum turgidum*	Pan	Perennial
Asclepiadaceae	*Pergularia tomentosa*	Pul	Perennial
Asteraceae	*Pulicaria undulata*	Rum	Perennial
Polygonaceae	*Rumex vesicarius*	Per	Perennial
Lamiaceae	*Teucrium oliverianum*	Teu	Perennial
Brassicaceae	*Zilla spinose*	Zil	Perennial
Rhamnaceae	*Ziziphus nummularia*	Ziz	Perennial

The cluster analysis based on Bray-Curtis distance measure (using presence/absence) was applied to determine the degree of similarities in the species composition among the seven plant communities (Fig. 3). The species composition in the C1 and C6 communities showed high degree of similarity and both of them are more related to the species composition in C4 community than others. The species composition in the C5 community showed remarkable separation compared to composition in other communities.

The multivariate analysis of canonical correspondence analysis (CCA) was applied to investigate the relationships between species distribution and the physical and chemical variables of soil (Fig. 4). The total variance explained (TVE) by the CCA model was about 51.15%. The CCA model was significant based on Monte-Carlo test (499 permutations) with F-value=1.437 (p<0.05). The first canonical axis F-value=3.096 (p<0.05). The total inertia was 5.704 and the sum of all canonical eigenvalues was 2.935. The organic matter (OM), total dissolved salts (TDS), phosphate (PO_4), carbonate (CO_3) and bicarbonate (HCO_3) are considered the strongest variables influencing the species distribution in Rawdhat Al Masodi.

Discussion

The present study revealed considerably high number of plant species (both annual and perennial) of 51 species belonging to 25 families collected from Rawdhat Al Masodi in Saudi Arabia. Out of the total number of species, 19 species are perennial which complete life cycle in more than two years. Interestingly, the number of species reported from Rawdhat Al Masodi was higher than what was reported from arid ecosystems of China (Zhao *et al*., 2010; Zhang *et al*., 2016). This implies high floristic diversity in Saudi Arabia in general and Rawdhat Al Masodi in particular, despite the persistent anthropogenic disturbance. Local reports from Saudi Arabia revealed consistent disturbance of the vegetation cover especially development and woodcutting (Al-Mutairi *et al*., 2015).

The plant communities in Rawdhat Al Masodi represent remarkable variations in the soil properties (i.e. chemical variables) except for pH thus supporting the different community's dominance for their specific environmental requirements. Furthermore, it reflects the variations in the geological history of the different parts of

Rawdhat Al Masodi and eventually results in variation of the organic matter and mineral inputs of the soil (Zak *et al*., 2003). On the other hand, the microbial fauna can play an important role in changing the soil physical and chemical parameters (Galal & Fahmy, 2012).

The multivariate analysis of canonical correspondence analysis (CCA) showed to be useful tool to explain the complex interactions between species composition and environmental variables (Ohmann & Spies, 1998). In this study, the variance in species composition which was explained by the soil physical and chemical variables was almost 51% of the total variation. This was in agreement with previous studies in which only 50% of variation in the species diversity could be explained by soil and environmental variables (Galal & Fahmy, 2012). However, in some studies amount of explained variance can be more than 50%. For instance, Al-Mutairi (2017) reported more than 76 % of variance and explained the variation in the species composition in Tabuk (Saudi Arabia).

The present study revealed that the soil variables of organic matter, total dissolved salts, phosphate, carbonates and bicarbonates are strong factors structuring the species composition. This is in agreement with previous reports on plant species composition from arid and semi-arid environments. Several studies emphasized on the physical and chemical variables of soil specifically; salinity, organic matter and carbonates to be the most important factors influencing distribution of the plant species in arid ecosystems (Shaltout & El-Sheikh, 1993; Shaltout *et al*., 1994; Al-Sodany, 1998; Al-Mutairi, 2017).

