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Research Article

Abundance and occurrence of *Danae racemosa* growing in Hyrcanian forest understory about static and dynamic environmental variables

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Abstract

Danae racemosa L., an endangered species, is an erect, evergreen shrub that grows in the shaded forest understory in the Hyrcanian forests of Iran. Except for limited knowledge of the sporadic occurrence of *D. racemosa* in unique moist locations, there is not much information about its ecological preferences and environmental requirements. This study investigated the relationship of *D. racemosa* presence (abundance) and occurrence with static (soil properties and elevation from sea level) and dynamic (climate, precipitation, and human disturbance) variables. Plant and soil samples from 21 locations of occurrence (sites) of *D. racemosa* were collected along the Caspian Sea's southern coastline. At each site of occurrence (site), three 100 m^2 (10×10 m) plot was set up, and plant biometry and density were recorded. Soil samples were taken from depths of 0-25 cm and left to air dry in the lab. Later, dried soil samples were crust left to pass through a 2 mm mesh sieve and analyzed for different physicochemical properties. Meteorological data over the past 10 years (2009-2019) in the relevant area were obtained from Iran Meteorological Organization. Cluster analysis classified 21 sampling sites into four groups of habitats. Data were analyzed using Principal Component Analysis (PCA) methods and habitats are classified based on environmental factors. Correlation analysis between environmental factors and density showed that soil texture (clay content), precipitation, and human activity are the most important factors affecting the abundance of *D.racemosa*. The findings of this investigation are useful in developing *D. racemosa* habitat protection, restoration, and management guidelines as well as necessitate urgency of awareness-raising.

Keywords: Ecological factors, habitat management, priority for conservation

Introduction

The relationship between biota and their environment has been a fundamental subject in ecological assessment in Hyrcanian forest studies (Naqinezhad et al., 2013). The presence and distribution of plant species in ecosystems are not random. Morphological characteristics and growth rates of plants are influenced by spatial-temporal variations in their immediate environments, such as temperature, precipitation, soil physicochemical properties, biota, and luminescence in heterogeneous environments (Ashcroft et al., 2011; Ghorbani et al., 2015; Akbarlou & Nodehi, 2016).

Ecological assessments by many researchers (Chahoki et al., 2007; Naqinezhad et al., 2013 and 2015; Amissah et al., 2014; Ahmed et al., 2015; Abdelaal, 2017; Bazdid et al., 2017) have shown the correlation of environmental factors with plant species occurrence and distribution, morphological characteristics and regeneration. These environmental factors can be related to the immediate surroundings of the plant population or geographical or topographical features of the habitat. For example, Mossivand et al. (2017), showed both *P. uloptera* and *P. pabularia* species prefer often soils with sandy-loam textures, and this means that they are more compatible with lighter textured soils. Kooch et al. (2007), in their investigation of the ecological distribution of plants in Hyrcanian forests, confirmed that habitat conditions and ecological variables significantly affect the growth and regeneration potential of each plant species differently. Also, Sternberg and Shoshany (2001), showed that the slope aspect affects vegetation occurrence in a Mediterranean woody formation. Furthermore, Zhang and Dong (2010), reported that elevation, soil type, and slope are important factors in plant population regeneration and species distribution and diversity in the Loess Plateau of China.

The Hyrcanian forests stretch from Talish in Azerbaijan and cover the northern slopes of the Alborz Mountains in northern Iran, throughout Guilan, Mazandaran, and Golestan provinces. The vegetation is composed mostly of deciduous forests. The diversity of tree species increases at higher elevations where the subalpine forests and scrubs of low shrubs of the timber-line are replaced by alpine grasslands in the northern slopes and the Irano-Turanian thorn-cushion steppe at the exposed summits and southern slopes. Main vegetation types of the Hyrcanian forest zone include sand dune vegetation along the Caspian Sea coasts; C_4-dominated grass communities on rocky outcrops; aquatic vegetation on wetlands; riverine and valley forests; alluvial and lowland deciduous forests; submontane and montane deciduous forests; subalpine deciduous forests; successional and transitional scrub and woodlands; subalpine and alpine meadows; montane steppe dominated by xerophytic and thorn-cushion species; rock cliff communities and halophytic communities. The riverine vegetation in the Caspian forests is largely degraded by human impact and most importantly by dams. The hygrophilous trees like *Alnus glutinosa*, *Populus caspica* Bornm., *Salix aegyptiaca* L., *Salix. alba* L., *Pterocarya fraxinifolia*, *Acer velutinum* Boiss., and *Diospyros lotus* L. are the most abundant species in such habitats. In deep valleys, surrounding steep rocks and along the rivers provide unique ecosystems with shade-tolerant species, like *Danae racemosa* (L.) Moench (Akhani et al., 2010).

Danae racemosa (L.) Moench (Syn. *Ruscus racemosus* L.) member of the family Asparagaceae (Simpson, 2005), in the order Asparagales of the monocots, is native in the mountains from Syria to Iran and Transcaucasia. *D. racemose,* known as Hamishak in Iran, naturally grows in Hyrcanian forest understory along the southern coastline of the Caspian Sea extended in geographical regions of Guilan, Mazandaran and Golestan Provinces. (Mozaffarian, 1996). *D. racemosa*, an erect, evergreen shrub growing under the shade of forest trees, with green shoots and glossy leaves along with thick unarmed alternate cladophylls and terminal racemes of white-yellow flowers followed by red berries is frequently used for its decorative green foliage in fresh flower arrangements (Baker, 1875; Ghahraman, 1994).

