Saudi Journal of Biological Sciences (2015) 22, 430–437

King Saud University

Saudi Journal of Biological Sciences

www.ksu.edu.sa
www.sciencedirect.com

ORIGINAL ARTICLE

Effects of open grazing and livestock exclusion on floristic composition and diversity in natural ecosystem of Western Saudi Arabia

Saud L. Al-Rowaily [a,*], **Magdy I. El-Bana** [b], **Dhafer A. Al-Bakre** [c], **Abdulaziz M. Assaeed** [a], **Ahmad K. Hegazy** [d,e], **Mohammed Basharat Ali** [a]

[a] *Department of Plant Production, King Saud University, PO Box 2460, Riyadh 11451, Saudi Arabia*
[b] *Department of Botany, Faculty of Science, Port Said University, Egypt*
[c] *Department of Biology, College of Science, University of Tabuk, Saudi Arabia*
[d] *Department of Botany and Microbiology, Faculty of Science, Cairo University, Giza 12613, Egypt*
[e] *Department of Botany and Microbiology, College of Science, King Saud University, Riyadh, Saudi Arabia*

Received 15 January 2015; revised 19 April 2015; accepted 20 April 2015
Available online 9 May 2015

KEYWORDS

Protection;
Fencing;
Grazing impacts;
Rangeland Steppes;
Restoration

Abstract Livestock grazing is one of the main causes of rangeland degradation in Saudi Arabia. Fencing to exclude grazers is one of the main management practices used to restore vegetation and conserve biodiversity. The main objectives of this study were to investigate the changes in plant diversity and abundance, floristic composition and plant groups of the major life forms in response to thirty-five years of grazing exclosure in western Saudi Arabia. These vegetation attributes and palatability were compared in 30 sampling stands located in the excluded and grazed sites. Our results showed that livestock exclusion significantly increased covers, density and species richness of annuals, grasses, perennial forbs, shrubs and trees. Exclosure enhanced the abundance and richness of palatable species and depressed the development of weedy species. About 66.7% of the recorded species at the excluded site were highly palatable compared to 34.5% at the grazed site. In contrary, about 55.2% unpalatable species were found in the grazed site compared to 25.8% in the protected site. Jaccard's similarity index between the excluded and grazed sites showed lower values of 0.39%, 0.40% and 0.31% at levels of families, genus and species, respectively. The results suggest that establishing livestock exclusion may be a useful sustainable management tool for vegetation restoration and conservation of plant diversity in degraded rangelands of arid regions.

* Corresponding author.
E-mail address: srowaily@ksu.edu.sa (S.L. Al-Rowaily).
Peer review under responsibility of King Saud University.

ELSEVIER Production and hosting by Elsevier

1. Introduction

In arid environments, the concentration of both water and nutrients provides suitable sites for vegetation establishment, and causes the heterogeneous pattern characteristic of vegetation and plant populations (Ludwig and Tongway, 1995; Al-

http://dx.doi.org/10.1016/j.sjbs.2015.04.012
1319-562X

Rowaily et al., 2012). Accordingly, the high rates of biomass removal and selective removal of palatable species result in sparse vegetation, reduced resource retention (seeds and litter reserve) and altered proportions of plant life-forms, each of which may respond differently to rainfall (Ludwig et al., 2005). Therefore, the relationship between grazing and vegetation is complex (Lavorel et al., 1997; McIntyre and Lavorel, 2001).

Grazing is the common land-use throughout the arid regions of the world. It has substantial effects on many ecosystem processes and functions, such as nutrient pool and cycling, soil moisture and structure, vegetation composition and productivity (Caldwell et al., 1981; Gao et al., 2007; Garrido et al., 2011; Al-Rowaily et al., 2012). It has generally been concluded that grazers could affect floristic composition and diversity in different ways, depending on the type of grazing animals, intensity of grazing and host plant species (Obeso, 1993; Müller et al., 2000; Bardgett and Wardle, 2010).

Livestock overgrazing is considered as the main cause of rangeland degradation through lowering both the productivity and resilience of host species, reduction of vegetation cover, increase of unpalatable species, decrease of species diversity, and alteration of soil structure and compactness (Kairis et al., 2015; Belgacem et al., 2013; Zhou et al., 2011; El-Keblawy et al., 2009; Keya, 1998; and Mainguet, 1994). Effects of grazing on the plant community and soils are viewed as destructive agents because of the reduction of ground cover, productivity and soil erosion (Al-Rowaily, 1999; Manzano and Návar, 2000; Firincioğlu et al., 2007; Al-Rowaily et al., 2012).

Rangelands of Saudi Arabia are essential terrestrial natural resources with great ecological, economic and social importance due to their crucial role in the development of rural areas. Generally, they support forage for both livestock and wild herbivores; offer the opportunity for outdoor recreational activities and enjoyment of nature (Al-Rowaily, 2003). In addition, they play great ecological role in conserving biodiversity. However, continuous overgrazing threatens the productivity, biodiversity and sustainability of these rangelands, and consequently enhances desertification process (Barth, 1999; Al-Rowaily et al., 2012, 2009; Al-Rowaily,1999), particularly in the absence of a specific policy for the protection and the sustainable management.

