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The autecological characteristics of *Desmostachya bipinnata* in hyper-arid regions

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Abstract: This study aimed to investigate the main autecological characteristics of *Desmostachya bipinnata* L. (Poaceae) in a hyper-arid region. The study was carried out on Sistan plain, south-eastern Iran. The habitats of *D. bipinnata* were identified and then the climatic and edaphic characteristics of habitats were determined. Phenological stages, reproduction, root system, and nutritive and preference values of *D. bipinnata* were also studied. One single habitat of *D. bipinnata* was identified on Sistan plain. Average annual rainfall and temperature of the habitat were 60 mm and 21.8 °C, respectively. Loamy and loamy sand soils of the habitat had EC and pH values of 10-60 DS/m and 8.03-8.31, respectively. Secondary roots of *D. bipinnata* penetrated up to 2 m depth in soil. Mean canopy cover was 21.3% in the habitat. Vegetative growth started in the middle of February followed by flowering in May and seed ripening in July. Crude protein content of leaves and stems was 7.56% and 6.71% during vegetative growth, respectively. For both sheep and goats, *D. bipinnata* had a similar preference value of 25%. This species, with high resistance to unfavourable conditions, can be used for rehabilitation of desertified rangeland in hyper-arid regions.

Key words: Autecology, *Desmostachya bipinnata*, habitat, Iran, rangeland, Sistan

Introduction

Recently, interest in the ecology of plants in desert areas has increased (Abdel-Ghani et al., 2011). Knowledge of ecological factors such as soil, topography, climate, and disturbance influencing plant species distribution is essential for conservation, management, and recovery of rangeland ecosystems (Ajeer & Shahmoradi, 2007; Nautiyal et al., 2009). At present, saxaul (*Haloxylon* sp.) and saltcedar (*Tamarix* spp.) are the major plant species employed in combating desertification and rehabilitating desertified rangelands on Sistan plain, Iran. However, there are many other native plant species such as caper (*Capparis spinosa* L.), *Calligonum* sp., and sacrificial grass (*Desmostachya bipinnata*) in hyper-arid regions that evolved in these environmental conditions. By knowing and understanding the ecological requirements of such native plant species, they can be used for improving desertified rangelands (Azarnivand & Dsamalchi, 1998) as establishment of exotic plant species is more costly than that of native species.

Autecological studies are essential for determination of the ecological requirements of

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plant species and provide basic knowledge for relevant authorities such as range managers (Abarseji et al., 2007) in identifying suitable plant species for the rehabilitation of degraded rangeland. Many studies (Saeedfar et al., 2003; Bashari & Shahmoradi, 2004; Kaya & Aksakal, 2007; Farahani et al., 2008) reported the autecological characteristics of various range plants species throughout the world. Bashari and Shahmoradi (2004) found no soil texture restrictions on the establishment of 3 range plants, i.e. *Artemisia siebiri* Besser, *Ferula gummosa* Boiss., and *Stipa hohenackeriana* Trin. & Rupr., in arid rangelands of Qom Province, Iran. Saeedfar et al. (2003) reported that *Salsola orientalis* S.G.Gmel. can be used for the rehabilitation of rangelands in poor ecological conditions in the central steppes of Iran. Ajeer and Shahmoradi (2007) found that *Ferula ovina* Boiss. can productively grow on calcareous soils with EC < 1 mmohs/cm, pH between 7 and 7.7, and sandy texture. A study by Farahani et al. (2008) on *Stipa barbata* Desf. showed that the loamy sandy and clay loamy soils with pH of 8.1 to 8.7 are principal soils in its habitats at semi-arid rangelands of Tehran Province, Iran. Kaya and Aksakal (2007) found a relationship between the distribution pattern of *Salvia rosifolia* Sm. and the concentrations of N, P, and K in soil. However, no study has reported the ecological requirements of *Desmostachya bipinnata* to date. Sacrificial grass (*D. bipinnata*) is an indigenous forage plant species in Sistan that grows productively under unfavourable conditions such as sandstorm, extreme temperatures, drought, and water stress (Gulzar et al., 2007). The objective of this study was to investigate some autecological characteristics of *D. bipinnata* to reveal its ecological requirements and provide basic knowledge for its successful establishment and survival in desertified rangeland.