This species is listed as endangered species by IUCN and introduced as a protected species in the Forests and Rangelands Organization of Iran (Naqinezhad et al., 2015).

Despite *D. racemosa* being listed as an endangered species, it is harvested illegally in abundance by local people and sold for profit widely. Except for limited knowledge of the sporadic occurrence of *D. racemosa* in unique locations, like deep valleys, and steep rocks surrounding and along rivers, there is not much information about its ecological preferences and features as well as environmental requirements at its places of occurrence along the Caspian Sea coast. This study investigated the relationship of *D. racemosa* presence (abundance) and occurrence with static (soil properties and elevation from sea level) and dynamic (climate, precipitation, and human disturbance) environmental variables in its natural habitats along with the Hyrcanian forests south of the Caspian Sea.

Materials and methods

Study site

The Hyrcanian (from "Hyrcania", the Greek form of an old Iranian term that described the region of Gorgan) forests stretch along the southern coastlines of the Caspian Sea from the Talish region in Azerbaijan (at longitude 48ºE) to Golestan National Park in Iran (at longitude 56ºE) and between latitudes 38º55'N in Azerbaijan and 35º05'N in Iran (Fig.1). Apart from this continuous belt located in the provinces of Guilan, Mazandaran, and Golestan, there are some isolated forests, one in the west known as Arasbaran forest, located in Eastern Azerbaijan province, and the forest patches near Jozak located at 55 km W of Bojnurd, in Northern Khorassan province. The total area covers approximately 50,000 km^2 (Akhani et al., 2010). The geological substrates are variable in the Hyrcanian region, with some dolomite and sandstone areas in the east, dolomite occurrences in the central part, and some areas of acidic rock (granite) occurring especially in the west. The most common soil type in these forests is brown soil, covering approximately 90% of the area, followed by alluvial soil, rending, colluvial soil, and ranker (Zarrinkafsh, 2002). The northern slopes of the Alborz Mountains, where the Hyrcanian forests have developed, are formed mainly along with Middle Jurassic to Upper Cretaceous limestone formations, while the foothills are mainly covered by Neogene continental clastic and marine sediments along the main faults (Gholizadeh et al., 2020).

The climate of the south Caspian region is controlled by several components of regional atmospheric circulation patterns and is strongly affected by a complex Alborz Mountain topography and the maritime influences of the Caspian Sea. The spatial analysis of precipitation seasonality shows that the western and eastern parts of the Hyrcanian region have markedly different precipitation regimes. Data from climate sites in the lowland cities of this area also show a decrease in the annual precipitation and an increase in the annual temperature from the west to the east of the Hyrcanian ecoregion (Gholizadeh et al., 2020).

The floristic biodiversity of the Hyrcanian region is on a global level remarkable with over 3,200 vascular plant species documented; about 44% of known vascular plants in Iran. Approximately 280 taxa are endemic and sub-endemic for the Hyrcanian region and about 500 plant species are Iranian endemics. A total of 80 native tree species have been documented (Akhani et al., 2010).

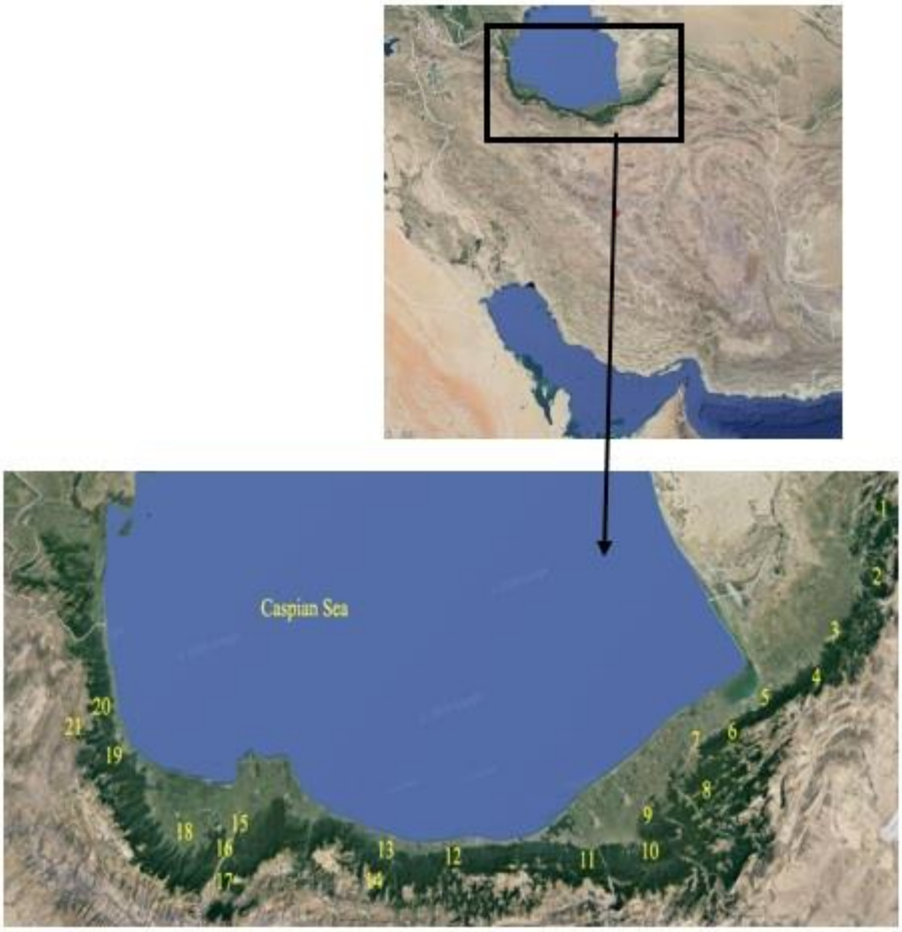

Figure 1. The map of the study region, East to West, Golestan, Mazandaran, and Guilan Provinces, respectively

Sampling

Soil and plant samples of *D. racemosa* were collected from 45 plots in 21 different locations (sites) in the Hyrcanian region from Park Meli Golestan in the east to Talish in the west (Table 1).