Several studies have highlighted the importance of establishing enclosures by fencing as a simple management tool for excluding animal grazing and restoration of degraded rangelands throughout the world (Kumar and Bhandari, 1992; El-Bana et al., 2003; Yeo, 2005; Kröpfl et al., 2013). However, few studies have evaluated such management approach in the rangelands of the Arabian Gulf countries, particularly is Saudi Arabia (Abulfatih et al., 1989; Shaltout et al., 1996; Al-Rowaily, 1999). The response of vegetation abundance and diversity to fencing vary with the period of protection within the same type of vegetation and type of grazing animals (Omar et al., 1990; Omar, 1991; Wu et al., 2009). In the rangelands of Kuwait and United Arab Emirates, short-term protection from grazing for 3–4 years resulted in a significant increase in species abundance and richness compared to low vegetation cover and richness under long-term protection for 10–15 years (Omar et al., 1990; El-Keblawy, 2003). However, Shaltout et al. (1996) reported an increase in vegetation cover and diversity after 11 years of protection in rangelands of Eastern Saudi Arabia. Long-term fencing to exclude large herbivores, in particular, has been adopted as a defense against overgrazing and has become a method used to implement conservation objectives. Comparison of vegetation composition and diversity including species richness and abundance, and plant functional groups in open and fenced areas could reflect the system stability and resilience of the rangelands (Metzger et al., 2005). Such approach can help to guide sustainable management strategies for conserving natural resources and ecosystem goods and services.

Following this management approach, the objectives of this study were to investigate the changes in plant diversity and abundance, floristic composition and plant groups of the major life forms in response to thirty-five years of grazing exclosure in western Saudi Arabia.

2. Materials and methods

2.1. Study area

The study area, the National Wildlife Research Center (NWRC), is located at about 30 km from Taif city, Saudi Arabia (21° 14′ 50″ N, 40° 42′ 30″ E, 1400 m altitude) (Fig. 1). Topography is flat with undulating plateau. The area is subject to continuous livestock grazing by sheep and camels which represent the only human activity that impacts vegetation. An area of about 35 km^2 was fenced in 1986 to prevent livestock grazing. Thirty-five years after fencing, vegetation and flora was surveyed in both the fenced site and in the surrounding open site subject to continuous overgrazing. Unfortunately there are no historical records on the levels of grazing with different animals and their effects on plant community attributes. Uncontrolled numbers of free-ranging camels, sheep and goats continuously grazed in the open site and there was no grazing by either domestic or wildlife animals in the fenced site (M.Z. Islam, personal communication).

The climate is arid with the 30 year average annual rainfall of 180.7 mm (Fig. 2). The rainy season falls between October and May while the summer months remain dry. The mean annual temperature is 22.8 °C, with the coldest mean temperatures (15.4 °C) in January and warmest (29 °C) in August. The study site's soil characteristics are relatively homogeneous with a high proportion of sand (80%) and low organic matter content amounting to 0.44% (Al-Bakre, 2008).

2.2. Field survey and data analysis

A total of 30 sampling stands (20 m × 20 m) were selected to represent the prevailing habitat and community variations inside and outside the exclosure (15 stands for each). Within each stand, five (5 m × 5 m) plots were randomly distributed to estimate plant frequency and density. However, line intercept method (Canfield, 1941) was applied for measuring cover of species using 5 lines of 20 m each, within each stand. The importance value index was calculated as the sum of relative values of density, frequency and cover. Nomenclature of species was according to using Chaudhary (1989, 2000), and Chaudhary and Akram (1987).

We classified the plant community into six functional groups according to their growth forms: annuals, grasses, perennial forbs, shrubs, trees and weeds. The weedy species were defined as those noxious species that are enhanced by

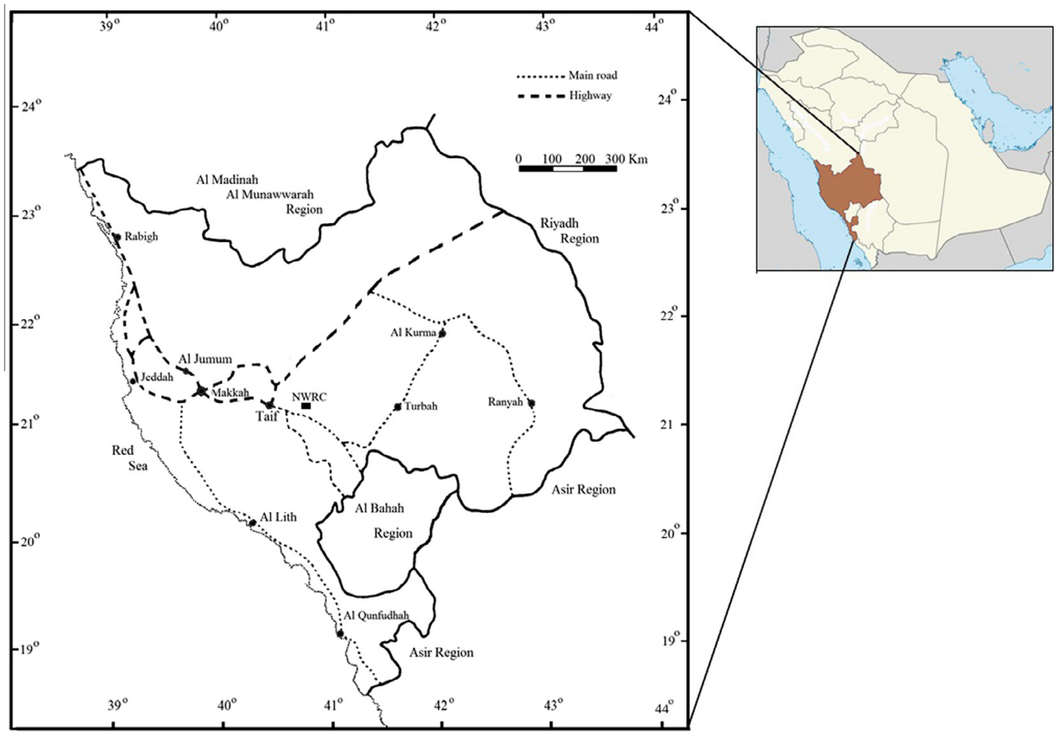

Figure 1 Study site (NWRC) in Makkah Region, Saudi Arabia.