Materials and methods

Study area

The study was carried out on Sistan plain, south-eastern Iran. Sistan, with a total area of 8350 km^2, lies between 60°36′18″ and 61°48′24″E longitude and 30°32′3″ and 31°32′50″N latitude (Figure 1). The mean elevation of the area is 480 m above msl. The climate was hyper-arid with mean annual precipitation and temperature of 60.8 mm and 22 °C, respectively. January and July were the months with mean minimum and maximum temperatures of −12 and 51 °C, respectively. Mean relative humidity

Figure 1. The location of study area.

and annual evaporation were 38% and 4820 mm over previous 20 years, respectively. The Sistan plain, with mean slope of 0.025%, is located on the alluvial deposits of the Hirmand River. Hirmand is a transboundary river; it originates from Hindu-kush Mountains in Afghanistan and terminates in Hamoon Lake on Sistan plain.

Desmostachya bipinnata is a perennial, bunch, and erect grass plant belonging to the tribe Eragrosteae, family Poaceae. It is a native grass in coastal and inland deserts (Pandeya & Pandeya, 2002) of Iran, India, China, Pakistan, Central Asia, Middle East, and northern Africa (Bor, 1960).

Measurement of habitat characteristics

The distribution area (habitat) of *D. bipinnata* was delineated through screening of the literature, i.e. published reports, land use maps, and vegetation type maps, as well as field inspection. A key area (300 m × 1700 m) with 3 replications was selected in the habitat of *D. bipinnata* with respect to its distribution pattern, grazing pattern, and being far enough from livestock watering points and camping sites. Hereafter, all measurements were performed only in the selected key areas.

The climatic (temperature, rainfall), topographic (slope, altitude), and edaphic (physical and chemical) properties of the habitat were determined in the key areas. Meteorological data including rainfall, temperature, evaporation, and relative humidity were obtained from Zabol Airport meteorological station. Three soil profiles were randomly dug at each key area and sampled every 30 cm up to 90 cm depth. Soil samples were analysed for OC, EC, pH, exchangeable cations (Na, Mg, and Ca), and texture. Plant height, density, abundance, canopy cover, and yield of *D. bipinnata* were directly measured in the field using the transect and quadrat method (Mannetje, 1978). Transect lines (300 m in length) were located systematically with 4 quadrats (10 m^2) located randomly on each. Each key area had 4 equally spaced transects spaced 350 m apart. Rooting depth was also measured in each soil profile. Major phenological stages of the species were recorded by weekly field inspection and interviews with rural villagers. Palatability, grazing timings, and dominant animal type in the area were asked to local people. Animal forage preference was determined as percent time spent grazing on the species (Lugenja et al., 1988). Nutritive value of *D. bipinnata* during vegetative growth, flowering, and seeding was determined by measuring crude protein (CP). Finally, the effects of various concentrations of EC on germinative capacity of seeds were measured in the lab.

Statistical analyses

Assumptions of normality and homogeneity of variance were checked and found to be valid. Duncan's test was used to compare the difference among all key areas in the habitat with regards to soil and plant characteristics. Meanwhile, an independent *t*-test was applied to compare 2 habitats, i.e. with and without *D. bipinnata*, to determine the effect of this species on soil chemical elements. All the tests were run using SPSS (SPSS Inc., 2007). A $P < 0.05$ level for testing significance was used in this study.

Results and discussion

Only 1 habitat of *D. bipinnata*, with an area of 1800 km^2, was identified in the north-eastern part of Sistan plain. The habitat lies between 61°15′ and 61°50′E longitude and 30°17′ and 31°45′N latitude. *D. bipinnata* was the dominant species and *Alhagi camelarum* Fisch. and *Tamarix* sp. were associated species in this habitat.

Using the De Martonne climate classification, the habitat of *D. bipinnata* was categorised as hyper-arid. The De Martonne aridity index (IdM) value was 1.9 in the habitat. Furthermore, according to the Köppen classification, the habitat was a very hot and dry region. The mean annual rainfall and temperature were about 60 mm and 21.8 °C for the habitat, respectively, with the bulk of the rains concentrated in January and February. Mean relative humidity in the habitat was 38% over 20 years.

