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Diversity and functional traits of spontaneous plant species in Algerian rangelands rehabilitated with prickly pear (*Opuntia ficus-indica* L.) plantations

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Abstract: The prickly pear (*Opuntia ficus-indica* L. Miller) is a xerophytic cactus species widely cultivated in arid and semiarid regions worldwide and used in rehabilitation programs of rangelands in Algeria since 1990. This study analyzed the diversity and functional traits of plant species established in prickly pear plantations growing under arid and semiarid climates. A 3-year plant assessment (2008–2010) was carried out using ecological descriptors (abundance, species richness, diversity indices, disturbance index, and Jaccard index) and plant functional traits (life forms, chorological types, dispersal types, Grime's, Noy-Meir's strategies, and morphological types). The results revealed 36 and 31 species in arid and semiarid rangelands, respectively, with remarkable dominance of therophytic (43.2%) and hemicryptophytic plants (41.1%) growing in the semiarid climatic zone. The Shannon and diversity index showed low values (0.93–1.84 in surveyed rangelands) with a maximum of 2.74 in 2009. The disturbance index ranged between 51% and 55% and the dispersion scheme of diaspores was dominated by anemochorous plants. The chorological analysis indicated that the study plants were oriented towards a Mediterranean pattern in the broad sense. The predominant adaptive strategies of Grime were ruderal-stress-tolerant (RS), competitive-stress-tolerant (CS) and competitive-ruderals (CR), which were attached to the two strategies of Noy-Meir (aridopassives and aridoactives).

Key words: Land rehabilitation, plant diversity, prickly pear, functional traits, Algerian steppes

1. Introduction

The Algerian rangelands cover about 20 million hectares, which represents more than 8.4% of the country's surface area, and is occupied by 25% of the Algerian population. Several natural factors like decrease in rainfall, severe long droughts, high thermal amplitude, and dry winds combined with anthropogenic factors like overgrazing, inappropriate cropping techniques, and deforestation accelerate desertification (Amghar et al., 2016). For over 40 years, these fragile ecosystems have been targeted by rehabilitation efforts and sustainable development programs (Le Houerou, 2000). The challenges of North African rangelands are multiple such as difficulties of plant natural regeneration and the regression of steppe areas, in particular the assemblages of *Stipa tenacissima* and *Artemisia herba-alba*, which are the key plant species of Algerian rangelands (Le Houerou, 1995; Neffar et al., 2011).

Several strategies have been adopted and significant investments have been made in the implementation of projects conceived in the framework of successive plans for the development of the steppe zones (Mulas and Mulas, 2004). However, these rangelands have continued to deteriorate with the advance of the desert and the migration of population (Djebaili, 1984; Le Houerou, 1995).

Among the established rehabilitation programs for North African rangelands, monospecific plantations of *Atriplex* sp. and prickly pear (*Opuntia ficus-indica*) were launched in these degraded habitats since 1990 (Le Houerou, 2000) and have been preferred to the reintroduction of indigenous plant species (Mulas and Mulas, 2004). Indeed, the presence of stress-tolerant plants can reduce severe environmental conditions and thus create favorable sites for other less-tolerant species (Neffar et al., 2011; Amghar et al., 2016). In general, these plants, which are qualified as "plant nurses", have many economic and ecological advantages (Mulas and Mulas, 2004).

According to Song et al. (2014), the specific diversity is not just related to the number of species in a community

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but also the number of individuals of each species, distribution, or mutual relations. It depends also on the respective function of species, that is, it is related to species functional diversity. In other terms, the description of ecological communities can be done either by a species “taxonomic” approach, centered on the diversity and abundance of species that coexist in time and space, or using a functional approach based on functional traits of species (Violle et al., 2007).

In grasslands and shrublands of the Mediterranean region, many studies used the functional approach to characterize vegetation (e.g., Lavorel et al., 2009). However, in North African rangelands, most of studies focused on bioclimatological patterns (Le Houerou, 1995), phytosociological groups (Djebaili, 1984), the impact of desertification (Chenchouni et al., 2010), and the effect of rehabilitation programs on soil and vegetation (Neffar et al., 2011; Amghar et al., 2016). To the best of our knowledge, the vital attributes and functional diversity of plant species associated with rehabilitating plantations in arid and semiarid steppes are neglected and poorly investigated. It is within this context that the current study was conducted to analyze degraded rangelands of northeastern Algeria in order to provide an accurate assessment of plant diversity (species richness, Shannon diversity index, evenness) and the functional traits (e.g., life forms, chorological types, dispersal types, Grime’s and Noy-Meir’s strategies) of spontaneously established plant communities associated with arid and semiarid rangelands rehabilitated with prickly pear plantations (PPPs).

2. Materials and methods

2.1. Study stations

The study was conducted in PPPs located in the region of Tebessa (eastern Algeria) along a north–south transect of 62 km (Figure). The Mediterranean climate (characterized by rainy and relatively cold winter, and hot summer) typifies this region. The choice of the north–south direction for the transect is based on the use of the De Martonne climate index (aridity index) (Kassas, 2008), which revealed two types of climates: arid and semiarid climates. Within these climatic regions, two stations of PPPs, representing two types of rangelands, were surveyed:

– Anba station (35°25′08.3″ N, 08°01′42.4″ E, altitude: 887 m a.s.l.). This station is subject to a semiarid climate where the De Martonne’s aridity index for the period 1972–2015 was 14.7 (Appendix 1). The average annual temperature was 15.8 °C with a maximum in July (24.7 °C) and a minimum in January (6.5 °C). September was the rainiest month, with 43.3 mm, while July was the driest month, with 14.4 mm; the average annual rainfall was 379.8 mm.

– M’zara station (34°51′08.4″N, 08°15′05.3″E, altitude: 780 m a.s.l.) is characterized by an arid climate with De Martonne aridity index = 6.73 (1990–2005) (Appendix 1). The average temperature was 15.5 °C with a maximum in July (27.7 °C) and a minimum in January (5.8 °C). September was the rainiest month, with 25.7 mm, whereas July was the driest month, with 7.3 mm. The average annual rainfall was 163 mm.

2.2. Vegetation sampling and identification

The study was performed during three consecutive years from 2008 to 2010. In each station, vegetation surveys were conducted during April (midst of spring season) of each year because most plant species are expected to be present during this period of active plant growth. Moreover, this period of the year coincides with the peak of vegetative growth of the majority of plants in the area. A floristic list, containing only spermatophyte species, was then established.

Within each station, six randomly chosen PPPs were studied each year. The PPPs are organized in rows with variable spacing distances between rows (2–13 m). Vegetation was sampled all along these spaces between PPP rows using the Canfield’s linear transect method (Canfield, 1941) with a length of sample lines varying between 2 and 13 m. For each studied PPP, four sample lines per plantation were carried out, totalizing 24 sample lines at each station per year. In each sample line, the method consists of stretching a rope over the vegetation and then measuring the length covered by different species along the rope, either at the level of the soil or above the dominant plant stratum.

Although most of plant species were common, plant samples were collected and identified at the laboratory using Quezel and Santa (1963), Blamey and Gray-Wilson (2009), and the database of Tela Botanica for the North African flora (www.tela-botanica.org/eflore).

2.3. Data analysis

To study biodiversity and functional characteristics of plant species in each climate region of rangelands and for the whole region in general, the following parameters and ecological indices were estimated for each plant community:

—Relative abundance (*RA*), which represents the ratio of the number of individuals to the total number of individuals (*N*).

— Species richness (*S*), which corresponds to the number of species present in a given sample (Magurran, 2004).

— Shannon diversity index (*H*’), which is commonly used to measure species diversity. *H*’ = 0, when the sample contains only one species; *H*’ ≈ 0, when a dominant species exists; *H*’ increases as the number of species increases. For a given number of species, *H*’ is maximum (H'_{max}) when all species’ abundances are exactly even in the sample.