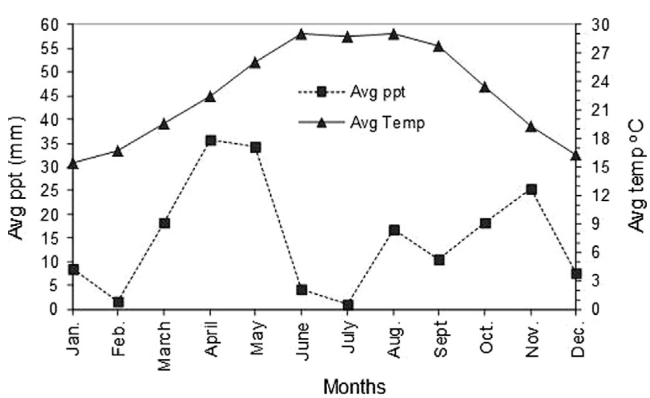

Figure 2 Average rainfall and temperature in Taif city (source: Presidency of Meteorology and Environment, Saudi Arabia).

overgrazing (Chaudhary and Le Houérou, 2006). Cover and plant density were calculated as means for each plant functional group. Species diversity was calculated for each functional group as total species number and mean species richness per unit area (100 m^2). Huston (1994) argued these as a simple and easily interpretable indicator of biological diversity. We further calculated the proportion of restricted species that were found only in either the fenced site or in continuous overgrazed site. The recorded species were rated to three palatability classes (1 = unpalatable, 2 = moderately palatable, 3 = highly palatable) based on field observation, available literature and expert knowledge (local herders and rangers). The similarity between the fenced and open sites as based on the presence/absence data was estimated by Jaccard and Sorenson similarity indices (Kent, 2010) by the following equations:

Jaccard index : $C_J = j/(a + b - j)$

Sorenson index : $C_S = 2j/(a + b)$

where a = number of species in the fenced site, b = number of species in the open site, and j = number of species common to both sites.

Diversity attributes, cover and density were compared among the five functional groups using one-way ANOVA, followed by Tukey's test (Zar, 1999). A paired Wilcoxon sign-ranks test was used to test for significant differences in vegetation attributes and palatability classes between fenced and grazed sites. All data analyses were carried out with the SPSS software (SPSS for Windows, Version 16.0, Chicago, IL, USA).

3. Results

3.1. Effect on floristic composition

Covers and density of annuals, grasses, perennial forbs, shrubs and trees were significantly greater in the exclosure than in the overgrazed site (Fig. 3a and b). The results showed that grasses were the most sensitive growth form to overgrazing as they were absent from the overgrazed sites. However, weed species were the more tolerant species to overgrazing as they were not recorded in the protected site. The cover of annuals, perennial forbs and trees was increased by about 3 times, and shrubs by 2.1 times in exclosure stands compared with overgrazed ones. Similarly, the density of annuals, shrubs, trees

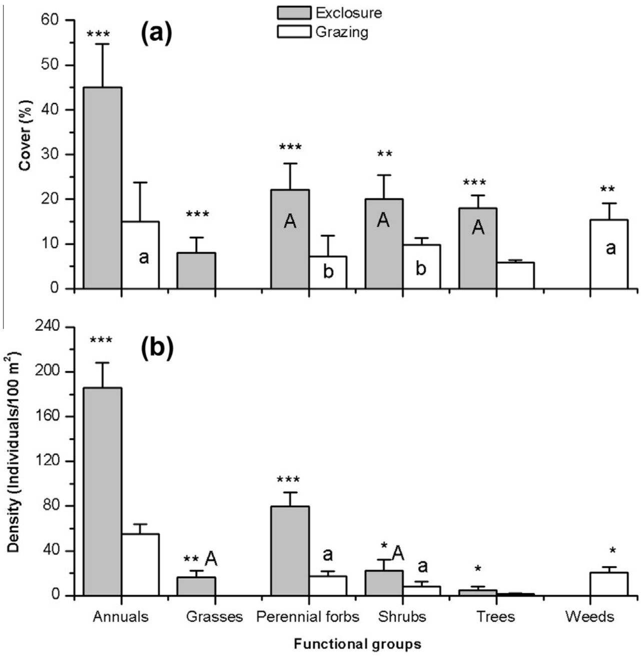

Figure 3 Effects of exclosure and grazing on cover (a) and density (b) of the different plant functional groups. Values (±SE) are means of fifteen stands for each site. Significant difference between excluded and grazed sites is indicated by symbols, ***$P < 0{\cdot}001$, **$P < 0{\cdot}01$, *$P < 0{\cdot}05$ (paired Wilcoxon sign-ranks test), while similar letters on bars are not significantly different between plant functional groups (Tukey's studentized range test). Capital letters are used for excluded site and lower-case letters for grazed site.

and perennial forbs was greater by 3.38, 2.83, 3.69 and 4.58 times in protected site, respectively, than in the overgrazed site.

Results in Table 1 show that livestock exclusion influenced the structural characteristics of the plant community. Tree species of *Acacia* (*A. ehrenbergiana, A. gerrardii and A. tortilis*), shrubs (*Indigofera spinosa, Lycium shawii* and *Ochradenus baccatus*) and perennial forbs (*Echinops viscosus* and *Fagonia indica*) were more abundant with higher importance values in the excluded than in the overgrazed plots (Table 1). Five grass species *(Panicum turgidum, Stipagrostis ciliata, Stipagrostis obtusa* and *Stipagrostis plumosa*), perennial forbs (*Blepharis ciliaris, Boerhavia repens*, *Farsetia longisiliqua, Felicia abyssinica*, *Polycarpaea repens* and *Pulicaria crispa*) and shrubs (*Psiadia punctulata* and *Salsola spinescens*) were not recorded in the overgrazed plots. However, the weedy and noxious species (*Calotropis procera, Citrullus colocynthis, Pergularia tomentosa, Senna italica* and *Solanum incanum*) were not found in the fenced plots.