The average canopy cover of *D. bipinnata* was 21.3% across the habitat. *D. bipinnata* started vegetative growth in the middle of February and reached peak growth in early May and fully flowered at the end of May. The duration of each growth stage of *D. bipinnata* is presented in a phenological diagram (Figure 2). Rooting depth of secondary roots, growing from rhizomes, was up to 2 m in soil. About

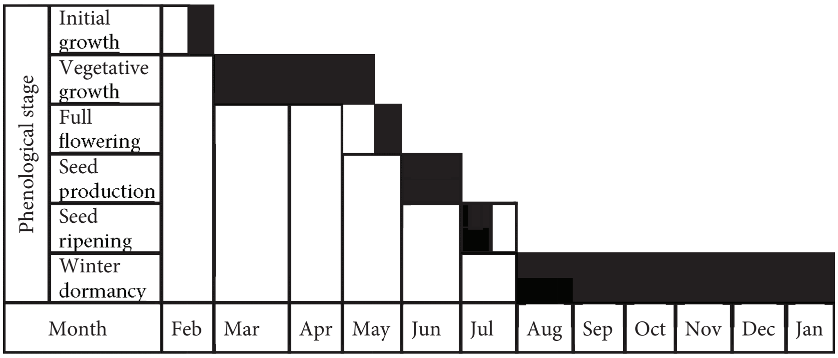

Figure 2. Phenological diagram of *Desmostachya bipinnata* on Sistan plain.

50%-55% of the root system was in surface soils (0-30 cm). Root branching in the middle parts of roots was lower than in the top and bottom parts. Furthermore, root branching was radial in deeper depths. The results showed that rooting depth of *D. bipinnata* in sandy soils was deeper than in clayey soils (Table 1).

Germinating capacity of seeds was 90% in laboratory conditions, but was reduced by increasing salinity level in the medium. However, it was still able to germinate in a salinity level up to 500 mmol. This can be attributable to differences in metabolic response to salinity effects during germination (Khan et al., 2006). Hamed et al. (2006) also reported similar results in relation to germinating capacity and salinity level.

As mentioned earlier, the habitat of *D. bipinnata* was located in the north-eastern part of Sistan plain. This is mainly due to the low reproduction capacity of species in the region. *D. bipinnata* produced large amounts of seeds in its habitat, but it was not able to reproduce by seed in this environment due to having tiny seeds and the locally harsh environmental conditions. It reproduces mainly by rhizomes in its habitat on Sistan plain. This reproduction method limits the distribution of the species in the region. However, this species can potentially establish itself across the region except in areas with heavy soil texture provided the availability of seed or rhizome.

Soils of the habitat were aridisols with a temperature regime of hyperthermic and a moisture regime of aridic. *D. bipinnata* was more abundant on light texture (sandy) than on heavy texture (clay) soils. Soil pH ranged from 8.03 to 8.31 across the habitat of *D. bipinnata*. The EC value in surface soil (0-30 cm) varied from 7.6 to 60 DS/m in the habitat, indicating that this species can tolerate high soil salinity (Table

Table 1. The morphological characteristics of *Desmostachya bipinnata* in the study area.

Variables	Key area			Mean in habitat
	1	2	3	
Canopy cover (%)	28a	22a	14b	21.3
Height (cm)	127.8a	104.3b	51.0c	94.4
Spike length (cm)	37.7a	28.8b	14.0c	26.8
Leaf length (cm)	35.4a	23.8b	10.3c	23.2
Leaf width (mm)	5.57a	4.29b	3.78b	4.5
Culm diameter (mm)	4.1a	3.9a	3.1b	3.7
Rooting depth (cm)	111.6a	77.5b	38.25c	75.8

Values with unlike letter in a row are significantly different at 0.05 level

Table 2. The mean values of soil chemical variables in the habitat of *Desmostachya bipinnata*.

Chemical properties	Key area								
	1			2			3		
	Soil depth (cm)			Soil depth (cm)			Soil depth (cm)		
	0-30	30-60	60-90	0-30	30-60	60-90	0-30	30-60	60-90
OC (%)	0.58a	0.46b	0.30c	0.35a	0.42b	0.32a	0.28a	0.36b	0.29a
pH (-log[H^+]	8.03a	7.94b	7.64b	8.31a	8.19b	8.23a	8.05a	8.21b	8.23b
EC (ds/m)	22.0a	17.2b	15.7b	23.0a	16.9b	10.15c	33.9a	19.5b	14.7c
SAR	22.3a	16.7b	19.6c	22.48a	13.7b	10.1b	28.13a	24.86b	21.8b
Na^+ (mEq/L)	142.5a	106.5b	102.0b	145.7a	80.5b	47.9c	228.3a	120.2b	99.7c
Sand (%)	44a	30b	34b	27a	25a	10b	10a	7b	7b
Clay (%)	15a	18a	15a	16a	26b	37a	45a	50a	52a
Silt (%)	51a	52a	51a	57a	49a	53a	40a	48a	50a

Note: Values with unlike letter in a row are significantly different at 0.05 level.

