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Camel as seed disperser in the northern Sahara rangelands of Algeria

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Abstract

The Saharan milieu harbors a relatively diverse floral community, surviving with a variety of adaptation strategies. This flora is valued by the camel, the only livestock species adapted to this harsh environment. The aim of this study is to investigate the role of the camel's alimentary canal in the regeneration of the desert flora by identifying, quantifying and germinating the seeds dispersed by camel's faeces. In this study, we have collected camel faecal samples from two selected areas, representative of the six known rangelands browsed by camels during the four successive seasons of the years 2010-2013. The collected faecal material was cultivated in pots in a greenhouse. A total of 712 seedlings emerged from 48 faecal samples examined. Fifteen plant types were distinguished, 13 of which have been identified at the species level. The seedlings of the 13 plant species were further divided into 5 perennial and 8 annual and assigned to 9 botanical families. The temporal plant species distribution shows that summer had a significant difference and is the most represented season. The spatial distribution analysis showed a significant differences between areas and the highest numbers of plant species were recorded on rangelands of Wadi Beds, Depressions and Hamadas, with 13 species. The Reg, Erg, and Salty Soil rangelands recorded 8 species. The results indicate that the Arabian camel in the Saharan desert of Algeria plays a vital role in seed dispersal and ecological restoration of desert plants.

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Introduction

Co-evolved plant–animal interactions can be complex and play a vital role in ecosystem functionality and persistence of biodiversity (Bascompte *et al*., 2006). Studies on endozoochorous seed dispersal indicated that large numbers of plant seeds are potentially dispersed and successfully germinated via animal dung. The germination success of seedlings from dung is determined by three main factors. First, the seeds have to be eaten by an animal. This can happen either deliberately due to high palatability or accidentally when a herbivore consumes seeds along with palatable leaves or neighbouring palatable plants "foliage is the fruit" (Janzen, 1984; Pakeman *et al*., 2002). Second, the seeds have to survive the digestive system (Cosyns *et al*., 2005). Third, depending on the species, dormancy may need to be broken, and germination requirements have to be fulfilled (Malo, 2000).

Therefore, the importance of seed dispersal by animals which consume fruits (endozoochory) tends to decline in dry habitats (Howe and Smallwood, 1982) and is relatively rare in the coastal strand, Mediterranean and desert climates (Ellner and Shmida, 1981). Nevertheless, endozoochory does occur in 3% of the true desert plants in Palestine (Ellner and Shmida, 1981).

In Algeria, the Sahara covers more than 85% of the total area. Some of geomorphological features in this ecosystem are favorable to the development and survival of plant species that are characteristic of and well adapted to the desert climatic conditions. On the one hand, perennial plants must be able to survive in dry conditions and endure prolonged periods of drought, by minimizing the loss of water during the hottest periods. On the other hand, ephemerals germinate after occasional rains and often reproduce and die before a new drought comes. They typically have an extremely short life cycle (Ozenda, 1991).

The plants of the Saharan rangelands that fall into this category contribute to camel feeding (Chehma *et al.,* 2010).

The dromedary is the only animal species capable to thrive in this ecological area (Chehma *et al*., 2008). Limited studies about endozoochory by camels have been conducted in the Saharan ecosystem (Trabelsi *et al*., 2012) and knowledge about the role of the camel in the dispersal of plant species of this area is scarce, especially with respect to spontaneous dispersal. The objective of this study is to investigate the role of the Arabian camel in the endozoochorous seed dispersal.

Materials and methods

Study area

Our study site is in the south East part of northern Algerian Sahara, known to be a popular rangeland for camels. The site is located between 3 and 7° E longitude and 31 and 33° N latitude. The criterion for choosing the study sites was to cover all the different rangelands (Erg, Reg, Hamada, Wadi Bed, Salty Soil and Depression), which offer feed resources that are preferred by the Arabian camels (Chehma *et al*., 2008).

The climate is arid to hyper arid, characterized by limited and irregular rainfall, high summer temperatures, intense brightness, and a high level of evaporation (Ozenda, 1991).