3.2. Effect on floristic diversity

Livestock exclusion has influenced different measured diversity attributes (Table 2). The diversity of plants showed differences between open and fenced sites at the levels of species, genera and families (Table 2; Fig. 4). The most common families in the protected site were Asteraceae, Fabaceae and Poaceae compared with Apocynaceae, Capparaceae, Euphorbiaceae and Fabaceae in the grazed site (Fig. 4).

Table 1 Variation in relative importance values of perennials at excluded and grazed sites. The last column shows the index of change (differences between excluded and grazed sets). Bold type indicates differences that are significantly different ($P < 0{\cdot}05$, paired Wilcoxon sign-ranks test).

Species	Excluded site	Grazed site	Index of change
Acacia ehrenbergiana	47.68	19.95	**27.73**
Acacia gerrardii	56.65	24.79	**31.86**
Acacia tortilis	38.18	16.38	**21.80**
Aerva javanica	0.00	22.08	**−22.08**
Blepharis ciliaris	28.25	0.00	**28.25**
Boerhavia repens	19.30	0.00	**19.30**
Calotropis procera	0.00	44.69	**−44.69**
Citrullus colocynthis	0.00	38.13	**−38.13**
Echinops viscosus	23.66	17.25	6.41
Fagonia indica	61.97	48.22	13.75
Farsetia longisiliqua	16.89	0.00	**16.89**
Felicia abyssinica	24.17	0.00	**24.17**
Indigofera spinosa	52.80	32.33	**20.47**
Lycium shawii	50.52	19.95	**30.57**
Ochradenus baccatus	27.79	16.32	11.47
Otostegia fruticosa	45.09	0.00	**45.09**
Panicum turgidum	21.54	0.00	**21.54**
Pergularia tomentosa	0.00	40.63	**−40.63**
Polycarpaea repens	22.22	0.00	**22.22**
Psiadia punctulata	16.85	0.00	**16.85**
Pulicaria crispa	15.16	0.00	**15.16**
Salsola spinescens	34.12	0.00	**34.12**
Senna italica	0.00	41.74	**−41.74**
Solanum incanum	0.00	32.43	**−32.43**
Stipagrostis ciliata	20.79	0.00	**20.79**
Stipagrostis obtusa	63.24	0.00	**63.24**
Stipagrostis plumosa	28.23	0.00	**28.23**

Table 2 Floristic diversity (alpha-diversity) in terms of total number of families, genus and species at excluded and grazed sites.

Taxonomic level	Excluded site	Grazed site	Species in common
Family	34	16	14
Genus	63	10	21
Species	87	29	20

The similarity between fenced and open sites (beta-diversity) showed that, in contrast to alpha-diversity, beta-diversity attained the lowest values at species level, i.e., 0.21 and 0.35 for Jaccard and Sorenson indices, respectively (Table 3). The beta-diversity attained the highest values of 0.40 and 0.58 at genus level for Jaccard and Sorenson indices, respectively.

Exclusion from grazing had a positive effect on the total number of species and species richness of annuals, grasses, perennial forbs, shrubs and trees groups (Fig. 5a and b). However, overgrazing had a positive effect on total number and richness of weedy species. The restricted species in the

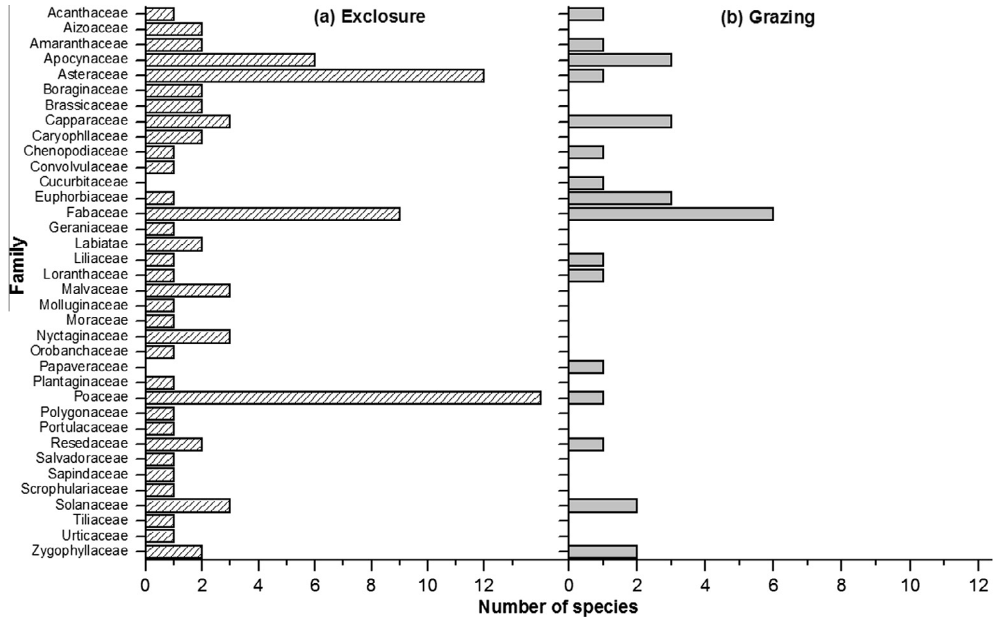

Figure 4 Variation in frequency of recorded species representing the different families at excluded and grazed sites of the study area.

Table 3 Floristic diversity (beta-diversity) according to similarity indices of families, genus and species between excluded and grazed sites.

Taxonomic level	Jaccard index	Sorenson index
Family	0.39	0.56
Genus	0.40	0.58
Species	0.21	0.35

fenced site for annuals, grasses, perennial forbs, shrubs and trees were 62.7%, 100%, 54.5%, 59.6% and 66.7%, respectively (Fig. 5c).