Table 1. Sampling site of *D. racemosa*

Site	site Code	Elevation (m)
Park Meli Golestan- Hamashli	1	1390
Tange Rah– Afraliko	2	1030
Aliabad- Kabudval	3	900
Gorgan- Sefid Cheshmeht	4	780
Kordkuy – Bahar Cheshmeh	5	650
Galugah- Tuska cheshme	6	940
Behshahr-Rostamkola	7	250
Behshahr-Merabanrud	8	420
Sari- Soleiman Tange	9	650
Sari- Zarin abad	10	340
Amol- Holomsar	11	130
Tonekabon –Nesamad	12	335
Tonekabon –Dohezar	13	880
Chalus - Kelarabad	14	400
Siakal- Balarud	15	260
Siakal- Lonak	16	510
Siakal- Deilaman	17	1125
Rasht- Saravan	18	100
Asalem- khalkhal road	19	430
Talesh- Mardavan Rik	20	150
Talesh- Shile Vesht	21	680

A vegetation survey of *D. racemosa* and associated species in each habitat was done using published reports. Besides, field scouting throughout the area was conducted thoroughly. In each plot (100 m^2) plant biometry, the abundance and density of *D.racemosa* were determined (Fig. 2).

Figure 2. Leaves and fruits of *D. racemose*

Soil analysis

Soil samples were taken from the top 25 cm; cleared off of leaves and organic pieces and placed in polyethylene bags and taken immediately to the laboratory, air-dried, crushed in a mortar, passed through a 2 mm mesh sieve, and analyzed for different physical-chemical properties. Dried powdered leaves were mixed with deionized water to prepare leaf extract for determining its content of elements. Soil texture, salinity, pH, K, Na, Ca, Mg, and P were determined according to the standard methods at the soil laboratory of the Faculty of Agriculture, Tarbiat Modares University. Soil texture was determined using the hydrometric method with the help of TAL (Texture Auto lookup) software (TAL for windows, ver 4.2) and the USDA soil texture triangle. Measurements of EC and pH were performed using a digital EC meter (brand Jenwey) and pH meter (brand Metrohm). Jenway Flame photometer was used to determine the concentration of sodium and potassium in the soil. Calcium and magnesium ions were measured by Shimadzu atomic absorption (Bower et al., 1952). The Olsen method was used to determine the amount of phosphorus in soil (Olsen, 1954). Meteorological data, such as average temperature, humidity, and precipitation over the past 10 years (2009-2019 in the relevant area were obtained from Iran Meteorological Organization.

Statistical Analyses

To investigate the environmental similarities between the studied sites and their categorization, the 21 sites of *D.racemosa* were clustered based on the relative Euclidean distance index (as a distance criterion) and with the method of least variance (Ward's method). Data processing was used by the PAST software version 2 under Windows. The identified group was subjected to Analysis of Variance (ANOVA) followed by Tukey's test (HSD). The results of ANOVA (F, P), were taken to express the impact of the environmental factors and their order of importance, on population distribution in the surveyed area (Spss ver 16). The classification results were plotted as dendrogram with the PAST software. Principal Component Analysis (PCA, Hotelling, 1933) was used to get a view of the influence of the variables (environmental factors) on population distribution and investigate the proximity among samples and how they relate to variables. Hill and Gauch (1980), used PCA to identify the main gradients that influence species distribution, as an indirect gradient analysis technique. The last correlation test was used (Spss ver. 16) to survey the relationship between ecological factors with *D.rascemosa* density in different sites to show which factor is the most important variable in *D.racemosa* dispersion.

Results

Ecological occurrence

According to field observations, *D. racemosa* grows in a wide range of habitats ranging from rocky upland areas to mainly along rivers and springs. It is a shade-tolerant species that grows in the understory of larger trees. *D.racemosa* grew in the understory of trees, such as *Alnus subcordata* (at sites 4, 6, 9, 10, 11, 12, 14, 16), *Parrotia persica* (at sites 3, 13, 15, 18, 20), *Fagus orientalis* (at sites 5 and 21), *Buxus hyrcana* (at sites 7 and 8), *Acer hyrcanium* (at site 2), *Carpiunus betulus* (at sites 1 and 17) and *Tilia caucasica* (site 19) communities. *Alnus subcordata* and *Parrotia persica* showed the most abundance in the upper strata in 24 and 10 plots, respectively. In the lower stratum, different species, such as *Ruscus hyrcanus*, *Dryopteris pallida*, *Polypodium vulgare,* and *Polystichum aculeatum* were the most abundant, respectively with *R. hyrcanus* occurring in 27 plots. *D. racemosa* occurred most abundantly in mixed *Alnus subcordata* and *Parrotia persica* community. Species elevation of occurrence ranged from 100 m in Saravan (west) to 1400 m in Golestan National Park (east). *D. racemosa* occurred most and least densely in Sites 5 (Sefid Cheshme) and 18 (Saravan) and sites 17 and 21, respectively (Fig. 3).