Conclusion

The present study revealed that soil physical and chemical parameters showed remarkable variation among different communities of perennial plants. The study identified seven different plant communities which showed considerable variation in the species dominance and composition. The multivariate analysis of CCA was employed to determine the relationship between species composition and soil physical and chemical variables. According to the observations, the study site, Rawdhat Al Masodi undergoes huge stress due to intensive anthropogenic pressure including occasional recreational activities, woodcutting, grazing and urbanization. Rawdhat Al Masodi is a hot spot for plant diversity as it has several endemic species such as *Rhazya stricta*, *Calotropis procera*, *Acacia ehrenbergiana* and *Acacia gerrardii*. Hence, the authorities should start launching several and effective conservational programs. Furthermore, the public awareness should be targeted through outreach and extension programs for the protection of flora and natural recourses in this area.

References

Alfarhan, A. 1999. A phytogeographical analysis of the floristic elements in Saudi Arabia. *Pak. J. Biol. Sci.,* 2: 702-711.

Alharbi, F.K. 2010. Plant Diversity of Al-Lawz Mountains, Tabouk Region, Saudi Arabia. Ph.D. thesis, King Saud University, Riaydh, Saudi Arabia. (In Arabic with English abstract).

Allen, S. 1986. Chemical analysis. Oxford: Blackwell Scientific Publications, UK.

Al-Mutairi, K.A. 2017. Effect of environmental conditions on the taxonomic diversity of plant species in the arid region of Tabuk. *Arid Ecosyst.*, 7: 271-276.

Al-Mutairi, K.A., A. Al-Atawi, A. Alajlan and S.A. Al-Shami. 2015. Woodcutting activities in Tabuk Region (Saudi Arabia): Assessment of conservation knowledge. *Aceh Int. J. Sci. Tech.*, 4: 54-58.

Al-Mutairi, K., S.A. Al-Shami, Z. Khorshid and M. Moawed. 2016. Floristic diversity of Tabuk Province, North Saudi Arabia. *J. Anim. Plant Sci.*, 26: 1019-1025.

Al-Nafie, A.H. 2008. Phytogeography of Saudi Arabia. *Saudi J. of Biol. Sci.*, 15: 159-176.

Alsherif, E.A., A.M. Ayesh and S.M. Rawi. 2013. Floristic composition, life form and chorology of plant life at Khulais region, Western Saudi Arabia. *Pak. J. Bot.*, 45(1): 29-38.

Al-Sodany, Y.M. 1998. Vegetation analysis of canals, drains and lakes of northern part of Nile Delta Region, Ph.D. Thesis, Faculty of Science, Tanta University, Egypt.

Al-Turki, T. 1997. A preliminary checklist of the flora of Qassim, Saudi Arabia. *Feddes Repertorium*, 108(3-4): 259-280.

Al-Turki, T. and H. Al-Olayan .2003. Contribution to the flora of Saudi Arabia: Hail region. *Saudi J. of Biol. Sci.*, 10: 190-222.

Alyamani M.N. and R.A. Alddosoqi. 2006. Factors of plant ecology (Practical). King Saudi University Press.

Barakat, N.A.M., A.M.A. El-Gawad, V. Laudadio, H.F. Kabiel, V. Tufarelli and E. Cazzato. 2014. A contribution to the ecology and floristic markers of plant associations in different habitats of Sinai Peninsula, Egypt. *Rendiconti Lincei*, 25: 479-490.

Chaudhary, S. 2001. Flora of the Kingdom of Saudi Arabia (Vascular Plants), Vol. 1. National Agriculture and Water Research Center, National Herbarium, Ministry of Agriculture and Water, Riyadh, Saudi Arabia.

Collenette, S. 1999. Wild Flowers of Saudi Arabia. National Commission for Wildlife Conservation and Development, Riyadh.

El-Ghanim, W.M., L.M. Hassan, T.M. Galal and A. Badr. 2010. Floristic composition and vegetation analysis in Hail region north of central Saudi Arabia. *Saudi J. of Biol. Sci.*, 17(2): 119-128.