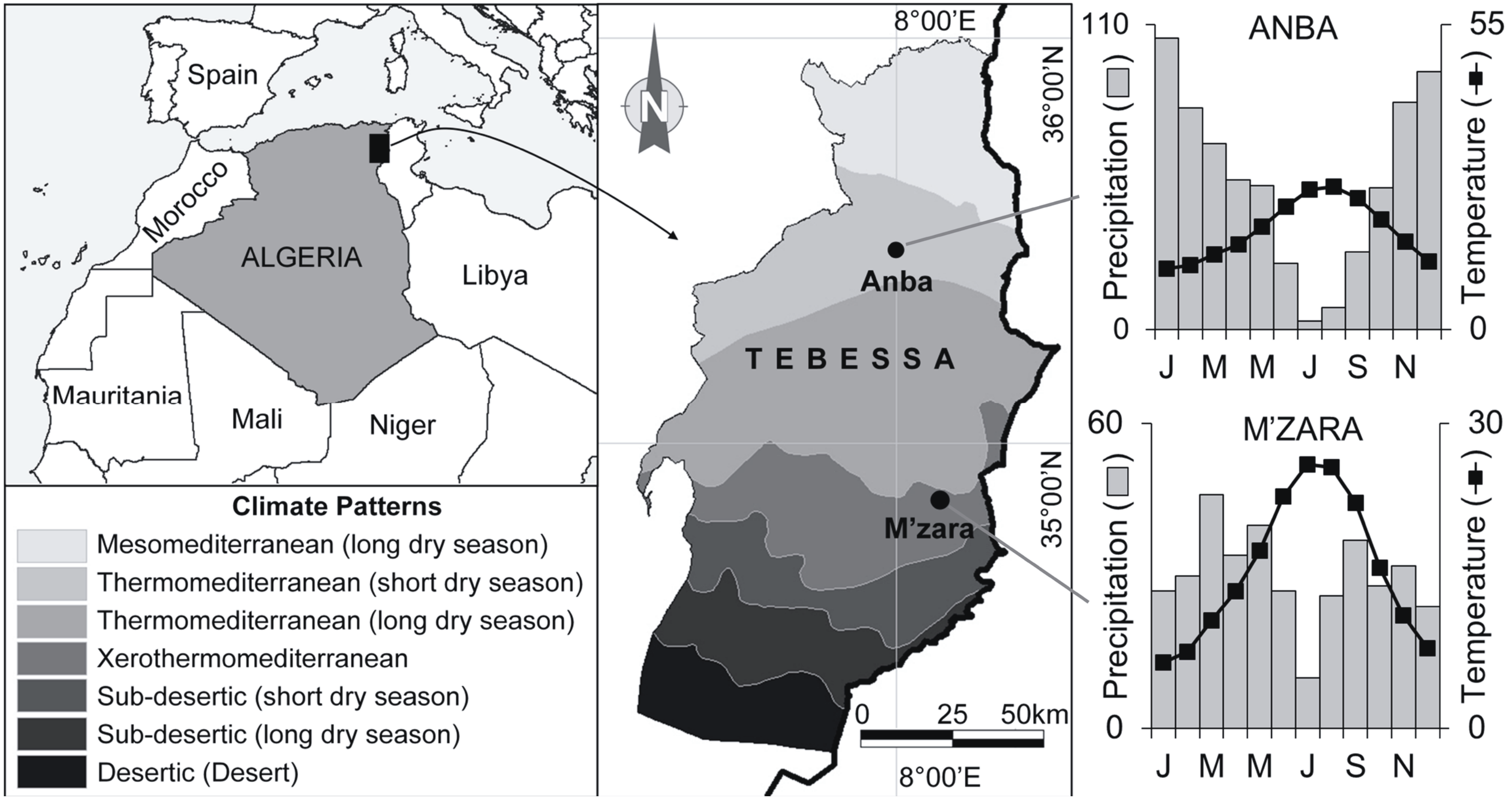

Figure. Location and climatic map of Tebessa (northeastern Algeria). Graphs on the right represent Gaussen's climatic diagrams applied for the study stations (Anba and M'zara), where mean temperature (in °C) and precipitation (in mm) are monthly averages.

$$H' = -\sum_{i=1}^{ni}\left[\left(\frac{ni}{N}\right)\times Log_2\left(\frac{ni}{N}\right)\right]$$

where n_i: number of individuals of the species i, N: total number of individuals of all species in the sample, S: species richness.

— Evenness index (E), with $E = H'/\log_2 S$. Evenness often accompanies Shannon's index. It is used to measure the distribution of individuals over species. Its values range between 0 and 1, when individuals are equally distributed between species (even population densities); E value tends to 1.

— Jaccard similarity index (C_J) was used to compare vegetation species richness between the two climate regions. Given the two climate regions, A and B, C_J was computed as $C_J = c/(a + b - c)$, where a and b: the total number of species present in region A and B, respectively; c: the number of species found in both regions A and B (Magurran, 2004).

2.4. Plant characteristics

Plant functional traits and types are useful concepts that relevantly help to detect disturbance responses of natural and managed ecosystems. In this study, the identified plant taxa were characterized by six plant functional traits (life forms, chorological types, dispersal types and Grime's, Noy-Meir's strategies, and morphological types). These traits have an impact on control growth, reproduction, and survival of plants (Violle et al., 2007). The classification of plant species into categories based on these functional traits, described hereafter, was facilitated by consultation of existing literature on the flora of Algeria, North Africa, and the Mediterranean basin (Quezel and Santa, 1963) and the database 'eFlora' of Tela Botanica (www.tela-botanica.org/eflore) (Appendix 2). For each category of the study functional traits, the percentage 'frequency' of species was calculated per year and per climate region of rangelands.

2.4.1. Life forms

Plant life forms are related to the phenological state of the species encountered. The Raunkiaer's classification (revised by Ellenberg and Mueller-Dombois, 1967) is based on the position of the vegetative buds in relation to the soil surface during the unfavorable season. The main life forms are therophytes, geophytes, hemicryptophytes, chamaephytes, and phanerophytes.

2.4.2. Chorological types

The chorological types of the taxa recorded in the two study climates of rangelands were determined mainly according to the flora of Algeria and North Africa of Quezel and Santa (1963) and the database 'eFlora' (www.tela-botanica.org/eflore). This trait is important as it helps to determine patterns of native and natural species vs. and alien and/or introduced species.

2.4.3. Dispersal types

As the geographical distribution of plants is closely linked to their ability to spread over long distances, Dansereau and Lems (1957) disclosed six categories of diaspores according to the dispersing agent involved in the process: anemochores, hydrochores, zoochores, barochores, autochores, and anthropochores. Diaspore dispersal types of the identified plants were determined based on Médail et al. (1998).

2.4.4. Grime's strategies (CSR)

This classification is used to link biological traits to three broad levels of stresses: environmental-type, biotic disturbances, and inter- and intraspecific competition. Thus, the plant species were classified into strategy C (competitors: plant species that live in habitats of low intensity stress and disturbance and thrive in biological competition), strategy S (stress tolerators: plant species that prosper in habitats of high intensity stress and low intensity disturbance), and strategy R (ruderals: plant species that thrive in areas of low intensity stress and excel in high intensity disturbance situations) (Grime, 2006).

2.4.5. Noy-Meir strategies

According to Noy-Meir (1973), "arido-passive" species do not exhibit photosynthetic activity during the dry period, while "arido-active" species maintain reduced photosynthetic activity during the adverse season.

2.4.6. Morphological types

Following plant life cycle and their response to the environment, morphological types of species were classified into two main classes based on 'growth form' and 'growth period'. Plants species identified in PPPs have two major biological forms: grasses (annual and perennial) and woody perennials (www.tela-botanica.org/eflore).

2.4.7. Disturbance index

According to Barbero et al. (1990), therophytization is an ultimate stage of vegetation degradation. The importance of this index is proportional to the dominance of therophytes (Bradai et al., 2015). The disturbance index (Id) established by Loisel and Gamila (1993) was calculated in order to measure the level of therophytization of each rangeland within a climatic region:

Id [%] = (Number of therophytes + Number of chamaephytes)/Species richness 'S'.