Mean annual temperatures of the coldest month (January) are 2–9 °C and mean annual temperatures of the warmest months (July-August) can reach 50 °C. Mean annual precipitation is 64.22 mm and the duration of insolation is 9 to 10 hours per day in the Sahara (Chehma and Youcef, 2009).

Faeces collection

The collection was carried over a period of three years (2010, 2011 and 2012), with four collections per year, in order to cover the four seasons of the year. At each collection we observed the camel defecation behaviour; freshly deposited faeces of several (between 14 and 20) individuals were collected immediately after defecation. The faecal samples were air dried and stored dry in paper bags until use. Each sample was tagged with the site, name and date of collection.

Greenhouse germination experiment

Four replicates of 250 g each of faeces per season and per year were sub-sampled from each sample and spread in layers of 32 cm length × 15 cm width × 10 cm depth in plastic trays containing 2 kg of potting mixture for healthy growth of plants. For all, a total quantity of 3 kg of faeces per season was cleaned on the outside (to avoid possible contamination by non-ingested seeds present in the soil), weighed and soaked overnight in water to breakdown crumbled faeces. The next day, the wet samples were deposited on the potting mixture for germination. The samples were placed in a greenhouse and watered daily during the whole germination period to maintain moisture. The greenhouse temperature fluctuated between about 15 and 40 °C daily, which mimics diurnal temperature variation in the field. The emerging seedlings were counted at emergence and identification was carried out at the appropriate stage of growth. All individuals were identified at the family, genus and species levels, except for some seedlings where it was not possible to do so and they were classified into unidentified dicots and unidentified monocots.

Species identification

Emerging seedlings were identified according to description of Saharan flora (Ozenda, 1991) and the Catalogue (Chehma, 2006).

Data analysis

The total number of seeds that germinated was presented and the relative frequencies of germinating seeds of each plant species were presented as percentages of the total number of germinated seeds (Bonn, 2004). One way ANOVA test and LSD test at $\alpha = 0.05$ is conducted when variances were normal and homogeneous, to observe any significant differences in seasons, years and regions effect on species identified number. These analysis were done by CoStat.6.4 (2008) Program.

Results and discussion

Germinating seed content in camel faeces

A total of 715 seedlings emerged from 48 samples of camel faeces, 706 of which were identified down to the species level. They were assigned to 13 different plant species and nine families (Table 1).

Table 1. List of species germinated from camel faeces and percentages of seedlings belonging to the different species.

Family	Species	Seedling number	Percentage (%)
Amaranthaceae	*Bassia muricata* (L.) Asch.	33	4.63
Cariophyllaceae	*Spergularia salina* (Ser.) Presl.	1	0.14
Cistaceae	*Helianthemum lippii* (L.)Pers.	316	44.38
Fabaceae	*Argyrolobium uniflorum* Jaub. et Spach.	81	11.37
	Astragalus cruciatus Link.	56	7.86
	Astragalus ghyzensis Bunge.	117	16.43
	Lotus roudairei Bonnet	21	2.94
Geraneacae	*Erodium glaucophyllum* (L.) L'Her.	5	0.70
Plambaginaceae	*Limoniastrum guyonianum* Boiss.	3	0.42
Poaceae	*Cutandia dichotoma* (Forssk.) Trab.	1	0.14
Zygophyllaceae	*Zygophyllum album L.*	58	8.14
	Fagonia glutinosa Del.	13	1.82
Unidentified monocots		4	0.56
Unidentified dicots		2	0.28
Total number of seedlings		712	100%
Mass of dung (kg)		12	
Seedlings per kg dung		60	

The remaining six seedlings were unidentified and assigned to the morpho-types "unidentified dicots", and "unidentified monocots". This is the first report that provides qualitative and quantitative estimates of plant species that are dispersed by camels in the Saharan desert of northern Algeria. This finding describes a mutualistic adaptation that both the camel and the plants benefit from.

The significance that the camel plays in restoring the desert ecosystem is assisted by its feeding behaviour and mobility. The fact that many plant species that are known to be as preferred browses by the camel are dispersed by camel's faeces makes the camel an important animal not only to the owner, but to restore the fragile ecosystem of the desert with sparse vegetation and harsh environment.

Table 2. Mean seasonal fluctuation of identified plant species.