2). Canopy cover and other measured vegetal factors of *D. bipinnata* decreased with increasing salinity and sodium absorption ratio (SAR) in soils with similar texture. The morphological characteristics of *D. bipinnata*, e.g., height, diameter, leaf length, and width, in sandy soils with low EC level were greater than in the clay and more saline soils. These morphological factors were negatively affected in heavy texture soil. Gulzar et al. (2007) stated that the yield of *D. bipinnata* decreased with increasing soil salinity and decreasing pH values. The morphological characteristics, i.e. reproductive and vegetative, of *D. bipinnata* were significantly different in rangeland with different conditions (Pandeya & Pandeya, 2002).

With respect to similar topographic and climatic conditions across the region, it can be concluded that soil properties were major determinants in the establishment and distribution of *D. bipinnata*. Danin (2008) stated that the edaphic factor has a high impact on the distribution of plants in desert areas. Soil texture, pH, EC, and SAR were more important factors than others among the soil properties. For example, this species was more abundant on soils with pH and EC of 8.03-8.31 and 7.64-33.9 DS/m, respectively. This is consistent with the findings reported by Aronson (1989) that *D. bipinnata* can tolerate soil EC up to 56 DS/m. *D. bipinnata* was dominant in soils with high EC and pH levels in which other species were unable to survive.

Table 3. The effect of *Desmostachya bipinnata* on selected chemical properties of soil.

Elemental concentration	With *D. bipinnata*	Without *D. bipinnata*
N (%)	0.15a	0.04b
P (mg/kg)	5.0a	0.5b
K^+ (mg/kg)	22.5a	3.0b
Na^+ (mg/kg)	150a	160a
Mg^{++} (mg/kg)	25a	11b
Ca^{++} (mg/kg)	160a	100b

Note: Values with unlike letter in a row are significantly different at 0.05 level.

The comparison of soils in the habitats with and without *D. bipinnata* showed that soil chemical elements, e.g., Ca, N, Na, K, P, and Mg, were significantly affected by the presence of this species. Table 3 depicts the effects of *D. bipinnata* on soil chemical elements. The concentrations of N, P, Ca, K, and Mg were significantly greater in the soils with *D. bipinnata* than in the soils without this species (Table 3). Malik et al. (1991) reported that *D. bipinnata* improved soil chemical and physical properties.

D. bipinnata had a similar preference value of 25% for both sheep and goat grazing. Although it has low palatability, it can be a good fodder resource for animals in the hyper-arid region due to relatively high protein content (7.56%) during vegetative growth. It should be mentioned that the average amount of protein in the animal diet is about 8%-10% (Oanh, 2002). The best harvesting or grazing time of *D. bipinnata* is in May, when it reaches peak vegetative growth. Gulzar et al. (2007) also reported that *D. bipinnata* contains the highest nutritive value in the middle of May.

Conclusions

Hyper-arid regions receive very low annual rainfall (<100 mm/year) and are subject to periodic drought and extreme temperatures, which may accelerate vegetation degradation, wind erosion, and sandstorm events, particularly in areas with seasonal wind, like Sistan. Native plant species that have evolved within these regions are perfectly adapted to thrive in the current climate, soil, and environmental conditions. *D. bipinnata* is a native plant species in Sistan that has adapted perfectly to unfavourable environmental conditions such as periodic drought, seasonal wind, sandstorms, extreme temperatures, and overgrazing on Sistan plain. It can be effectively used for rehabilitation of desertified rangeland and improvement of degraded rangeland in hyper-arid regions. Soil properties are major determinants in the establishment and distribution of *D. bipinnata* on Sistan plain. In addition, *D. bipinnata* could be a good fodder resource for animal in hyper-arid regions due to its relatively high protein content (7.56%) during vegetative growth. Peak vegetative growth is the best harvesting and grazing time of this species.

References

Abarseji GH, Shahmoradim I & Zarekia S (2007). Investigation of autecology of *Hedysarum kopetdaghi* in rangelands in Golestan Province. *Iranian Journal of Range and Desert Research* 14: 421-431 (in Persian).