2.5. Statistical analysis

Data of diversity parameters and functional traits in the two stations were processed by analysis of variance (two-way ANOVA) at $\alpha = 0.05$, where the effects of the two factors 'climate' and 'year' and their interaction 'climate × year' were considered. Sample-based data retrieved at each station per year (i.e. raw data at sampling unit 'sample line' of each PPP) were used in computations. The analysis was carried out using the software STATISTICA version 6.0.

3. Results

3.1. Frequency of plant families

Overall, the semiarid rangeland station had nine plant families compared with 17 families at the arid rangeland station (Table 1). Based on relative frequencies of botanical families, in terms of species richness, in the two plantations, there were three dominant families in semiarid and arid rangelands, where Asteraceae had the highest frequency with 35.5% and 24.3% of total species, followed by Poaceae with 25.8% and 18.0%, and Fabaceae with 10.7% and 17%, respectively. On the other hand, the families Boraginaceae, Euphorbiaceae, Geraniaceae, Resedaceae, and Scrophulariaceae had the lowest frequency (1.2% each).

In term of abundances, the plant species with the highest relative abundance (*RA*) were *Hordeum murinum* (*RA* = 15.53%), *Artemisia campestris* (*RA* = 11.19%), *Plantago albicans* (*RA* = 9.98%), and *Cynodon dactylon* (*RA* = 9.50%). The rest of the species have low abundances (*RA* < 7%) (Appendix 3).

3.2. Diversity parameters

During the 3-year study, a total of 151 individuals were recorded on the arid steppes and 263 individuals on the semiarid steppes. The maximum was reached in 2009 with respectively 249 and 390 individuals in semiarid and arid plantations. The average abundance was only 25 in arid plantations compared to 43 in semiarid rehabilitated rangelands. However, the abundance in relation to climate and time (year) factors indicated a highly significant variation ($F_{(1,30)}$ = 14.08, P < 0.001) and $F_{(2,30)}$ = 16.86, P < 0.001, respectively), while the interactive effect was nonsignificant ($F_{(2,30)}$ = 1.06, P = 0.35) (Table 2).

For plant species richness, arid and semiarid plantations recorded respectively an average of 17 and 15 species with a maximum of 29 and 25 species in 2009. The average number of species ranged between 6 and 7 in the two rangelands. The variation of species richness in relation to climate and year factors was statistically significant ($F_{(1,30)}$ = 4.19, P = 0.049 and $F_{(2,30)}$ = 63.95, P < 0.001, respectively), but for the interaction effect (climate × year) no significant effect was detected (P = 0.18) (Table 2).

Values of Shannon's diversity and evenness indices showed significant variations between the two climates of rangelands. In the arid plantations, the Shannon index averaged 0.92 with a maximum of 1.53 recorded in 2009, whereas it averaged 1.84 (max = 2.74 in 2009) in the semiarid plantations. The Shannon index in relation to climate and year factors indicated a significant variation ($F_{(1,6)}$ = 21.72, P = 0.003 and $F_{(2,6)}$ = 17.63, *P* < 0.003, respectively), but no significant variation for the interactive effect (climate × year), where P = 0.28. Evenness values in arid plantations were lower (average = 0.25, max = 0.34 in 2009) than in semiarid plantations (average = 0.51, max = 0.63 in 2009). The variation in evenness values in relation to climate and year factors was deemed significant ($F_{(1,6)}$ = 33.19, P = 0.001 and $F_{(2,6)}$ = 12.50, P = 0.007, respectively). However, it was not significant for the interactive effect (climate × year) $F_{(2,6)}$ = 1.30, P = 0.33 (Table 2). The Jaccard index revealed a low similarity value (34%) between plantations of the two climates.

3.3. Life forms

Under arid climate, over the 3 years, hemicryptophytes were present with 38%, followed by therophytes (34%), geophytes (18.9%), and chamaephytes (16.8%) and then phanerophytes (4.8%). PPPs grown under semiarid climate housed a spontaneous plant community without phanerophytes. Therophytes (40.4%) and hemicryptophytes (35%) were dominant compared to geophytes (12%) and chamaephytes (14%). The frequency of phanerophytes showed a significant variation in relation to climate ($F_{(1,6)}$ = 20.58, P = 0.003) and years ($F_{(2,6)}$ = 12.11, P = 0.007), as well as the interaction of these factors ($F_{(2,6)}$ = 12.11, P = 0.007). Geophyte frequencies varied significantly between climates ($F_{(1,6)}$ = 6.68, P = 0.04) and years ($F_{(2.6)}$ = 18.79, P = 0.002). The variations in frequencies of the rest of life forms in relation to climate, year, and their interaction were not significant (Table 3).

3.4. Disturbance index

Under the two climates, the disturbance index values were around 50% (51.1% in semiarid rangelands and 54.5% in arid rangelands) with a maximum of 70% during 2009 (Table 4). The disturbance index varied significantly between study years ($F_{(2,6)}$ = 9.27, P = 0.01), but no effect of climate nor the interaction 'climate × year' was observed.

3.5. Dispersal types

The plant community of PPPs grown under arid climate was mainly anemochores (49.9%) and barochores (41%), followed by zoochores (32%). The autochorous plant species were present with only 1.6%. On the other hand, anemochores (59.5) and barochores (37.5%) were frequent in rangelands under semiarid climate compared to zoochores (22%) and autochores (1.4%). Among the plant dispersal types, only anemochores and autochores varied significantly in relation to the factor 'year' ($F_{(2,6)}$ = 14.71, P = 0.004, $F_{(2.6)}$ = 8.69, P = 0.01, respectively). No significant effect of climate, year, or their interaction was detected for the other dispersal categories (Table 5).

3.6. Chorological types

In both climates of rangelands, two chorological types dominated: Mediterranean and Cosmopolitan. In semiarid rangelands, the Mediterranean type represented 73%, followed by Cosmopolitans (12.8%), then Eurasian (9.4%), and the Paleo-temperate (4.4%). In arid rangelands, the Mediterranean type constituted 48.7% of species, followed by Cosmopolitans (12.8%), then Ibero-Mauritanians

Table 1. Frequencies of plant families [%] (based on species richness) in prickly pear plantations grown under arid and semiarid climates of northeastern Algeria. Overall values are given as arithmetic means with standard deviations

Plant family	Climate regions of rangelands (study years)							
	Arid climate				Semiarid climate			
	2008	2009	2010	Overall	2008	2009	2010	Overall
Apiaceae	—	—	8.3	2.8 ± 4.8	—	—	9.1	3.0 ± 5.2
Asteraceae	18.2	21.4	33.3	24.3 ± 8.0	50.0	20.0	36.7	35.5 ± 15.0
Boraginaceae	—	3.6	—	1.2 ± 2.1	—	—	—	—
Brassicaceae	18.2	14.3	——	10.8 ± 9.6	—	4.0	9.1	4.4 ± 4.6
Chenopodiaceae	9.1	3.6	—	4.2 ± 4.6	—	—	—	—
Euphorbiaceae	—	3.6	—	1.2 ± 2.1	—	4.0	—	1.3 ± 2.3
Fabaceae	9.1	25.0	16.7	16.9 ± 7.9	8.3	24.0	—	10.9 ± 12.0
Geraniaceae	—	3.6	—	1.2 ± 2.1	—	4.0	—	1.3 ± 2.3
Lamiaceae	—	—	—	—	8.3	—	—	2.8 ± 4.8
Liliaceae	9.1	3.6	8.3	6.9 ± 3.0	—	—	—	—
Malvaceae	—	—	—	—	8.3	4.0	—	4.1 ± 4.1
Plantaginaceae	9.1	3.6	8.3	7.0 ± 3.0	8.3	4.0	9.1	7.1 ± 2.7
Poaceae	18.2	10.7	25.0	18.0 ± 7.1	16.7	24.0	36.7	25.8 ± 10.1
Primulaceae	—	—	—	—	—	4.0	—	1.3 ± 2.3
Resedaceae	—	3.6	—	1.2 ± 2.1	—	4.0	—	1.3 ± 2.3
Scrophulariaceae	—	3.6	—	1.2 ± 2.1	—	4.0	—	1.3 ± 2.3
Zygophyllaceae	9.1	—	—	3.0 ± 5.2	—	—	—	—

Table 2. Variation in diversity parameters of plant assemblages in prickly pear plantations under arid and semiarid climates of Tebessa, northeastern Algeria. Overall values are given as arithmetic means with standard deviations (N: total abundance, N_m: mean abundance, S: species richness, S_m: mean S).