El-Sheikh, M.A., J. Thomas, A.A. Alatar, A.K. Hegazy, G.A. Abbady, A.H. Alfarhan and M.I. Okla. 2013. Vegetation of Thumamah Nature Park: a managed arid land site in Saudi Arabia. *Rendiconti Lincei*, 24: 349-367.

Fried, G., L.R. Norton and X. Reboud. 2008. Environmental and management factors determining weed species composition and diversity in France. *Agric. Ecosyst. Environ.,* 128(1): 68-76.

Galal, T.M. and A.G. Fahmy. 2012. Plant diversity and community structure of Wadi Gimal protected area, Red Sea Coast of Egypt. *Afr. J. Ecol.*, 50: 266-276.

Hatim, M.Z., K.H. Shaltout, J.H. Schaminée, H.F. El-Kady, J. Janssen and M.A. El-Sheikh. 2016. Veg Egypt ecoinformatics: contribution to Sinai flora and vegetation. *Rendiconti Lincei*, 27: 383-399.

Hosni, H.A. and A.K. Hegazy. 1996. Contribution to the flora of Asir, Saudi Arabia. *Candollea,* 51(1): 169-202.

Jacson, M. 1965. Soil chemical analysis. Constable, Ltd. Co., London 498.

Kandi, B., S. Sahu, N. Dhal and R. Mohanty. 2011. Species diversity of vascular plants of Sunabeda wildlife sanctuary, Odisha, India. *NY Sci. J.,* 4: 1-9.

Kent, M. and P. Coker. 1992. Vegetation description and analysis: A practical approach. Belhaven Press, London, pp. 263.

Khalik, K.A., M. El-Sheikh and A. El-Aidarous. 2013. Floristic diversity and vegetation analysis of wadi Al-Noman, Mecca, Saudi Arabia. *Turk. J. Bot.*, 37: 894-907.

Migahid, A.M. 1996. Flora of Saudi Arabia. 4th ed. Riyadh: King Saud University Press.

Ohmann, J.L. and T.A. Spies. 1998. Regional gradient analysis and spatial pattern of woody plant communities of Oregon forests. *Ecol. Monogr.*, 68: 151-182.

Rajasab, A.H. 2011. A Pictorial Guide to the Plants of Tabuk Region, Saudi Arabia: and their Traditional Uses. Lamber Academic Publishing, Germany.

Shaltout, K.H., E.A. Farahat and A.I. Shalapy. 2016. Effect of a desert planted forest on the understory plant diversity: implication to conservation. *Rendiconti Lincei*, 27: 711-719.

Shaltout, K. and M. El-Sheikh. 1993. Vegetation-environment relations along water courses in the Nile Delta region. *J. Veg. Sci.*, 4: 567-570.

Shehata, H.S. and T.M. Galal. 2014. Factors affecting the distribution and associated species of Malva parviflora in the Nile Delta, Egypt. *Weed Biol. Manag.*, 15: 42-52.

ter Braak, C.J. 1989. CANOCO-an extension of DECORANA to analyze species-environment relationships. *Hydrobiologia*, 184: 169-170.

Zak, D.R., W.E. Holmes, D.C. White, A.D. Peacock and D. Tilman. 2003. Plant diversity, soil microbial communities, and ecosystem function: are there any links? *Ecology*, 84: 2042-2050.

Zhang, R., T. Liu, J.L. Zhang and Q.M. Sun. 2016. Spatial and environmental determinants of plant species diversity in a temperate desert. *J. Plant Ecol.*, 9: 124-131.

Zhao, H., L. Tong, L. Jia Qiang, G. Dong Wei and Z. Xin Jun. 2010. β Diversity characteristic of vegetation community on south part of Gurbantunggut Desert and its interpretation. *Acta Prataculturae Sinica*, 19: 29-37.

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