3.3. Effect on palatability

Highly palatable species was significantly higher in the fenced plots than in the grazed ones (Fig. 6). About 66.7% of the recorded species at the excluded site were highly palatable compared to 34.5% at the grazed site. In contrary, about 55.2% unpalatable species were found in the grazed site compared to 25.8% in the protected site.

4. Discussion

Livestock exclusion has been suggested as a simple and effective method for restoring and conserving vegetation productivity and diversity in degraded rangelands (Shaltout et al., 1999; El-Keblawy et al., 2009; Todd and Hoffman, 2009; Rutherford and Powrie, 2010). The results of the present study in degraded rangelands of the western Saudi Arabia indicated that establishing exclosures had a positive effect on vegetation cover and density as well as on improvement of vegetation diversity in terms of increasing species richness and diverse functional groups.

Our results showed that the dissimilarity in community composition between the excluded and grazed sites was

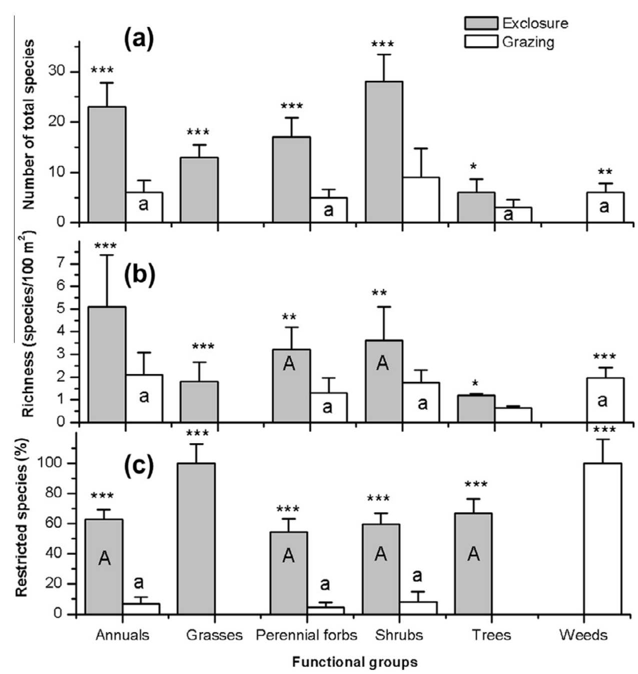

Figure 5 Total number of species (a), species richness (b), and the proportion of species found exclusively in excluded site or grazed site (c) for the different plant functional groups. Bars are averages ±SE of 15 stands. Significant difference between excluded and grazed sites are indicated by symbols, $^{***}P < 0{\cdot}001$, $^{**}P < 0{\cdot}01$, $^{*}P < 0{\cdot}05$ (paired Wilcoxon sign-ranks test), while similar letters on bars are not significantly different between plant functional groups (Tukey's studentized range test). Capital letters are used for excluded site and lower-case letters for grazed site.

maintained at the different taxonomic levels (families, genus and species) and even within different plant functional groups. Livestock exclusion increased cover, density and richness of

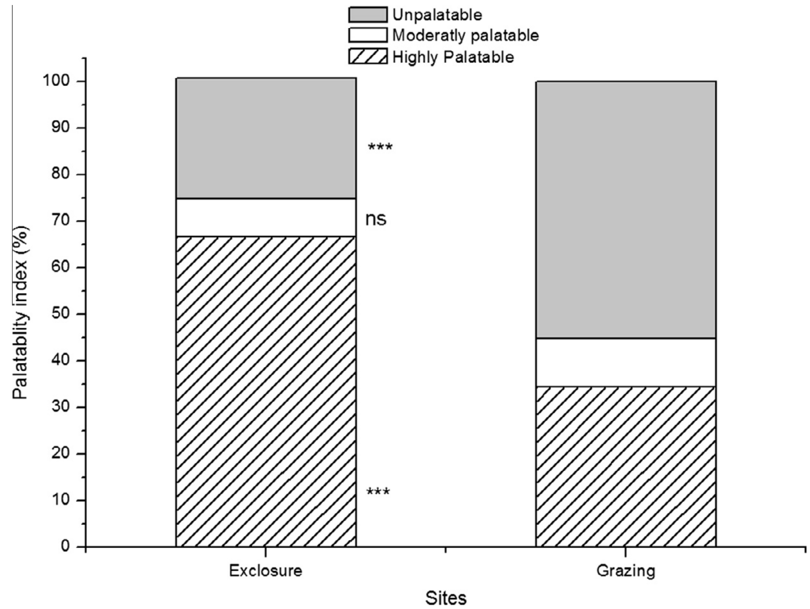

Figure 6 Proportions of unpalatable, moderately palatable and highly palatable species in excluded and grazed sites. Significant difference are indicated by symbols, $^{***}P < 0{\cdot}001$; ns, no significant difference according to paired Wilcoxon sign-ranks test.

annuals, perennial forbs, and woody shrubs and trees. Annual plants are considered as a main component of vegetation in the rangelands of Saudi Arabia (Shaltout et al., 1996; Al-Rowaily et al., 2012). They are a highly variable fodder resource especially for goat and sheep during the rainy periods (Chaudhary and Le Houérou, 2006). This may explain the reduction in its cover, density and richness at the grazed site. Although heavy grazing is known to promote the abundance of annuals and forbs (Noy-Meir et al., 1989; Landsberg et al., 2002; Brooks et al., 2006), this does not appear to be an important effect in the study area. Our results showed that the exclusion of animals enhances the cover, density and richness of woody shrubs and trees which facilitate the establishment and growth of herbaceous and annual species under their canopies (El-Bana et al., 2007; Abdallah et al., 2008; Al-Rowaily et al., 2012). In addition, field observations made during sampling indicated that *Acacia* species in the excluded site had dense cover of annuals and forbs under their canopies, suggesting that they are probably key factors in promoting floristic productivity and diversity, especially for annuals and forbs (Munzbergova and Ward, 2002; Abdallah et al., 2008). This could clarify the higher abundances of annuals and perennial forbs compared to other functional groups in the excluded site.