Climate region of rangelands	Year	Plant diversity parameters					
		N	Nm	S	Sm	Shannon index	Evenness
Arid	2008	122	20.3 ± 8.0	11	3.6 ± 1.0	0.75 ± 0.07	0.27 ± 0.00
	2009	249	41.5 ± 18.1	29	11.1 ± 2.4	1.53 ± 0.51	0.34 ± 0.09
	2010	83	13.3 ± 3.2	12	4.3 ± 2.3	0.49 ± 0.12	0.15 ± 0.02
	Overall	151.3 ± 86.8	25.0 ± 14.6	17.3 ± 10.1	6.3 ± 4.1	0.92 ± 0.54	0.25 ± 0.13
Semiarid	2008	270	45.0 ± 23.1	11	6.1 ± 1.1	1.87 ± 0.04	0.59 ± 0.04
	2009	390	65.0 ± 14.8	25	12.8 ± 1.9	2.74 ± 0.54	0.63 ± 0.12
	2010	131	21.8 ± 17.2	10	4.0 ± 1.7	0.92 ± 0.46	0.31 ± 0.08
	Overall	263.7 ± 129.6	43.9 ± 21.6	15.3 ± 8.3	7.6 ± 4.6	1.84 ± 0.91	0.51 ± 0.17
Jaccard index (C_J)				34%			
ANOVA							
Climate effect	F-stats	$F_{(1,30)}$ =14.08	—	$F_{(1,30)}$ = 4.19	—	$F_{(1,6)}$ = 21.72	$F_{(1,6)}$ = 33.19
	P-value	< 0.001	—	0.049	—	0.003	0.001
Year effect	F-stats	$F_{(2,30)}$ =16.86	—	$F_{(2,30)}$ = 63.95	—	$F_{(2,6)}$ = 17.63	$F_{(2,6)}$ = 12.50
	P-value	< 0.001	—	< 0.001	—	0.003	0.007
Interaction (climate × year)	F-stats	$F_{(2,30)}$ = 1.06	—	$F_{(2,30)}$ = 1.81	—	$F_{(2,6)}$ = 1.56	$F_{(2,6)}$ = 1.30
	P-value	0.355	—	0.180	—	0.283	0.338

Table 3. Percentage of life forms [%] of plant growing in prickly pear plantations used for the rehabilitation of arid and semiarid rangelands in northeastern Algeria. Overall values are given as arithmetic means with standard deviations

Climate region of rangelands	Year	Plant life forms [%]				
		Phanerophytes	Chamaephytes	Hemicryptophytes	Geophytes	Therophytes
Arid	2008	0	21.4 ± 30.2	46.4 ± 5.9	22.5 ± 8.4	25.0 ± 35.3
	2009	2.3 ± 3.3	7.1 ± 10.0	29.2 ± 1.0	4.8 ± 0.1	63.5 ± 9.0
	2010	12.1 ± 3.0	22.1 ± 11.1	39.2 ± 15.1	29.2 ± 1.0	14.2 ± 20.2
	Overall	4.8 ± 6.4	16.8 ± 8.4	38.3 ± 8.6	18.9 ± 12.6	34.2 ± 25.9
Semiarid	2008	0	17.5 ± 10.6	45.0 ± 7.0	11.25 ± 1.7	26.2 ± 19.4
	2009	0	10.0 ± 0.0	25.0 ± 7.0	5.0 ± 7.0	60.0 ± 14.1
	2010	0	15.0 ± 7.0	35.0 ± 21.2	20.0 ± 0.0	35.0 ± 7.0
	Overall	0	14.1 ± 3.8	35.0 ± 10.0	12.0 ± 7.5	40.4 ± 17.5
ANOVA						
Climate effect	$F_{(1,6)}$	20.58	0.10	0.24	6.68	0.28
	P	0.003	0.759	0.636	0.041	0.612
Year effect	$F_{(2,6)}$	12.11	0.67	2.57	18.79	4.50
	P	0.007	0.545	0.156	0.002	0.063
Interaction (climate × year)	$F_{(2,6)}$	12.11	0.11	0.02	1.77	0.41
	P	0.007	0.889	0.979	0.247	0.675

Table 4. Values of disturbance index [%] evaluated inside rangelands rehabilitated using prickly pear plantations grown under arid and semiarid climates in northeastern Algeria.

Study years	Climate region of rangelands		ANOVA	
	Arid climate	Semiarid climate	F-statistics	P-value
2008	46.4 ± 5.0	43.5 ± 9.1	Climate: $F_{(1,6)} = 0.35$	P = 0.575
2009	70.5 ± 0.7	70.0 ± 14.1	Year: $F_{(2,6)} = 9.27$	P = 0.014
2010	36.4 ± 9.0	50.0 ± 14.1	Interaction: $F_{(2,6)} = 0.80$	P = 0.490
Overall	51.1 ± 17.5	54.5 ± 13.8		

(7.9%), and North African endemic plants (8.2%). Frequencies of other chorological types (Eurasian, Paleo-temperate, Saharan-Arabian, Saharan-Sindian, Endemic to Saharan and SPCEWA) were less than 7% (Table 6).

3.7. Grime's strategies

Grime's spectrum of plant community of arid rangelands was represented by RS (37%), CR (33.8%), CS (13%), S (11%), CSR (8.4%), and then R (7.6%). Under semiarid climate, RS occupy the first position with 57% of species, followed by CS and RS with 18% and 17%, respectively, and then S (6%) and CSR (2.5%). The variation of Grime's types revealed a significant variation in CR in relation to 'climate' factor ($F_{(1,6)} = 14.85$, P = 0.008) and the interaction 'climate × year' ($F_{(2,6)} = 8.79$, P = 0.01). No significant differences were shown for the other strategies (Table 7).

3.8. Noy-Meir's strategies

Under arid climate, 53% of species were aridopassives and 45.9% were aridoactives. Under semiarid climate, aridopassive species represented 67.5%, whereas aridoactives were 31.5%. For both types of strategies, no significant variation was observed in relation to climate and year factors or their interaction (Table 8).

3.9. Morphological types

In both climatic regions, morphological types of plants associated with PPPs were highly represented by grasses, which were mostly annuals. Regarding growth forms,

Table 5. Frequency of dispersal types [%] of plant species living in prickly pear plantations under arid and semiarid climates in northeastern Algeria. Overall values are given as arithmetic means with standard deviations.

Climate region of rangelands	Year	Dispersal types [%]			
		Anemochores	Autochores	Barochores	Zoochores
Arid	2008	61.9 ± 6.7	—	39.2 ± 15.1	30.9 ± 3.3
	2009	24.4 ± 0.8	4.8 ± 0.1	51.0 ± 8.5	35.0 ± 7.0
	2010	63.5 ± 9.0	—	34.2 ± 8.0	31.4 ± 16.1
	Overall	49.9 ± 22.1	1.6 ± 2.8	41.4 ± 8.6	32.4 ± 2.2
Semiarid	2008	61.2 ± 1.7	—	40 ± 14.1	38.7 ± 1.7
	2009	47.5 ± 10.6	2.5 ± 3.5	37.5 ± 3.5	2.5 ± 3.5
	2010	70.0 ± 14.1	—	35.0 ± 7.0	25.0 ± 7.0
	Overall	59.5 ± 11.3	1.4 ± 0.8	37.5 ± 2.5	22.0 ± 18.3
ANOVA					
Climate effect	$F_{(1,6)}$	3.75	0.90	0.46	0.06
	P	0.100	0.378	0.519	0.809
Year effect	$F_{(2,6)}$	14.71	8.69	0.88	0.64
	P	0.004	0.016	0.460	0.559
Interaction (climate × year)	$F_{(2,6)}$	2.00	0.90	0.64	0.86
	P	0.215	0.453	0.556	0.465

Table 6. Frequency of chorological types [%] of plant species living in prickly pear plantations used for the rehabilitation of arid and semiarid rangelands in northeastern Algeria. Overall values are given as arithmetic means with standard deviations.