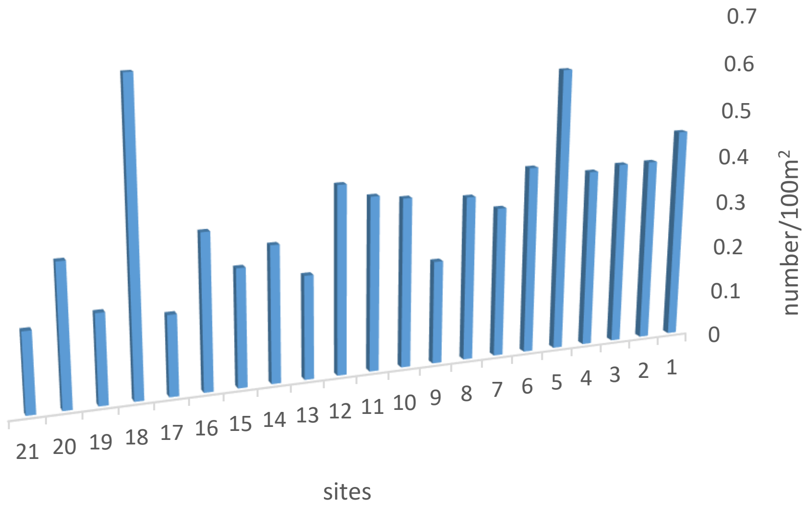

Figure 3. The density of *D. racemosa* in different sites of occurrence

Soil classification

According to the USDA soil taxonomy classification system which uses 12 textural qualitative classes, 21 collected soil samples were categorized into three soil texture types as follows: clay loam in 10 sites, loam in 5 sites, and silty loam in 6 sites. Hamashli, Bahar Ceshmeh and Sefid Cheshme populations (sites 1,4 and 5) from Golestan province, Tuska Cheshme, Merabanrud, Soleiman Tange, Holomsar and Nesamad populations (sites 6, 8, 9, 10, 11 and 12) from Mazandaran province and Saravan population (site 18) from Guilan province are located in clay-loamy soil class. The above populations are spread in the altitude range of 100 up to near1400 meters above sea level. Populations of Hamashli and Saravan, which have the highest plant densities in the Hyrcanian region, fall into this category. Afralico population from Golestan province (site 2), populations of Rostamkola (site 7) and Dohezar (site 13) from Mazandaran province, and populations of Mardavan Rik and Shile Vesht (sites 21 and 22) from Guilan province have grown in a loamy soil. These populations are distributed in the elevation range of 150 to 1030 m above sea level. Kabudval population (site 3) from Golestan province, populations of Zarin Abad and Kelarabad (site 9 and 14) from Mazandaran province, and Balarud, Lonak, Deilaman, and Asalem populations (sites 15, 17, and 19) from Guilan province are in the silty loam soil group (Fig. 4) ranging from 260 - 1125 m above sea level.