The abundance of spiny *Acacia* species (*A. ehrenbergiana*, *A. gerrardii*, and *A. tortilis*) and spiny shrubs (*I. spinosa* and *L. shawii*) was reduced in the grazed site, indicating that these species are tolerant of heavy grazing pressure. The twigs, leaves and pods of these species are considered as an appealing forage source for browsers, such as camels and goats, during drought (Keya, 1997; Skarpe et al., 2000; Chaudhary and Le Houérou, 2006). The spiny nature of these species is noted as a mechanical defense against heavy grazing, making them tolerant to grazing pressure (Gowda, 1996; Keya, 1997). On the other hand, the higher abundance of such palatable species at the excluded site, suggesting that current grazing pressure has a negative impact on vegetation composition. It has been shown that heavy browsing of the above-ground plant parts of *Acacia* species is the most likely mechanism leading to a decline in their canopy cover and density, and may be prone them to severe impact (Noumi et al., 2010; Al-Rowaily et al., 2012).

The remarkable difference between the grazed site and excluded site was the disappearance of grasses and weeds, respectively. Grasses such as *P. turgidum*, *S. ciliata* and *S. obtusa* are described as sensitive and intolerant grazing, and consequently they are dominant under protected conditions (Le Houérou, 2002; Chaudhary and Le Houérou, 2006). Oatham et al. (1995) found that overgrazing resulted in a significant reduction in the abundance and cover of the palatable grass, *S. plumosa* in the rangelands of UAE. With intense grazing pressure and drought there may be a reduction in, or complete loss of these grasses. Al-Rowaily et al. (2012) noted a deterioration of perennial grasses under heavy grazing in the rangelands of central Saudi Arabia, and such deterioration accelerates erosion and desertification (Barth, 1999).

The current results (Tables 1 and 3 and Fig. 6) demonstrated dissimilarity between grazed and excluded sites, and a shift in species composition from palatable species to unpalatable ones under continuous grazing. The dominant weedy species in the grazed site were *C. procera, C. colocynthis, P. tomentosa, S. italica* and *S. incanum* which are all widespread unpalatable species (Chaudhary and Le Houérou, 2006; Gallacher and Hill, 2006). It seems that these species have replaced the highly palatable grasses and intolerant grazing species as a result of heavy grazing (Briske, 1991; Gallacher and Hill, 2006; Al-Rowaily et al., 2012). Li et al. (2005) stated that overgrazing in the Inner Mongolian desert steppe has led to a significant reduction in palatable species. This could be attributed to the selective grazing of highly palatable species that are not tolerant to heavy grazing and trampling (Milton et al., 1994; Ksiksi et al., 2007).

In the exclosure, the higher richness and restriction of many palatable and rare species such as *B. repens, Maerua crassifolia, Otostegia fruticosa, P. crispa, P. punctulata* and *S. plumosa* confirmed the positive effect of establishing fencing. From a viewpoint of ecological restoration and land use as well as conservation of plant diversity, a sustainable option for natural resources management in arid regions should be directed toward establishing fencing in different habitats for restoring vegetation and preventing rangeland degradation. In this respect, more research are needed to assess the effect of animal exclusion on ecosystem process and function at different time scale in degraded rangelands of arid regions.

References

Abdallah, F., Noumi, Z., Touzard, B., Ouled Belgacem, A., Neffati, M., Chaieb, M., 2008. The influence of *Acacia tortilis* (Forssk.) subsp. *raddiana* (Savi) and livestock grazing on grass species composition, yield and soil nutrients in arid environments of South Tunisia. Flora 203, 116–125.

Abulfatih, H.A., Emara, H.A., El-Hashish, A., 1989. Influence of grazing on vegetation and soil of Asir highlands in south western Saudi Arabia. Arab Gulf J. Sci. Res. 7, 69–78.

Al-Bakre, D.A., 2008. Effect of protection on vegetation diversity on the National Wildlife Research Center and Rukba Fenced Areas in Taif M.Sc. thesis. King Saud University, Riyadh, Saudi Arabia.

Al-Rowaily, S.L., 1999. Rangeland of Saudi Arabia and the "Tragedy of commons". Rangeland 21 (3), 27–29.

Al-Rowaily, S.L., 2003. Present condition of Rangelands of Saudi Arabia: degradation steps and management options. Arab Gulf J. Sci. Res. 21 (3), 188–196.

Al-Rowaily, S.L., Al-Bakre, D.A., Al-Qarawi, A.A., Alshahrani, T.S., 2009. Effect of protection on plant diversity and soil characteristics: a comparative study of inside and outside Rukba Fenced Area. Saudi J. Biological Sci. 16 (3), 15–31.

Al-Rowaily, S.L., El-Bana, M.I., Al-Dujain, F.A., 2012. Changes in vegetation composition and diversity in relation to morphometry, soil and grazing on a hyper-arid watershed in the central Saudi Arabia. Catena 97, 41–49.

Bardgett, R.D., Wardle, D.A., 2010. Aboveground-belowground linkages: biotic interactions, ecosystem processes and global change. Oxford University Press, Oxford.

Barth, H.J., 1999. Desertification in the Eastern Province of Saudi Arabia. J. Arid Environ. 43, 399–410.