Chorological types	Climate regions of rangelands and study years							
	Arid climate				Semiarid climate			
	2008	2009	2010	Overall	2008	2009	2010	Overall
Cosmopolitan	18.2	3.6	16.6	12.8 ± 8.0	8.3	12.0	18.2	12.8 ± 5.0
Endemic to N. Africa	9.1	7.1	8.3	8.2 ± 1.0	—	—	—	—
Endemic to Sahara	—	7.1	—	2.4 ± 4.1	—	—	—	—
Eurasian	—	7.1	—	2.4 ± 4.1	8.3	20.0	—	9.4 ± 10.0
Ibero-Mauritanian	—	7.1	16.7	7.9 ± 8.3	—	—	—	—
Mediterranean	54.5	50	41.6	48.7 ± 6.5	83.3	72.0	63.6	73.0 ± 10.0
Paleo-temperate	9.1	3.6	—	4.2 ± 4.6	—	4.0	9.1	4.3 ± 4.6
Saharan-Arabian	—	3.6	—	1.2 ± 2.1	—	—	—	—
Saharan-Sindian	—	3.6	—	1.2 ± 2.1	—	—	—	—
SPCEWA *	—	—	8.3	2.8 ± 4.8	—	—	—	—
Irano-Tur-Eur	9.09	0	0	0	—	—	—	—
Undetermined	—	7.1	16.7	7.9 ± 8.3	—	—	—	—

Note. Some types (Mediterranean and Eurasian) are taken in a broad sense. Exp. Eurasian types include Mac-Eurasian and Eurasian.
* SPCEWA: Spain-Canaries to Egypt and West of Asia

Table 7. Frequency of Grime's strategies [%] of plant species found in prickly pear plantations grown under arid and semiarid climates in northeastern Algeria. Overall values are given as arithmetic means with standard deviations. Grime's strategies (C: competitive, S: stress tolerant, R: ruderal).

Climate region of rangelands	Year	Grime's strategies [%]					
		R	S	RS	CR	CS	CSR
Arid	2008	8.3 ± 11.7	15.4 ± 1.6	15.4 ± 1.6	50.5 ± 0.8	15.4±1.6	8.3 ± 11.7
	2009	7.3 ± 3.7	7.2 ± 3.2	56.1 ± 5.3	26.7 ± 2.5	9.7±0.3	4.8 ± 0.1
	2010	7.1 ± 10.1	12.1 ± 3.0	41.4 ± 2.0	24.2 ± 6.0	15.0±21.2	12.1± 3.0
	Overall	7.6 ± 0.6	11.6 ± 4.1	37.6 ± 20.6	33.8 ± 14.5	13.4 ± 3.1	8.4 ± 3.6
Semiarid	2008	16.2 ± 5.3	6.2 ± 8.8	48.7 ± 15.9	17.5 ± 10.6	27.5 ± 3.5	—
	2009	15.0 ± 0.0	2.5 ±3.5	62.5 ± 10.6	25.0 ± 7.1	7.5 ± 3.5	2.5 ± 3.5
	2010	20.0 ± 0.0	10.0 ±14.1	60.0 ± 28.2	20.0 ± 0.0	20.0 ± 0.0	5.0 ± 7.0
	Overall	17.0 ± 2.6	6.2 ± 3.7	57.0 ± 7.3	20.8 ± 3.8	18.3 ± 10.1	2.5 ± 2.5
ANOVA							
Climate effect	$F_{(1,6)}$	5.70	1.66	5.63	14.85	0.912	3.02
	P	0.054	0.244	0.055	0.008	0.376	0.132
Year effect	$F_{(2,6)}$	0.12	0.94	3.86	4.30	2.17	0.82
	P	0.888	0.438	0.083	0.069	0.194	0.482
Interaction (climate × year)	$F_{(2,6)}$	0.18	0.24	0.91	8.79	0.64	0.28
	P	0.836	0.789	0.451	0.016	0.559	0.763

Table 8. Frequency of Noy-Meir strategies [%] of plant species found in prickly pear plantations under arid and semiarid climates in northeastern Algeria. Overall values are given as arithmetic means with standard deviations.

Climate region of rangelands	Study years	Noy-Meir strategies	
		Arido-active	Arido-passive
Arid	2008	52.3 ± 26.9	47.6 ± 26.9
	2009	20.0 ± 7.0	80.0 ± 7.0
	2010	65.5 ± 20.3	31.4 ± 16.1
	Overall	45.9 ± 23.4	53.0 ± 24.7
Semiarid	2008	35.0 ± 21.2	65.0 ± 21.2
	2009	22.5 ± 10.6	77.5 ± 10.6
	2010	40.0 ± 0.0	60.0 ± 0.0
	Overall	32.5 ± 9.01	67.5 ± 9.01
ANOVA			
Climate effect	$F_{(1,6)}$	1.86	2.54
	P	0.220	0.161
Year effect	$F_{(2,6)}$	3.60	3.78
	P	0.093	0.086
Interaction (climate × year)	$F_{(2,6)}$	0.71	0.74
	P	0.527	0.512

level of grasses reached 88% and 95% in arid and semiarid PPPs, respectively. Woody species were weakly represented (range: 4.9%–34.2%). ANOVA indicated that only growth periods showed a significant variation in relation to 'year' factor for annuals ($F_{(2,6)}$ = 6.50, P = 0.031) and perennial species ($F_{(2,6)}$ = 5.70, P = 0.040). No significant differences were shown for climate, interactions, and the other types (Table 9).

4. Discussion

4.1. Diversity traits

Species richness in PPPs grown under the two climates is 50 plant species (31 species in semiarid climate and 36 in arid climate) attached to 17 families, which represents 1.25% of the total flora of Algeria (4000 species) (Yahi et al., 2012). The most represented families under both climates were unquestionably Asteraceae, Poaceae, and Fabaceae (other families were marginal). Generally, these three families are frequently found in continental and island regions of Algeria (Benhamiche-Hanifi and Moulai, 2012) and the Mediterranean region (Jeanmonod et al., 2011). According to Falaki et al. (2014), when degradation level of the vegetation is high, the number of plant species of some families such as Asteraceae increase in the flora of that region. Most of plant species recorded in this survey are annual plants, which are precipitation-dependent (Bradai et al., 2015). This particular situation was observed in semiarid rangelands during 2009, where precipitations reached 436.4 mm compared to 2008 with 376.2 mm and 2010 with 372.3 mm; whereas, in arid rangelands, rainfall was 147 mm in 2008, 225 mm during 2009, and 200.6 mm during 2010. Alatar et al. (2012) reported that the rainy season provides a good opportunity for the appearance of a considerable number of annual plants, which explains the high values of species abundances and richness in 2009.

Our findings showed significant differences in diversity parameters between years and the two climates of rehabilitated rangelands. It is well known that when both indicators of species richness and evenness in a community have relatively high values, this implies high species diversity in the area (Magurran, 2004). Bradai et al. (2015) argue that the floristic richness is very influenced by the rainfall regime, particularly in drylands of North Africa, where, following the often weak and irregular rainfall, there is an explosion of germination of annuals.

The values of Shannon and evenness indices are higher in semiarid rangelands compared to arid rangelands with a significant difference between study years and the type of climate. However, values of these indices remain low with H' = 1.84 and E = 0.51 for the semiarid against H'

Table 9. Frequency of morphological types [%] of plant species found in prickly pear plantations grown under arid and semiarid climates in northeastern Algeria. Overall values are given as arithmetic means with standard deviations.