Mean Name	Mean	±SE	n Non-significant ranges
Summer	4.87	0.76	24 a
Winter	2.91	0.31	24 b
Autumn	2.62	0.38	24 b
Spring	2.33	0.37	24 b

This result concurs with other studies that found that ruminants (cattle, sheep and goats) are important vectors for endozoochorous seed dispersal. On large scales, seed dispersal systems associated with domestic ruminants have been proven to be particularlyfavorable for the introduction of alien plant species, and herbivores have facilitated the naturalization and spread of many alien herbaceous species from their initial points of introduction (Troumbis, 2001 ; Bruun and Poschlod, 2006 ; Gardiner *et al.*, 2012). The amount and diversity of viable seeds contained in the faeces of domestic ruminants grazing in nature may be quite high (Troumbis, 2001; Gardiner *et al.,* 2012).

Table 3. Mean number of species per year.

Mean Name	Mean	± SE	n Non-significant ranges
2010	3.46	0.64	32 a
2011	3.12	0.31	32 a
2012	2.96	0.34	32 a

Type of plants emerged

The results of biological category inventory have shown that the Arabian camel is helping to spread more annual species in its faeces (60.5%) than perennials (38.5%) (Fig. 1).

The biological and ecological significance of annual plants are due to their palatability and nutritional value for the camel under Saharan arid conditions (Longo *et al.,* 2007 ; Chehma *et al.,* 2008).

In general, ephemeral plants have a very short growth season and better nutritional values than perennial Saharan plants, despite their capricious lives and their direct dependence on rainfall (Chehma *et al.,* 2008).

Ephemeral adopt the strategy of appearance and disappearance according to environmental conditions, without a histological aerial phytomass changes, contrary to perennials which tend to harden their tissues and decrease surface area and number of leaves (Ozenda, 1991; Chehma, 2005).

Seasonal fluctuation of species

The mean of species was significantly different between the seasons ($P<0.0000$); Summer had a significant 4.87±0.76 mean number of species than, autumn, winter and spring with 2.62±0.38, 2.91±0.31 and 2.33±0.37 respectively (Table 2).

The dominance of species is an indicator of their palatability and preference by camels and their ability to form seeds while conditions are favourable. According to Ozenda (1991) and Chehma (2005), the Saharan plants begin to develop their aerial part in late winter (the rain period), continuing into spring and attaining their maximum production in early summer.

Seasonal variability of seedlings types is affected by fruiting plant phenology. In fact, it is not only a physiological phenomenon of a plant itself, but a comprehensive indicator to the habitat, climate and hydrology in a region (Chang *et al.,* 2012).

Table 4. Mean number of species per region.

Mean Name	Mean	± SE	n Non-significant ranges
Ghardaia	4.20	0.45	48 a
Touggourt	2.16	0.17	48 a

In arid regions, the phenophases of desert plants are influenced mainly by precipitation pattern and temperature (Rossi *et al.,* 1999); evaporation rates are higher than precipitation and the amount of annual rainfall is highly variable from one year to another (Gutterman, 2002). Other factors include the availability of soil moisture, duration of daylight and the position of the seeds on mother plants (Ghazanfar, 1997).

As with flowering, the phenology of fruiting is governed by its own set of constraints. Jordano (1992) has compiled a summary of fruiting phenology in a wide range of ecosystems, which indicated that fruiting peaks generally occur during periods of low photosynthetic activity or after periods of high rates of reserve accumulation.

In general, maturation of seeds coincides with the summer, which is characterized by climatic conditions unfavorable for seed germination. So, they are conserved in the faeces during the dry summer period of the year that is characterised by high temperature and lack of moisture.

Annual fluctuation of species

The results of mean annual fluctuation species indicated that there were no differences between mean species number, and the effect of year was no significant (P=0.517) (Table 3). The dromedary is known for its selectivity, which it keeps walking while grazing and tends to eat a variety of plants rather than consuming a particular species, it was better nutritional value (Chehma *et al.*, 2010).