Belgacem, A.O., Tarhouni, M., Louhaichi, M., 2013. Effect of protection on plant community dynamics in the Mediterranean arid zone of southern Tunisia: a case study from Bou Hedma national park. Land Degrad. Dev. 24, 57–62.

Briske, D.D., 1991. Developmental morphology and physiology of grasses. In: Heitschmidt, R.K., Stuth, J.W. (Eds.), Grazing management: an ecological perspective. Timber Press, Portland, pp. 85–108.

Brooks, M.L., Matchett, J.R., Berry, K., 2006. Effects of livestock watering sites on plant communities in the Mojave Desert, USA. J. Arid Environ. 67, 125–147.

Caldwell, M.M., Richards, J.M., Johnson, D.A., Nowak, R.S., Dzurec, R.S., 1981. Coping with herbivory: photosynthetic capacity and resource allocation in two semi-arid *Agropyron* bunchgrasses. Oecologia 50, 14–24.

Canfield, R.H., 1941. Application of the line interception method in sampling range vegetation. J. For. 38, 388–394.

Chaudhary, S.A., 1989. Grasses of the Saudi Arabia. National Agriculture and Water Research Center, Riyadh, Saudi Arabia, p. 465.

Chaudhary, S.A., 2000. In: Flora of the Kingdom of the Saudi Arabia, vol. II. Ministry of Agriculture and Water, Riyadh, Saudi Arabia.

Chaudhary, S.A., Akram, M., 1987. Weeds of Saudi Arabia and the Arabian Peninsula. Regional Agriculture and Water Research Center, Ministry of Agriculture and Water, Riyadh, Saudi Arabia, p. 246.

Chaudhary, S.A., Le Houérou, H.N., 2006. The rangelands of the Arabian Peninsula. Secheresse 17 (1), 179–194.

El-Bana, M.I., Li, Z.Q., Nijs, I., 2007. Role of host identity in effects of phytogenic mounds on plant assemblages and species richness on coastal arid dunes. J. Veg. Sci. 18, 635–644.

El-Bana, M.I., Nijs, I., Khedr, A.A., 2003. The importance of phytogenic mounds (Nebkhas) for restoration of arid degraded rangelands in Northern Sinai. Restor. Ecol. 11 (3), 317–324.

El-Keblawy, A., 2003. Effect of protection from grazing on species diversity, abun- dance and productivity in two regions of Abu-Dhabi Emirate, UAE. In: Alsharhan, A.S., Wood, W.W., Goudie, A.S., Fowler, A., Abdellatif, E. (Eds.), Desertification in the Third Millennium. Swets & Zeitlinger Publisher, Lisse, The Netherlands, pp. 217–226.

El-Keblawy, A., Ksiksi, T., El Alqamy, H., 2009. Camel grazing affects species diversity and community structure in the deserts of the UAE. J. Arid Environ. 73, 347–354.

Firincioğlu, H.K., Seefeldt, S.S., Sahin, B., 2007. The effects of long-term grazing exclosures on range plants in Central Anatolian region of Turkey. Environ. Manage. 39, 326–337.

Gallacher, D.J., Hill, J.P., 2006. Effects of camel vs oryx and gazelle grazing on the plant ecology of the Dubai Desert Conservation Reserve. In: Mohamed, A.M.O. (Ed.), Pages Reclaiming the Desert: Towards a Sustainable Environment in Arid Lands. Proceedings of the Third Joint UAE-Japan Symposium on Sustainable GCC Environment and Water Resources (EWR2006). Taylor & Francis, Abu Dhabi, UAE, pp. 85–95.

Gao, Y., Wang, D.L., Ba, L., Bai, Y.G., Liu, B., 2007. Interactions between herbivory and resource availability on grazing tolerance of *Leymus chinensis*. Environ. Exp. Bot. 63, 113–122.

Garrido, E., Andraca-Gómez, G., Fornoni, J., 2011. Local adaptation: simultaneously considering herbivores and their host plants. New Phytol. 193, 445–453.

Gowda, J.H., 1996. Spines of *Acacia tortilis*: what do they defend and how? Oikos 77, 279–284.

Huston, M.A., 1994. Biological diversity: the coexistence of species on changing landscapes. Cambridge University Press, Cambridge.

Kent, M., 2010. Vegetation description and data analysis. John Wilry & Sons Ltd., UK.

Keya, G.A., 1997. Effects of defoliation on yield and reproduction of the dwarf shrub *Indigofera spinosa*. Acta Oecol. 18, 449–463.

Keya, G.A., 1998. Herbaceous layer production and utilization by herbivores under different ecological conditions in an arid savanna of Kenya. Agric. Ecosyst. Environ. 69, 55–67.

Kairis, O., Karavitis, C., Salvati, L., Kounalaki, A., Kosmas, K., 2015. Exploring the impact of overgrazing on soil erosion and land degradation in a dry Mediterranean Agro-Forest Landscape (Crete, Greece). Arid Land Res. Manage. 29 (3), 360–374.

Kröpfl, A.I., Cecchi, G.A., Villasuso, N.M., Distel, R.A., 2013. Degradation and recovery processes in Semi-Arid patchy rangelands of northern Patagonia, Argentina. Land Degrad. Dev. 24, 393–399.

Ksiksi, T., El-Keblawy, A., Al-Ansari, F., Elhadramy, G., 2007. Desert ecosystems vegetation and potential uses as feed sources for camels and wildlife. In: Proceeding of the 8th Annual Conference for Research Funded by UAE University, Al-Ain, United Arab Emirates, pp. 71–81.

Kumar, M., Bhandari, M.M., 1992. Impact of protection and free grazing on sand dune vegetation in the Rajasthan Desert, India. Land Degrad. Rehabil. 3, 217–229.