Climate region of rangelands	Year	Morphological types [%]			
		Growth form		Growth period	
		Grass	Woody	Annual	Perennial
Arid	2008	75.5 ± 30.30	21.4 ± 30.2	32.1 ± 25.5	67.8 ± 25.2
	2009	88.0 ± 9.9	12.0 ± 9.9	75.7 ± 6.0	29.1 ± 5.8
	2010	65.7 ± 8.0	34.2 ± 8.0	19.8 ± 13.1	80.7 ± 13.1
	Overall	77.4 ± 17.7	22.5 ± 17.7	42.3 ± 29.4	54.2 ± 27.2
Semiarid	2008	86.6 ± 4.7	13.3 ± 4.7	51.6 ± 25.9	48.3 ± 25.9
	2009	95.0 ± 0.5	4.9 ± 0.5	80.0 ± 8.9	19.9 ± 8.9
	2010	85.4 ± 2.9	14.5 ± 2.9	58.3 ± 11.7	41.6 ± 11.7
	Overall	89.0 ± 5.3	10.9 ± 5.3	63.3 ± 18.8	36.6 ± 18.8
ANOVA					
Climate effect	$F_{(1,6)}$	2.18	2.19	4.54	5.28
	P	0.189	0.189	0.076	0.061
Year effect	$F_{(2,6)}$	1.38	1.38	6.50	5.70
	P	0.321	0.320	0.031	0.040
Interaction (climate × year)	$F_{(2,6)}$	0.26	0.26	1.04	0.79
	P	0.776	0.776	0.407	0.494

= 0.92 and E = 0.25 in arid rangelands. It is evident that these values cannot reflect balanced floristic assemblages. These values imply a real critical situation of the state that the degradation of Algerian steppes has reached. These fragile and vulnerable ecosystems are still being subjected to desertification combined with intense human pressure through overgrazing and ineffective land use management practices (Neffar et al., 2013). Moreover, we know that in all processes of land restoration or rehabilitation the early stages are characterized by the thriving of ruderal species, which under both types of climate have taken the first position according to Grime's strategies (ruderal-stress tolerators), Raunkiaer types (therophytes), or Noy-Meir's strategies (aridopassives).

4.2. Functional traits

This study revealed that the distribution of plant life forms is characterized by the following scheme: Ther > Hem > Geo and Cham in rehabilitated rangelands under semiarid conditions and Ther > Hem > Cham > Geo > Phan in rehabilitated rangelands under arid conditions. It is clear that therophytic plants predominated overall. They are followed by hemicryptophytes and then chamaephytes or geophytes. The high level of therophytes registered is in agreement with the study by Olivier et al. (1995) that argues that the level of this plant life form in the Mediterranean region is about 50%. Our results indicated high similarities of life form composition between the climates of study stations. These resemblances denote that most of plants have a ruderal strategy characterized by a broad ecological niche. The predominance of therophytes is generally a typical indicator of hot dry climates with human and animal disturbances (Neffar et al., 2013; Bradai et al., 2015) and can also occur under Mediterranean climatic conditions, whether in continental or insular habitats (Benhamiche-Hanifi and Moulai, 2012), especially when associated with strong disturbances (Grime, 2006). On the other hand, the heterogeneity of local topography, edaphic factors, and microclimatic conditions could lead to variation in the distributional pattern of plants (Abdel-Khalik et al., 2013; Chenchouni, 2017).

In Mediterranean vegetation landscapes subject to recurrent climate hazards such as intense and long droughts, the percentage of therophytes is usually high (Neffar et al., 2013) where primary productivity is limited by the seasonality of soil resources, mainly moisture and nitrogen (Seligman and van Keulen, 1989). Thus, therophytization is a characteristic of arid zones expressing a strategic adaptation to unfavorable conditions and a form of resistance to extreme climatic conditions (Jauffret and Lavorel, 2003; Bradai et al., 2015). Barbero et al. (1990) present therophytes as a form of resistance to drought and high temperatures in arid environments. In the same order of ideas, the importance of the disturbance index is proportional to the dominance of therophytes that find here a favorable environment for their development. It has been shown that therophytization of an area follows steppization, which is treated as the ultimate stage of degradation of different ecosystems (Barbero et al., 1990; Loisel and Gamila, 1993). The level of therophytization can be considered a proxy that indicates desertification stage and intensity (Jauffret and Lavorel, 2003). In our case, this index reached 50% and 70% in 2009.

It was denoted by Jauffret and Lavorel (2003) that ephemeral plants are more resistant to summer drought than hemicryptophytes and geophytes because they spend the summer in the form of seeds, while the others remain in the form of vegetative organs. Since the therophytes behave as drought-evaders, they are called ephemerophytes with an early flowering stage that is centered around the rainy season (Bradai et al., 2015). This allows plants to complete their life cycle in a few months or even a few weeks (Chenchouni, 2012). Hemicrytophytes, which take the second position in the scheme, rather prefer soils poor in organic matter (Barbero et al., 1990). Contrary to the usual pattern, chamaephytes of the Mediterranean region in general and semiarid in particular take third or last place after hemicryptophytes. It is true that they are better adapted to high temperatures and aridity than phanerophytes (Floret et al., 1990), since they partially reduce their transpiration and assimilation organs in summer (Danin and Orshan, 1990). As for the phanerophytes, the arid and semiarid climates are not favorable for their presence (Bradai et al., 2015), hence their absence or their small percentage in our case.

The analysis of the plant chorological spectrum of the surveyed PPPs shows a very heterogeneous flora (10 phytochoric elements) with a dominance of Mediterranean elements in the broad sense, which is the image of the Algerian flora as a whole (Quezel and Santa, 1963; Benhamiche-Hanifi and Moulai, 2012). According to Grapow and Blasi (1998), Mediterranean plant species are adapted to various forms of disturbances, including grazing, trampling, fire, etc. However, other biogeographical elements such as Ibero-Mauritanian, Eurasian, North African endemic, and others are slightly present. De Bélair and Samraoui (2000) considered this heterogeneity as a richness favored by the position of Algeria towards the Mediterranean basin. Furthermore, plant diversity, distributional patterns, and species ranges are mainly due to the particular position of North African ecosystems, including rangelands, between two very contrasting climates, a humid Mediterranean climate in the north and hot desertic climate in the south (Meddad-Hamza et al., 2017).

The taxa recorded at the study stations are predominantly anemochores, zoochores, barochores, and slightly autochores, which shows the importance of wind and effect of fauna as well as the role of livestock in arid regions (Bradai et al., 2015).

Reading the triangular model (CSR) describing the various equilibria that are possible between competition, stress, and disturbance (C: competitive, S: stress tolerant, R: ruderal) linked to different stages of succession (Smith et al., 2010), plant species recorded in both plantations are rich in intermediate strategies, especially ruderal-stress-tolerant species, followed by competitive-ruderals then competitive-stress-tolerant. Other strategies (S, R, and CSR) are present with a low percentage. Most of the plant species were ruderal-stress-tolerators. Species with this functional trait have a combination of stress-tolerant and ruderal traits. According to Çakir et al. (2010), competitive species, i.e. species with dominant competitive ability (C s.l. strategy: C+CR+CS) present high vegetative development, ecological plasticity, and occasionally some allelopathic potential (Vidal et al., 2000). Competitor-ruderals (CR) occurred under two selective pressures, competition and disturbance. Grime (2006) explained CR as adapted to circumstances in which there is a low impact of stress, while competition is restricted to a moderate intensity by disturbance.