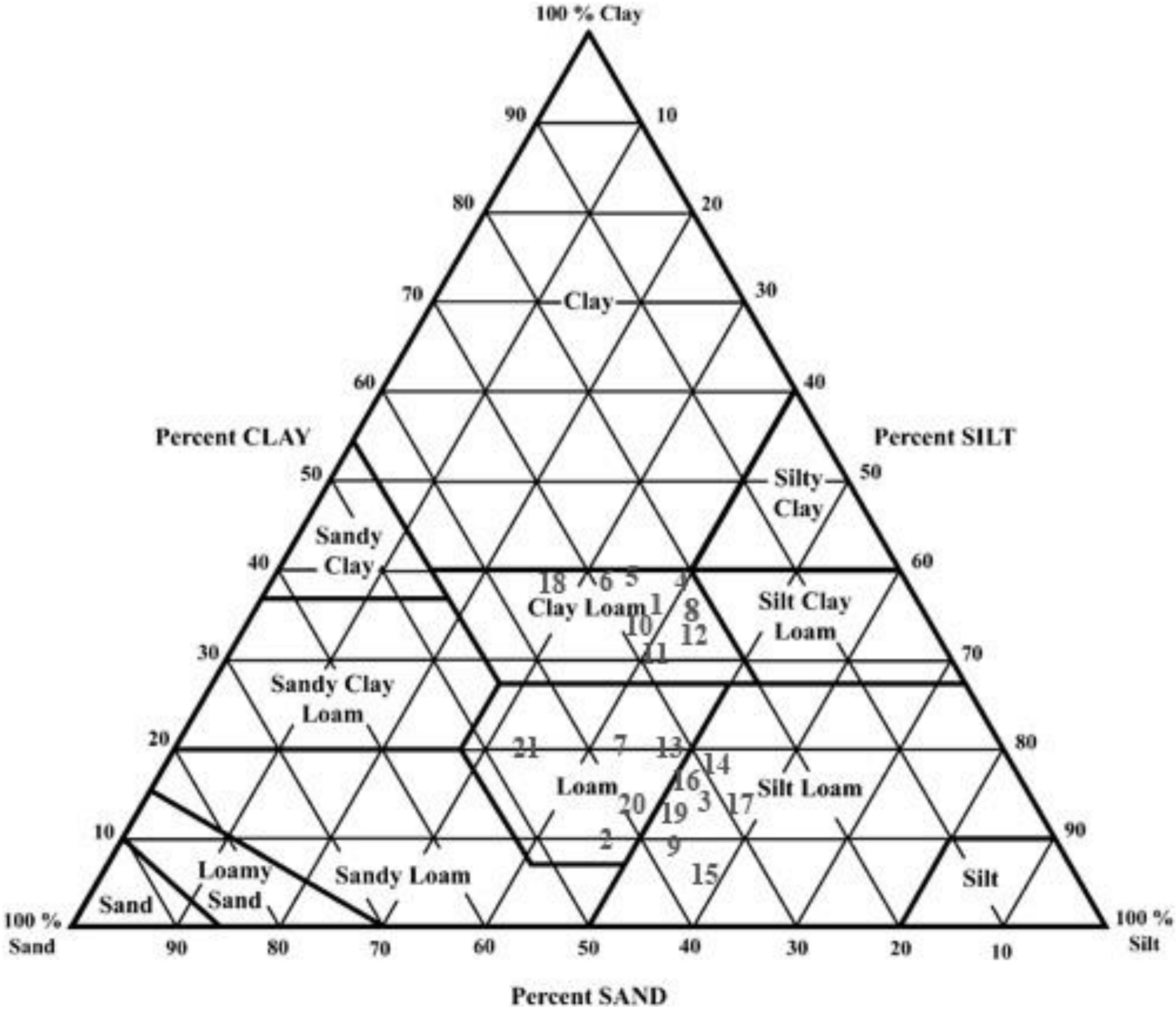

Figure 4. the position of populations at the soil texture triangle

Soil's physical and chemical properties

Soil analysis showed the range of values for pH (6.15-7.59), EC (265-601 mmohs), P (3.89-17.12 mg/Kg), Na (14.06-34.24 mg/Kg), K (9.33-27.82 mg/Kg), Ca (37.71- 76.04 mg/Kg) and Mg (6.5- 26.9 mg/Kg) differed throughout the region.

Data analysis

Cluster analysis classified 21 *D. racemosa* occurrence areas into two main groups of habitats.

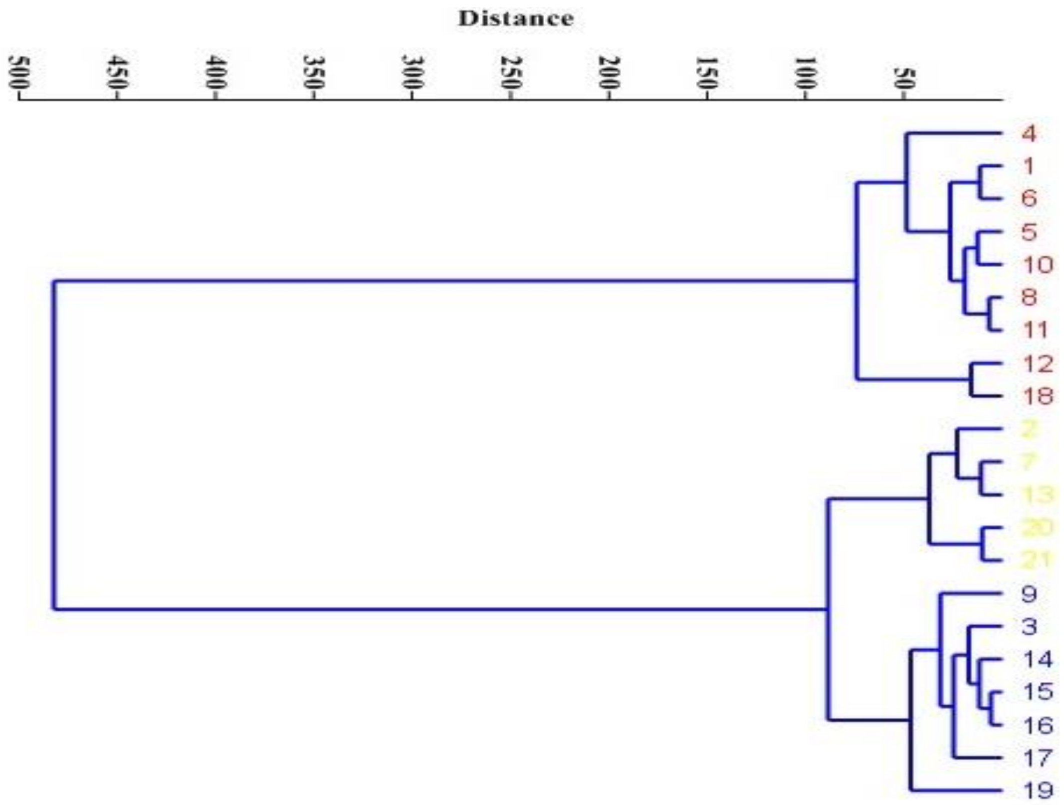

Figure 5. Dendrogram of Cluster analysis of *D. racemosa* occurrence along with the Hyrcaninan understory vegetation

Group 1 is divided into two subgroups A and B. Subgroup (A) includes 7 sites (1, 4, 5, 6, 8, 10, 11), and subgroup (B) includes two sites (12, 18). Group 2 also includes two subgroups (C and D). Subgroup C includes 5 sites (2, 7, 13, 20, 21) and subgroup D includes 7 sites (3, 9, 14, 15, 16, 17, 19) (Fig. 5). The mean scores of the properties for the four groups in Table 2 indicated that group 2 sites are characterized mostly by the highest precipitation, humidity, soil EC, and contents of clay, P, Mg, and K. The sites of the other groups are characterized by soil pH and contents of sand, silt, Na and Ca. Applying Tukey's test (HSD) for these variables and comparing the p-value to the significance level (P-value ≤ 0.05) indicated that 9 environmental variables (precipitation, relative humidity, soil texture, disturbance grade, and contents of elements P, K, and Ca) are statistically significant between two main groups (Table 2). The percent of sand and the amount of precipitation separated subgroups A and B. Also, the content of K and Ca separated subgroups C and D.