Despite an annual rain precipitation total difference between years and regions (337,8mm in Touggourt and 153,9mm in Ghardaia in 2011 versus 24mm , 54.6mm in Touggourt and 42.4mm, 39.8mm in Ghardaia in 2010 and 2012 respectively, no significant annual differences found. It is related to species selectivity grazed by camels, where camels graze not all species in the same rangeland, it may be related to feeding behavior of dromedary that selects the species according to its needs (Yagil, 1985 ; Faye and Tisserand, 1989) even if the forage is abundant, this animal pasture walking and grazing generally little of each plant.

Spatial distribution of species

The camel is known for practicing a feeding behavior of itinerant grazing (Chehma *et al.,* 2005); it can browse every day over a distance of 30 to 50 km even where large quantities of food are available locally (Slimani *et al.,* 2013). Thus it is impossible to establish, with confidence, links between site faeces harvested and species location making it necessary to omit the rangeland effect. Thus we considered only the factor of two collection regions that are more than 400 km from each other. Our results show a significant differences between mean species number and region ($p<0.0000$) (Table 4). From a spatial point of view, this unequal distribution of seed density is mainly due to the production of phytomass in the rangelands. In fact, the results obtained by Chehma *et al.,* (2008) show that the Wadi Beds and Depressions registered the highest values of plant biomass, the Regs and Salty Soils were the lowest.

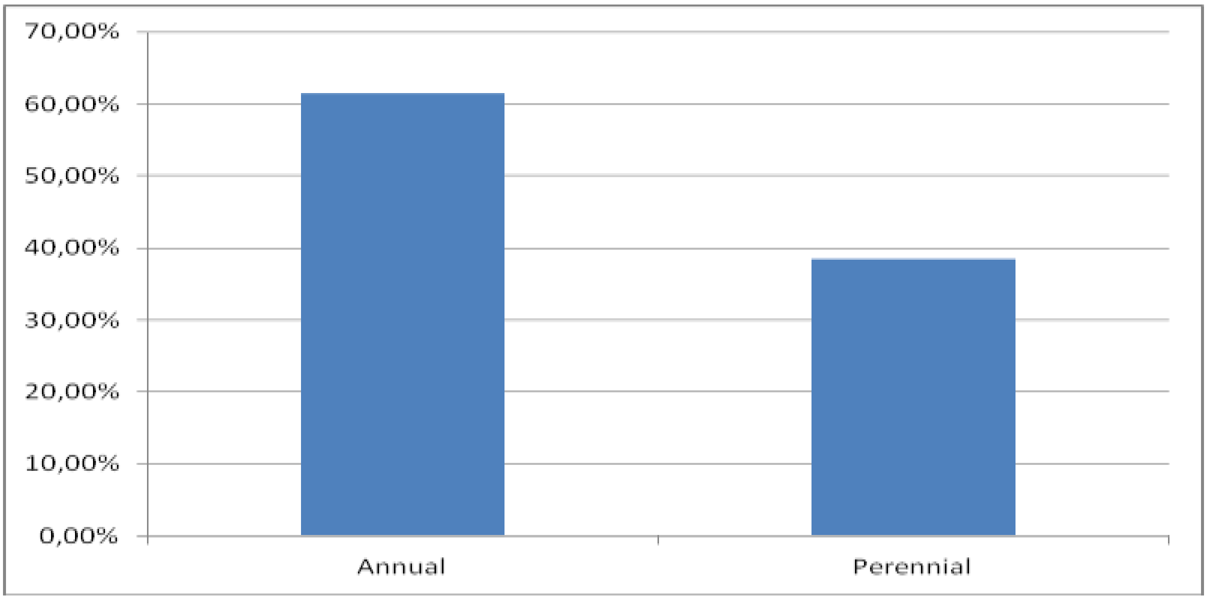

Fig. 1. Life form of seedlings

Conclusion

The Arabian camel can act as a dispersal vector, both quantitatively and qualitatively despite the camel's ability to deal with rigid structural plant components. In addition, the faeces in which the seeds are deposited and dispersed provide favourable conditions for preservation and seed germination (faeces represent a significant source of organic matter that promote seedling growth).

Due to this study the camel plays an important role in preserving the fragile Sahara desert's ecosystem and maintains a reasonable vegetation of plant types that are most suited for the harsh environment.

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