According to Smith et al. (2010), in early phases of ecosystem succession fast-growing ruderal species are dominant, but in progressive phases of succession, because of competition, competitors are dominant. Competitor species have some selective advantages, such as rapid growth, and can be dominant in the vegetation, but ruderal species are characterized by rapid growth, high seed production, relative biomass, small stature with limited lateral spread, and high frequency of flowering (Grime, 2006). The situation seems difficult when it comes to linking the functional traits of plant species and the rehabilitation of the environment by a species such as *Opuntia ficus-indica.*

The value of the Jaccard index is 34%, representing a high dissimilarity in the floristic composition between the two climates of rangelands, where several functional types that exist under both climates are mostly therophytes (ephemerophytes). This group of plants species avoid drought by seasonal dormancy, especially annual herbs that complete their life cycle in just one single season reproduce just before the onset of the dry season and persist in the dry season as dormant seeds (Gao et al., 2015). It is true that this group of plants have the same behavior towards climatic constraint, which is aridity, but it is not true that all the species have the same ecological requirements for their growth (Kilinç et al., 2010), which explains the heterogeneity observed in Grime's spectrum. According to McIvor and McIntyre (1997), the balance between competition, stress, and disturbance is a major determinant of vegetation structure and species composition.

The coexistence of the two types of Noy-Meir's strategies with comparable levels in the arid climate or with differences in the semiarid climate is an indicator of the severe climatic conditions exerting selective forcing on a flora that avoids the "unfavorable climatic period". The ephemeral (arido-passive species) and persistent (arido-active species) types thus represent the two major strategies for surviving during the dry season (Evenari et al., 1975), especially through therophytes and chamaephytes. On the other hand, arido-passive plants are abundant during all stages of degradation due to their ability to avoid the drought period in various forms of dormancy (Glatzle, 1985). In contrast, Jauffret and Lavorel (2003) advanced that the qualitative analysis of the Noy-Meir's types does not make it possible to judge the degradation of the environment.

It is noteworthy to mention that the functional traits that characterize arid plant communities vary following temporal variations of environmental conditions such as the quantity of available water, soil fertility, and available light (Barbaro et al., 2000), and accordingly influence plant species to be grouped according to their tolerance to abiotic conditions (Lavorel et al., 1997). The vegetation is indicative of the responses of environmental conditions it undergoes (Chenchouni, 2017), including soil degradation, which is the case of North African rangelands that tend more and more towards desertification (Neffar et al., 2013). This decline appears clearly through the disturbance index estimated in plots planted for the purpose of rehabilitation, such as PPPs used as a plant nurse; the level of therophytes remains high around 50% during the 3 years (2008–2010) with the high level of 70% during 2009.

It would be very interesting to investigate this situation "high level of therophytes" with other perspective approaches. The establishment of PPPs is encouraged in these fragile environments because of prickly pear's innumerable ecological and economic benefits, especially for the revitalization of these habitats as a plant nurse. In addition, these ephemerophytes may be the element that triggers an early successional stage towards a more diverse and complex vegetation and thus indicates a spontaneous restoration process of rangelands. The disturbance index calculated at this stage does not imply tangible evidence about the deterioration of the Algerian rangelands. A new approach is needed to be developed to ensure a successful and sustainable rehabilitation of degraded environments in drylands. This approach should not consider the abundance of therophytes as an indicator of desertification, but rather a sign of biological regeneration since these ephemeral annual plants represent a pool of carbon and thus of soil organic matter of from that this ecosystem is lacking.

Finally, this evaluation represents just preliminary results contributing to the characterization of the first stages of evolution of the analyzed perimeters planted by the prickly pear. It is necessary to continue investigations in order to trace the dynamics of these plantations and to affirm or disprove their success in the rehabilitation of degraded pastoral areas.

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Appendix 1. Location, climatic, and soil characteristics of study prickly pear plantations (PPPs) in northeastern Algeria.

Site features	Study stations	
	Anba	M’Zara
Location		
Latitude	35°25′08.3″N	34°51′08.4″N
Longitude	08°01′42.4″E	08°15′05.3″E
Elevation (m a.s.l.)	887	780
Plot area of PPP [km^2]	0.01	0.01–0.04
Climate characteristics		
Emberger classification	Semiarid with fresh winter	Arid with fresh winter
Köppen–Geiger class	BSk	BSk
	B = Arid climate	B = Arid climate
	S = Steppe	S = Steppe
	k = Cold	k = Cold
Budyko climate class	Desert	Desert
Radiation index of dryness	3.497	4.314
Budyko evaporation [mm/year]	352	308
Budyko runoff [mm/year]	9	4
Budyko evaporation [%]	97.4	98.7
Budyko runoff [%]	2.6	1.3
Aridity index	0.31	0.24
Aridity index class	Semiarid	Arid
Moisture index (MI) [%]	–69	–76
De Martonne index	14.7	6.7
Precipitation deficit [mm/year]	802	1002
Climatic net primary production	639	561
NPP (temperature)	1896	1993
NPP (precipitation)	639	561
NPP limitation	Precipitation	Precipitation
Gorczynski continentality index	36.8	38.5
Soil characteristics		
Soil texture	Clay, silty-clay, loamy-silty-clay	Silty
Organic matter [%]	3.12 ± 0.41	0.59 ± 0.45
pH	8.01 ± 0.13	8.14 ± 0.03

*NPP: net primary production in g of dry matter/m^2/year is precipitation limited.

Appendix 2. Functional traits and ecological characteristics of plant species recorded in prickly pear plantations used for the rehabilitation of arid and semiarid rangelands in northeastern Algeria.

Family	Species	Functional traits and ecological characteristics						
		LF	DT	CT	NMT	Grime	GF	Gp
Apiaceae	*Eryngium campestre* L.	Geo	Ane	Eur-Med	AA	RS	G	Pr
Asteraceae	*Artemisia campestris* L.	Ch	Ane	Med	AA	RS	W	Pr
	Artemisia herba-alba Asso	Ch	Bar	SPCEWA	AA	RS	W	Pr
	Echinops spinosissimus Turra	Hc	Zoo	S.Med.Sah	AP	CR	G	An
	Anthemis arvensis L.	Th	Bar	Med	AP	R	G	An
	Asteriscus aquaticus (L.) Less.	Th/Hc	Bar	Med	AP	RS	G	An
	Pallenis hierochuntica (Michon) Greuter	Th	Zoo/Bar	Sah-Sind	AP	RS	G	An
	Pallenis spinosa (L.) Cass.	Hc	Ane	Euro-Med	AP	RS/CR	G	An
	Calendula arvensis M.Bieb.	Th	Zoo	Submed	AP	RS	G	An
	Reichardia tingitana (L.) Roth	Th	Bar	Iber-Mar	AP	SR/CS	G	An
	Reichardia picroides (L.) Roth	Hc	Bar/Ane	Med	AP	RS/CS	G	An
	Centaurea sp.	Th	Zoo	Und	AP	RS	G	An
Boraginaceae	*Echiochilon fruticosum* Desf.	Ch	Bar	Sah-Ara	AA	CS	W	Pr
Brassicaceae	*Sinapis arvensis* L.	Th	Bar	Paleo-Tem	AP	S/CR	G	An
	Raphanus raphanistrum L.	Th	Bar	Med	AP	CR	G	An
	Matthiola capiomontana (Durieu) Pomel	Th	Bar	End NA	AP	RS	G	An
	Diplotaxis erucoides (L.) DC.	Th	Ane/Bar	Med	AP	RS	G	An
Chenopodiaceae	*Anabasis articulata* (Forssk.) Moq.	Ch	Bar	End.Nor-Sah	AA	S	W	Pr
	Haloxylon scoparium Pomel	Ch	Ane	Sah-Med	AA	S	W	Pr
Euphorbiaceae	*Euphorbia guyoniana* Boiss. & Reut.	Hc	Zoo	End Sah	AP	RS	G	An
	Euphorbia helioscopia L.	Th	Zoo	Eura	AP	R	G	An
Fabaceae	*Hippocrepis unisiliquosa* L.	Th	Zoo	Med	AP	RS	G	An
	Medicago littoralis Loisel.	Th	Zoo	Med	AP	RS	G	An
	Lotus sp.1	Hc/Th	Aut	Und	AP	RS	G	Pr/An
	Lotus sp.2	Hc/Th	Aut	Und	AP	RS	G	Pr/An
	Retama monosperma (L.) Boiss.	Ph	Zoo	Ibero-Maur	AA	S	W	Pr
	Astragalus armatus Willd.	Ch	Bar	End NA	AA	CR	W	Pr
	Astragalus hamosus L.	Th	Bar	Med	AP	RS	G	An
	Coronilla scorpioides (L.) Koch	Th	Aut	Med	AP	RS	G	An
	Melilotus officinalis (L.) Lam.	Th	Bar	Euras	AP	RS	G	An
	Medicago orbicularis (L.) Bartal.	Th	Ane	Med	AP	RS	G	An
Geraniaceae	*Erodium moschatum* (L.) L'Hér.	Th	Zoo	Med	AP	RS	G	An
Lamiaceae	*Ajuga iva* (L.) Schreb.	Ch	Zoo/Bar	Med	AA	S	G	Pr
Liliaceae	*Asparagus horridus* L.	Hc	Zoo/Ane	Macar-Med	AA	CS	G	Pr
Malvaceae	*Malva sylvestris* L.	Hc	Bar	Euras	AA	CR	G	Ba/Pr
Plantaginaceae	*Plantago albicans* L.	Hc	Ane/Bar	Med	AP	CRS	G	Pr