Table 2. Comparison of environmental factors between groups by one-way ANOVA

Variables	Subgroup A	Subgroup B	Subgroup C	Subgroup D	F	P-value
clay	37±3.36[b]	**40±1.41[b]**	16±5.21[a]	14±4.07[a]	53.92	0.001*
silt	38.71±3.4[a]	42±4.24[a]	45±5.7[ab]	**52.71±2.56[b]**	15.67	0.002*
sand	25±3.1[b]	18±2.82[a]	**39.8±4.43[c]**	35±3.41[c]	27.79	0.001*
pH	**7.34±0.21[a]**	6.87±1.01[a]	7.04±0.51[a]	6.89±0.4[a]	1.4	0.27
EC	430.71±72.97[a]	**450.5**±71.41[a]	377.6±96.06[a]	353.85±64.01[a]	1.6	0.22
P	15.49±1.16[a]	**16.5±0.8[a]**	4.5±0.74[b]	5.46±0.92[b]	206.2	0.001*
K	25.15±2.4[c]	**27.52±5.53[c]**	19.37±0.85[b]	13.52±2.38[a]	46.76	0.004*
Na	16.70±1.57[a]	15.95±2.39[a]	**27.06**±4.18[a]	24.95±6.93[a]	4.78	0.06
Mg	11.7±5.03[a]	**22.81±7.77[a]**	16.41±3.03[a]	22.8±6.46[a]	20.02	0.07
Ca	43.03±6.88[a]	40.48±3.91[a]	59.81±1.67[b]	**72.72±2.49[c]**	59.87	0.00*
Humidity	74.18±7.34[bc]	**81.53±1.78[c]**	54.44±3.66[a]	64.37±3.24[ab]	20.7	0.001*
Precipitation	57.58±11.1[b]	**103.35±2.3[c]**	64.37±13.44[a]	72.53±19.65[a]	72.53	0.012*
Disturbance grade	1.7±0.2[a]	2±0.12 [a]	2.8±0.3 [b]	**3.3±0.34** [b]	3.83	0.02

*The mean difference is significant at the 0.05 level; there is no significant difference between groups with the same letters

Thirteen environmental factors were used to determine the most effective ecological parameters controlling the distribution of *D.racemosa* populations in the Hyrcanian area. PCA results are presented in the form of graphs (three-plot species-environment-location diagrams) (Fig. 6). The first, second, and third axes of PCA analysis justify 52, 16, and 8% of the variances of environmental changes, respectively. To accurately select the important components, eigenvalues were compared with another variable called the Broken Stick eigenvalue (BSE). Components with eigenvalues larger than BSE were selected. In the first and second components, these conditions apply and include 68 percent of the vegetation change variances which is a moderately good result. The first component is the most important, as it contains 52% of the changes and explains most of the total variability.

The correlation of the variables with the components indicates that the first component includes contents of clay, P, K, Ca, Ec and sand, and the second component includes precipitation, the content of Mg, and disturbance grade. Correlation analysis for environmental variables showed that in the first component, the amount of sand and Ca showed a negative correlation coefficient and the amount of P, K, EC, Humidity and clay, a positive correlation coefficient, so the population in the positive direction of the first axis, with K, EC and clay have direct relationship and are inversely related to contents of sand and Ca. In the second component, the amount of precipitation, content of Mg and disturbance grade have a positive correlation coefficient, so populations that are in the positive direction are directly related to precipitation and content of Mg and disturbance grade.

Figure 6 shows the spatial distribution of *D.racemosa* communities in relation to environmental factors. Depending on the location of populations in Figure 6, it is indicated that the presence of species in section 1(sites 1, 4, 5, 6, 8, 10 and 11) and section 2 (sites 12, 18) were affected by soil contents of clay, K and P more than the other sites. These also indicated that the frequencies of species in section 3 (sites 2, 7, 13, 20 and 21) and in section 4 (sites 3, 9, 14, 15, 16, 17 and 19) were affected by soil content of sand and Ca more than the other sites. Section 2 which represents clay loamy soil texture is located at the far positive end of PC1, while those belonging to section 4 which represents loamy- silt soil texture is located at the far negative end of PC1. Section 1 (clay loamy soil texture) and site 3 (loamy soils texture) occupy an intermediate position and upon drawing the convex hulls there is a degree of overlap between sections 3 and 4. To interpret this figure, we need to consider the length of the vectors as well as their angles with each of the coordinate axes. Thus, the smaller the angle with the coordinate axis and the longer the vector, the higher the correlation coefficient of the vector with that coordinate axis. Therefore, among the studied environmental factors, precipitation, the content of clay and concentration of K, P and Ca are the most important factors in the separation of populations in the study area.