Abdel-Ghani M, Abo el-Kheir M, Abdel-Dayem M & Abd el-Hamid M (2011). Vegetation analysis and soil characteristics of five common desert climbing plants in Egypt. *Turkish Journal of Botany* 35: 561-580.

Ajeer F & Shahmoradi A (2007). Autecology of range plants species of *Ferula ovina* in Tehran Province. *Iranian Journal of Range and Desert Research* 14: 367-359 (in Persian).

Aronson JA (1989). *HALOPH, a Data Base of Salt Tolerant Plants of the World*. Tucson: University of Arizona Press.

Azarnivand H & Dsamalchi H (1998). Phenology of four plants species in Kashan desert region. *Desert Journal* 5: 15-25 (in Persian).

Bashari H & Shahmoradi A (2004). Autecology of three range plants species, *Artemisia sieberi*, *Stipa hohenackeriana* and *Ferula gumosa* in range ecosystems of Ghom Province. *Iranian Journal of Range and Desert Research* 11: 287-307 (in Persian).

Bor NL (1960). *The Grasses of Burma, Ceylon, India and Pakistan*. Oxford: Pergamon Press.

Danin A (2008). Desert rocks – a habitat which supports many species that were new to science in the last 40 years. *Turkish Journal of Botany* 32: 459-464.

Farahani A, Shahmoradi A, Zarekia S & Azhir F (2008). Autecology of *Stipa barbata* in Tehran Province. *Iranian Journal of Range and Desert Research* 15: 86-94 (in Persian).

Gulzar S, Khan MA & Liu X (2007). Seed germination strategies of *Desmostachya bipinnata*: a fodder crop for saline soils. *Rangeland Ecology and Management* 60: 401-407.

Hamed A, Zaheer M & Khan MA (2006). Comparative effects of NaCl and sea salt on seed germination of coastal halophytes. *Pakistan Journal of Botany* 38: 1605-1612.

Kaya Y & Aksakal O (2007). The morphological and autecological properties of *Salvia rosifolia* Sm. (Lamiaceae) grown in Erzurum and its Environs in Turkey. *Pakistan Journal of Biological Science* 10: 2178-2184.

Khan MA, Ahmed MZ & Hameed A (2006). Effect of sea salt and L-ascorbic acid on the seed germination of halophytes. *Journal of Environment* 67: 535-540.

Lugenja MMS, Mero RN & Kajuni AR (1988). Relationship between phytomass productivity, animal forage preference and environmental factors on semi-arid grazed and ungrazed key range plants in Tanzania. *In*: Proceedings of the Third Workshop on African Forage Plant Genetic Resources, Evaluation of Forage Germplasm and Extensive Livestock Production Systems. 27-30 April, Arusha, Tanzania.

Malik KA, Bilal R, Rasul G, Mahmood K & Sajjad MI (1991). Associative N2-fixation in plants growing in saline soils and its relative quantification based on 15N natural abundance. *Journal of Plant and Soil* 137: 67-74.

Mannetje L (Ed.) (1978). *Measurement of Grassland Vegetation and Animal Production.* Commonwealth Agricultural Bureau, Bulletin 52, Hurley, Berkshire, England.

Nautiyal BP, Nautiyal MC, Khanduri VP & Rawat N (2009). Floral biology of *Aconitum heterophyllum* Wall.: A critically endangered alpine medicinal plant of Himalaya, India. *Turkish Journal of Botany* 33: 13-20

Oanh BT (2002). Developments and issues relating to livestock production, protein supplies and the feed industries of Vietnam. *In*: Proceedings of FAO Animal Production and Health: Protein Sources for the Animal Feed Industry. 29 April-3 May, Bangkok, Thailand.

Pandeya A & Pandeya SC (2002). Environment and population differentiation in *Desmostachya bipinnata* (Linn.) in western India. *Journal of Tropical Ecology* 43: 359-362.

Saeedfar M, Khodagholi M, Fezi M & Shahmoradi A (2003). Investigation of autecological properties of *Salsola orientalis* in steppe rangeland in Esfahan Province. *Iranian Journal of Range and Desert Research* 13: 116-127 (in Persian).

SPSS Inc., 2007, SPSS 16.0 for Windows, Release 16.0.1. SPSS Inc. an IBM company, Chicago, Illinois.