Appendix 2. (Continued).

Poaceae	*Cynodon dactylon* (L.) Pers.	Geo/Hc	Ane	Cosm	AA	CR	G	Pr
	Hordeum murinum L.	Th	Zoo/Ane	Cosm	AP	RS/R	G	An
	Stipa capensis Thunb.	Th	Zoo	Circum-Med	AP	RS	G	An
	Stipa tenacissima L.	Hc/Geo	Ane	Ibero-Maur	AA	CS	G	Pr
	Stipella parviflora (Desf.) Röser & Hamesha	Geo	Ane	Med	AA	CS	G	Pr
	Melica ciliata L.	Hc	Ane	Mac-Euras	AA	RS	G	An
	Avena sativa L.	Th	Zoo	Med	AP	R	G	An
	Aegilops triuncialis L.	Th	Ane	Med-Irano-Tur	AP	RS	G	An
	Bromus madritensis L.	Th	Ane	Eur-Med	AA	CR	G	An
Primulaceae	*Lysimachia monelli* (L.) U.Mann & Anderb.	Ch	Ane	Med/Cosm	AP	RS	G	An
Resedaceae	*Reseda alba* L.	Th	Bar/Zoo	Euras	AP	RS	G	An
Scrophulariaceae	*Linaria reflexa* (L.) Desf.	Th	Ane	Med	AP	RS	G	An
Zygophyllaceae	*Peganum harmala* L.	Geo	Bar	Irano-Tur-Eur/Cosm	AP	CR	G	Pr

LF: life form [Ch: chamaephyte, Geo: geophyte, Hc: hemicryptophyte, Phan: phanerophyte, Th: therophyte],
CT: chorological types (following Quezel and Santa, 1963) [Circum-Med: Circum-Mediterranean; Cosm: cosmopolitan; Eur-Med: Euro Mediterranean; End.NA: Endemic to North Africa; End.Nor.Sah: Endemic to North Sahara; End-Sah: Endemic to Sahara; Euras: Eurasian; Ibero-Maur: Ibero-Mauritanian- Irano-Tur-Eur: Irano-Turanian European - Mac-Euras: Mac-Eurasian; Macar-Med: Macaronesian Mediterranean; Med: Mediterranean; Med-Irano-Tur: Mediterranean Irano-Turanian; Paleo-temp: Paleo-temperate; Sah-Ara: Saharan-Arabian; Sah Med: Saharan Mediterranean; S.Med.Sah: Sub-Mediterranean Saharan; Sah.Sind: Saharian Sindian; SPCEWA: Spain-Canaries to Egypt and West of Asia; Und: Undetermined].
DT: dispersal types [Ane: anemochores, Auto: autochores, Baro: barochores, Zoo: zoochores],
NMT: Noy-Meir's strategies [AA: arido-actives, AP: arido-passives],
CRS: Grime's strategies [C: competitive, S: stress-tolerant, R: ruderal],
GF: growth form [G: grass, W: woody],
GP: growth period [An: Annual, Ba: Biannual, Pr: Perennial].

Appendix 3. Specific total abundance (*Ni*) and relative abundance (*RA* in %) of plant species recorded in prickly pear plantations used for the rehabilitation of arid and semiarid rangelands in northeastern Algeria.

Plant species	Climate regions of rangelands					
	Semiarid		Arid		Overall	
	Ni	*RA*	*Ni*	*RA*	*Ni*	*RA*
Eryngium campestre	2	0.25	4	0.89	6	0.48
Artemisia campestris	137	17.3	2	0.44	139	11.19
Artemisia herba-alba	—	—	1	0.22	1	0.08
Echinops spinosissimus	11	1.39	2	0.44	13	1.04
Anthemis arvensis	26	3.29	31	6.87	57	4.58
Asteriscus aquaticus	1	0.13	—	—	1	0.08
Pallenis hierochuntica	—	—	1	0.22	1	0.08
Pallenis spinose	5	0.63	—	—	5	0.40
Calendula arvensis	13	1.64	3	0.67	16	1.28
Reichardia tingitana	—	—	1	0.22	1	0.08
Reichardia picroides	77	9.73	7	1.55	84	6.76
Centaurea sp.	—	—	1	0.22	1	0.08
Echiochilon fruticosum	—	—	5	1.11	5	0.40
Sinapis arvensis	17	2.15	7	1.55	24	1.93
Raphanus raphanistrum	—	—	19	4.21	19	1.52
Matthiola capiomontana	—	—	27	5.99	27	2.17
Diplotaxis erucoides	—	—	1	0.22	1	0.08
Anabasis articulata	—	—	3	0.67	3	0.24
Haloxylon scoparium	—	—	1	0.22	1	0.08
Euphorbia guyoniana	—	—	1	0.22	1	0.08
Euphorbia helioscopia	2	0.25	—	—	2	0.16
Hippocrepis unisiliquosa	27	3.41	4	0.89	31	2.49
Medicago littoralis	57	7.21	5	1.11	62	4.99
Lotus sp. 1	—	—	1	0.22	1	0.08
Lotus sp. 2	—	—	1	0.22	1	0.08
Retama monosperma	—	—	12	2.66	12	0.96
Astragalus armatus	—	—	19	4.21	19	1.52
Astragalus hamosus	46	5.82	2	0.44	48	3.86
Coronilla scorpioides	2	0.25	—	—	2	0.16
Melilotus officinalis	34	4.30	—	—	34	2.73
Medicago orbicularis	7	0.88	—	—	7	0.56
Erodium moschatum	1	0.13	2	0.44	3	0.24
Ajuga iva	1	0.13	—	—	1	0.08
Asparagus horridus	—	—	8	1.77	8	0.64
Malva sylvestris	5	0.63	—	—	5	0.4
Plantago albicans	75	9.48	49	10.86	124	9.98
Cynodon dactylon	4	0.51	114	25.28	118	9.50
Hordeum murinum	176	22.2	17	3.77	193	15.53

Appendix 3. (Continued).

Stipa capensis	—	—	64	14.19	64	5.15
Stipa tenacissima	—	—	1	0.22	1	0.08
Stipella parviflora	25	3.16	—	—	25	2.01
Melica ciliata	2	0.25	6	1.33	8	0.64
Avena sativa	2	0.25	—	—	2	0.16
Aegilops triuncialis	4	0.51	—	—	4	0.32
Bromus madritensis	13	1.64	—	—	13	1.04
Lysimachia monelli	17	2.15	—	—	17	1.36
Reseda alba	1	0.13	2	0.44	3	0.24
Linaria reflexa	1	0.13	1	0.22	2	0.16
Peganum harmala	—	—	26	5.76	26	2.09
Total abundance	791	100	451	100	1242	100