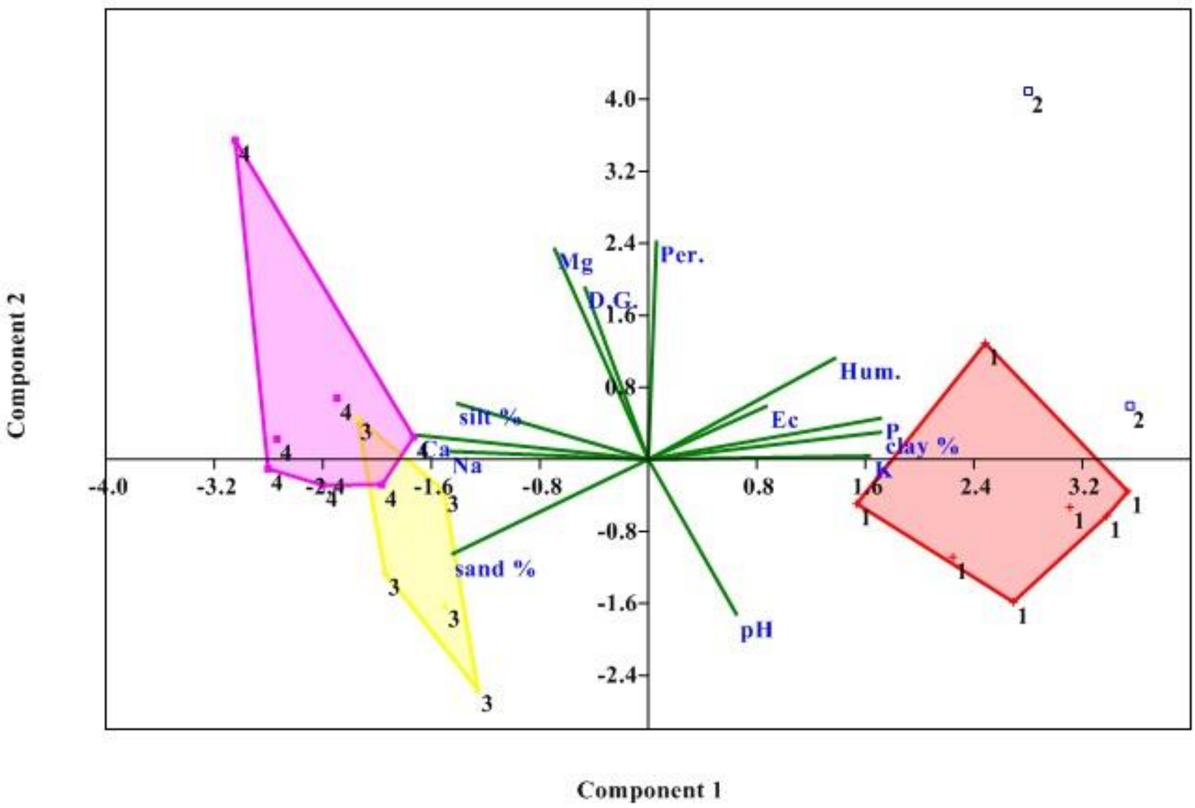

Figure 6. Biplot representing PCA for the 21 sites, the environmental variables, the 4 groups superimposed, and the convex hulls drawn

Correlation analysis of environmental factors with *D.racemosa* density in different sites indicated a positive correlation with some factors, such as the content of soil clay, humidity, and precipitation and the contents of soil P and K showed and negative correlation with the contents of Ca, sand and disturbance grade (Table 3).

Table 3. Correlation between environmental factors and *D. racemosa* density

variable	density	
	r	P-value
Clay	0.68**	0.001
Silt	-0.43	0.051
Sand	- 0.65**	0.002
pH	0.66	0.1
EC	0.39	0.07
P	0.75**	0.002

Ca	- 0.71**	0.001
Mg	0.55	- 0.13
Na	0.1	-0.36
K	0.78**	0.001
Precipitation	0.59**	0.008
Humidity	0.64**	0.002
Disturbance Grade	-0.66**	0.001

** p<0.01

Discussion

In the long run, the distribution of plant communities is more influenced by, climate, edaphic factors, and human actions on a larger scale. At a local scale, edaphic factors and available nutrient sources, and man-made alterations or disturbances of the ecosystem are important factors of habitat sustainability (Fridley, 2001; Lavergne, 2005; Badano et al., 2005; Davies et al., 2006; Chuangye, 2015). The present study examined the relationship between environmental variables and *D.racemosa* occurrence and abundance in the Hyrcanian forest ecosystem, in the north of Iran. In our study area, although the overall altitudinal range of occurrence varied substantially (100 to near 1400 m above sea level), still because of the shade-tolerance habit of *D. racemosa*, evidently elevation was less restrictive and more so soil properties, climate and human disturbance affected its growth, regeneration, and occurrence.

According to the field observations, no *D. racemosa* was observed in sites with elevations above 1,400 m above sea level and greater density occurred in the lower elevations. *D. racemosa* mostly grows in the moist places, such as along rivers and springs in the form of mass communities (colonies) and understory vegetation. They occur in different slopes and habitats, such as valleys, rocky substrates, and incline flat places. The most abundant *D.racemosa* population was observed in the under-canopy of *Alnus subcordata* forest community. This observation collaborates findings of Akhani et al. (2010), in the study of biodiversity of Hyrcanian forests, who in terms of vegetative growth types classified *D. racemosa* along with Alnus, Populous, Acer, Dryopteris and Polypodium in the riverine and valley forests group.

The relationship between species distribution and climate is well documented. It is predicted that climate change will remain one of the major drivers of biodiversity patterns in the future (Sala et al., 2000; Duraiappah, 2006 ; Dadamouny & Schnittler, 2015). The meteorological records of the study area showed that the regional climate is influenced by the Caspian Sea, which moderates temperature and differentiates seasons into variable rainy winters, autumns, and moderately hot moist summers.

The most affected regions by the prevailing climate are the western side of Hyrcanian forest faced with heavy rainfalls compared with lesser precipitation and warmer temperatures on the eastern side. ANOVA and PCA analysis for the four groups based on environmental variables indicated that the prevailing climate is the most significant environmental factor and the most affected group was plants in section 4 (sites 12 and 18).