Landsberg, J., James, C.D., Maconochie, J., Nicholls, A.O., Stol, J., Tynan, R., 2002. Scale-related effects of grazing on native plant

communities in an arid rangeland region of South Australia. J. Appl. Ecol. 39, 427–444.
Lavorel, S., McIntyre, S., Landsberg, J., Forbes, D., 1997. Plant functional classifications: from general groups to specific groups based on response to disturbance. Trends Ecol. Evol. 12, 474–478.
Le Houérou, H.N., 2002. Man-made deserts: desertization processes and threats. Arid Land Res. Manage. 16, 1–36.
Li, J.H., Li, Z.Q., Ren, J.Z., 2005. Effect of grazing intensity on clonal morphological plasticity and biomass allocation patterns of *Artemisia frigida* and *Potentilla acaulis* in the Inner Mongolia steppe. New Zealand J. Agr. Res. 48, 57–61.
Ludwig, J.A., Tongway, D.J., 1995. Spatial organization of landscapes and its function in semi-arid woodlands, Australia. Landscape Ecol. 10, 51–63.
Ludwig, J.A., Wilcox, B.P., Breshears, D.D., Tongway, D.J., Imeson, A.C., 2005. Vegetation patches and runoff-erosion as interacting eco-hydrological processes in semiarid landscapes. Ecology 86, 288–297.
Mainguet, M., 1994. Desertification: Natural Background and Human Mismanagement, second ed. Springer-Verlag, Berlin, Germany, 314p.
Manzano, Mario G., Návar, José., 2000. Processes of desertification by goats overgrazing in the Tamaulipan thornscrub (matorral) in north-eastern Mexico. J. Arid Environ. 44, 1–17.
McIntyre, S., Lavorel, S., 2001. Livestock grazing in sub- tropical pastures: steps in the analysis of attribute response and plant functional types. J. Ecol. 89, 209–226.
Metzger, K.L., Coughenour, M.B., Reich, R.M., Boone, R.B., 2005. Effects of seasonal grazing on plant species diversity and vegetation structure in a semi-arid ecosystem. J. Arid Environ. 61, 147–160.
Milton, S.J., Dean, W.R.J., du Plessis, M.A., Siegfried, W.R., 1994. A conceptual model of arid rangeland degradation. Bioscience 44, 70–76.
Müller, I., Schmid, B., Weiner, J., 2000. The effect of nutrient availability on biomass allocation patterns in 27 species of herbaceous plants. Perspect. Plant Ecol. Evol. Syst. 3, 115–127.
Munzbergova, Z., Ward, D., 2002. Acacia trees as keystone species in Negev desert ecosystems. J. Veg. Sci. 13, 227–236.
Noy-Meir, I., Gutman, M., Kaplan, Y., 1989. Responses of Mediterranean grassland plants to grazing and protection. J. Ecol. 77, 290–310.
Noumi, Z., Touzardb, B., Michalet, R., Chaieb, M., 2010. The effects of browsing on the structure of *Acacia tortilis* (Forssk.) Hayne ssp. *raddiana* (Savi) Brenan along a gradient of water availability in arid zones of Tunisia. J. Arid Environ. 6, 625–631.
Oatham, M.P., Nicholls, M.K., Swingland, I.R., 1995. Manipulation of vegetation communities on the Abu Dhabi rangelands. I. The effects of irrigation and release from long term grazing. Biodivers. Conserv. 4, 696–709.
Obeso, J.R., 1993. Does defoliation affect reproductive output in herbaceous perennials and woody plants in different ways? Funct. Ecol. 7, 150–155.
Omar, S.A., Taha, F.K., Nassef, A., 1990. Ecological monitoring of vegetation in Kuwait's rangelands. In: Halwagy, R., Taha, F.K., Omar, S.A. (Eds.), Advances in Range Management in Arid Lands. Kegan Paul International, London, New York, pp. 57–71, 234p.
Omar, S.A., 1991. Dynamics of range plants following 10 years of protection in arid rangelands of Kuwait. J. Arid Environ. 21, 99–111.
Rutherford, M.C., Powrie, L.W., 2010. Severely degraded rangeland: implications for plant diversity from a case study in Succulent Karoo, South Africa severely degraded rangeland: implications for plant diversity from a case study in Succulent Karoo, South Africa. J. Arid Environ. 74, 692–701.
Shaltout, K.H., El-Kady, H.F., El-Sheikh, M.A., 1999. Species diversity of the ruderal habitats in the Nile Delta. Taeckholmia 19 (2), 203–225.
Shaltout, K.H., El Halawany, E.F., El Kady, H.F., 1996. Consequences of protection from grazing on diversity and abundance of the coastal lowland vegetation in eastern Saudi Arabia. Biodivers. Conserv. 5, 27–36.
Skarpe, C., Bergström, R., Bråten, A.L., Danell, K., 2000. Browsing in a heterogeneous Savanna. Ecography 23, 632–640.
Todd, S.W., Hoffman, M.T., 2009. A fence line in time demonstrates grazing-induced vegetation shifts and dynamics in the semiarid Succulent Karoo. Ecol. Appl. 19, 1897–1908.
Wu, G.L., Du, G.Z., Liu, Z.H., Thirgood, S., 2009. Effect of fencing and grazing on a Kobresia-dominated meadow in the Qinghai-Tibetan Plateau. Plant Soil 319, 115–126.
Yeo, J.J., 2005. Effects of grazing exclusion on rangeland vegetation and soils, east central Idaho. West. N. Am. Naturalist 65, 91–102.
Zar, J.H., 1999. Biostatistical Analysis, fourth ed. Prentice Hall, Upper Saddle River, NJ.
Zhou, Z.Y., Li, F.R., Chen, S.K., Zhang, H.R., Li, G.D., 2011. Dynamics of vegetation and soil carbon and nitrogen accumulation over 26 years under controlled grazing in a desert shrubland. Plant Soil 341, 257–268.