Barnes et al. (1997), said that the effect of the presence of trees and their canopy on airflow, soil moisture, water, light regime, and access to food sources is well known. Opening of the canopy, followed by a reduction in litter accumulation, has a negative effect on the number and activity of microorganisms and ultimately on the concentration of elements (Makineci et al., 2007). In an open canopy, because of low species density, high light, high evaporation, and perspiration, seed establishment, germination, and growth are difficult (Shabani et al., 2011). In support of the latter statement, our ANOVA analysis of the biometric data and environmental variables indicated that human disturbance was a significant variable contributing to the restricted occurrence of *D. racemosa*. The sparse occurrence of *D. racemosa* is attributed to zealous harvesting of this species by nomads living in forest areas and also by wood smugglers and licensed wood traffickers who build accessible roads deeper into the forest. Kowarik (1995) and Marzluff (2001), indicated that such disturbances produce some of the greatest local extinction rates and frequently eliminate the large majority of native species. Kowarik (1995), also indicated that the number of non-native species increases toward centers of urbanization and inversely for the number of native species. Naqdi et al. (2014), reported a lowering of moisture, soil clay, and the amount of organic matter in the exposed areas of the forest near roads and inversely increase of sand and silt. In confirmation of the above observations, many researchers also stated that forest roads create extensive corridors in terms of light received moisture, and physical and chemical properties of the soil over the long term by creating a corridor in the habitat to harvest forest trees (Trombulak & Frissell, 2000; Forman et al., 2002; Dupre & Ehrlen, 2002). These findings coincide with those results obtained by Kowarik (1990) and Shaltout et al. (2010), who reported that vegetation with a low degree of human interference is more diverse than undisturbed one.

Vegetation structure and the sustainability of the natural ecosystems changes in time and space as a result of human disturbance and habitat alterations. For example, growing of plants in the protected area and remote regions reduces the degree of encroachment in the habitat and allows increases in shrubs density. The density data of Hamshali population (site 1), which is located in the protected area of Golestan National Park, the Saravan population (site 18), which is located in the Saravan region of Rasht and Bahar cheshme (site 5) in the protected area of Jahan Nama clearly confirm above observation.

Soil type and its properties is one of the major environmental factors affecting the plant community structure in an area (Dale et al., 1992; Tamado & Milberg 2000). In this investigation, the impact of soil type on species occurrence and plant community structure was obvious through the results of Multivariate analyses as follows: 1) the separation of the sampling sites dominated by clay loam soils from those dominated by loam and silty loam soil along PC1, 2) the sites of subgroups A and B characterized by the highest soil content of clay, P and K while the sites of subgroup C characterized by the highest soil content of sand and site of subgroup D characterized by the highest soil content of Ca and Mg. Andreasen et al. (1991), examined soil properties affecting the distribution of 37 weed species in Danish fields and concluded that “Crop type and soil clay content were generally those explanatory variables that had the greatest influence on the occurrence of the weed species, but all other factors examined (pH, P, K, Mg, and Mn) also had an effect on the occurrence of some species.

The results of the PCA analysis are consistent with the results of field evidence so that the moisture and precipitation along with soil factors and human disturbance have a positive effect on the density of the *D.racemosa*, a finding supported by other researchers (Enright et al., 2005; Zhang et al., 2013; Adel et al., 2014). *D. racemosa* is distributed in the Hyrcanian districts at different locations, but the occurrence of this plant shows inconsistency, particularly considering the far distance between the habitats and masses of *D.racemosa* in the area. This discontinuity can be attributed, firstly, to improper harvesting of this species as well as human encroachment and harvesting, and secondly to differences in microhabitat properties and microbial activities. It was observed where there is suitable soil quality, no human disturbance, a high density of trees, and sufficient moisture and water, the density of *D. racemosa* is high. The highest density of *D. racemosa* was observed from subgroups 1 and 2 (Fig. 3) primarily because of the following reasons; (1) these habitats were located near neighboring rivers and springs frequented with seasonal flooding which enriches river banks with excess clay and silt. such as P and K; (2) Because of the high density of P and K in clay and silty soils, the rate of vegetative growth and rhizomes (Shen et al., 2013) and the formation of lateral buds in *D. racemosa* is usually higher which in turn, raises the potential for reaching its greater density as well (Mahmoudi et al., 2012). *D. racemosa* in natural environments mainly prefers to be propagated by vegetative parts and rhizomes because its seed germination rate is very low as a result of prolonged dormancy and (3) lower disturbance incidence frequencies which allow for vegetative as well as very slow reproductive growth of the plant through seed germination of seeds dormant for no less than 3 years.

Conclusions

According to the results, among the environmental factors studied, parameters of soil texture, human disturbance, and climate are important factors in the distribution and density of populations of *D. racemosa* in the study area. Because of excessive disturbance and destruction of the forest habitat with the excessive cutting of trees, livestock feeding in forest areas, smuggling for ornamental purposes, and soil erosion in recent years, habitats of *D. racemsa* are becoming less supportive for extended sustainable growth. Therefore, *D. racemosa* has changed its habitat into hard-to-access places in valleys and over rocky waterfalls. This in itself limits the soil territory in which plants can grow optimally. The findings of this research illuminate the failing state of *D. racemose* habitats and point out the necessity for greater protection of existing habitats through increased public awareness, specialized research, and management of local or outside disturbance sources. The latter include fencing off healthy habitats, enforcing plant conservation laws against illegal harvesting and grazing, promoting agroforestry for *D. racemosa*, and rehabilitating and protecting damaged habitats.

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