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Investigation of environmental effective factors to distribution of *Salvia officinalis* (Case study: Ghohroud watershed in Kashan, Iran)

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Abstract

This research aims to study the existing relationships between the phytosociology characteristics of *Salvia officinalis* and environmental factors in order to find the most important factors governing the development of the species in middle Ghohroud rangelands, Iran. Subsequent to indicating the study region, the required flora and environmental data were collected by field survey. Plot size and sample size were determined by minimum area and vegetation procedure methods, using 40 plots along four 100 m transects. The characteristics including floristic list, percentage of canopy cover, number of plants as well as height, the largest and smallest diameter, and freshness of *S. officinalis* were recorded. Likewise, bare soil percentage, litter percentage, and stone and gravel percentage of topsoil were recorded in each plot. Moreover, in order to study the soil features, eight soil profiles were taken at each site up to 30 cm depth at the beginning and end of each transect. Classification of vegetation cover was performed by TWINSPAN analysis while factors influencing the change in vegetation characteristics of the *S. officinalis* were determined by PCA analysis. Results demonstrated that factors involving slope, altitude, organic matter, lime content, nitrogen content and soil texture show the highest impact on vegetation characteristics. Overall, variables including elevation ranging between 2300-2500 m, slope in the range of 20% - 40%, and fertile sandy loam textured soils in the presence of nitrogen and high organic matter content as well as low lime content provides the most suitable condition to develop a high production *T. kotschyanus*.

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Introduction

Iran has a potential habitat for many plant species due to variation of soil types and climate diversity. Getting knowledge on effective factors on development and adaptation of the species can lead to time and cost effective planning for rangeland restoration (Escudero *et al*., 2000).

The evolution of ecosystem and the dynamic of vegetation diversities in ecological habitats of the rangelands are not formed in a randomized manner but rather are formed as matrices of most important environmental factors over time (Kent and Coker, 1992). Cognition of vegetation communities and evaluating their interaction with environment is known as an important subject to achieve sustainable rangelands management in order to introduce the appropriate species for reclamation of degraded area. Furthermore, information on environmental factors can be used to predict success and fail of establishment of species.

Salvia sp. is a valuable medicinal plant widely used since many years ago. The species studied in this research is *Salvia officinalis*, which is widely distributed in different parts of Iran, especially in southern Kashan Mountains at Ghohroud rangelands in the west of Esfahan province where it is considered as one of three dominant species of the region. It is a fragrant species most prominent and renowned in essence quality and quantity (Zargari, 1990). In this research, we deal with quantitative attributes of *S.officinalis* under environmental factors to achieve maximum yield through choosing appropriate environmental factors.

S.officinalis plays important role in the economy of local people at Ghohroud region where its cultivation helps regional economy. Therefore, it is necessary to protect the species through identifying and permanent conservation of the habitats, and restoration of the renewable resources.

Akbarzadeh (2003) reported that in Mazandaran province, Iran, *S.officinalis* grows in the sandy loam soils of the elevation ranging between 2200-2900 m above sea level at the habitat extends in the north-east direction. Likewise, the species dominates the community forming the clustered patterns along with *Festuca ovina* and *Astragalus gossypinus*. Jamshidi *et al*. (2006) revealed that *S.officinalis* shows a high frequency and high density in the habitat while the best essence yield is seen in 2400 m elevation. Furthermore, the species mostly appears as dominant type together with *Bromus tomentellus* and some *Astragalus* species. Habibi *et al*. (2006) demonstrated that density of *S.officinalis* increases with increase in elevation at Ghohroud rangelands. According to Mirdavoodi and Babakhanloo (2007) the habitats of *S.officinalis* is extended in the elevation ranging between 1850-2500 m above sea level at north and east regions of Markazi province, Iran. Larti and Ghasempour (2009) evaluated the suitable ecological conditions for *Salvia* species in western Azerbaijan province, Iran.

They showed that different *Salvia* species are distributed in the elevations ranging between 1200-2500 m while preferring slopes between 15% - 45% placed at north and northeast directions. Generally, the *Salvia* species tend to develop in moderate to highly eroded, deep or semi-deep calcareous soils of high elevation mountains. Corticchiato *et al*. (1998) stated that the main factors affecting the distribution of *Salvia* species involve climate, altitude, soil type, soil texture, organic matter and calcium content of soil in east regions of Spain. Boira and Blanquer (1998) pointed out that some factors involving elevation, soil texture, and climate affect development of *Salvia piperella* in Spain. Stahl-biskup (1991) demonstrated that heavy soil texture and low soil calcium content are responsible for less *Salvia* sp. Essence yield. Given to all researches on effect of environmental factors on *Salvia* sp. communities, it is worth to note that all of them contributed in formation and distribution of its communities.

The main objective of this study is to detect the most important factors forming the community of *S.officinalis* in middle Ghohroud region in southern Kashan Mountains, Iran in order to identify the best habitat for distribution of the species producing maximum and high quality yield.

Materials and Methods

Site description

Study area involves a natural habitat of *S.officinalis* located at the southern of the middle Ghohroud rangelands of Esfahan province, Iran with an area of 4994 ha where altitude ranged between 1800 - 3000 m and slope is below 25%. The soil involve a semi heavy (clay loam) to heavy texture (clay and silty-clay) type while recorded mean annual precipitation and temperature show 500 mm and 4.48°C, respectively.

Soil sampling and measurements

The data of vegetation cover and environmental factors were collected after primary visiting and indicating the study area. Plot size and sample size were determined by minimum area and vegetation procedure using 40 plots along four 100 m transects. In each plot, floristic list, canopy cover percentage, number of plants, litter percentage, bare soil percentage, and stone and gravel percentage of topsoil were determined. Furthermore, characteristics of each individual *S.officinalis* in each plot were considered involving height, frequency, the largest and smallest diameter, and the status of freshness. In addition, in order to study the soil features, number of eight soil profiles were taken in each site up to 30 cm depth at the beginning and end of each transect. In each sample, the data consist of latitude and longitude, altitude, slope, and aspect of slope were recorded.

Arial plant biomass (roots and shoots) was harvested and weighted for further analyses. Soil samples were dried and then sieved to pass through a 2 mm mesh in order to determine soil characteristics involving soil texture, gravel percentage, lime percentage, organic matter percentage, pH, EC, nitrogen, phosphorus content, and potassium content.

Data analysis

Floristic analysis was performed by PC-ORD v.4.17 software package while plant ecological groups were determined based on the Two-Way Indicator Species Analysis (TWINSPAN) (Hill and Hill, 1979). At first, an unconstrained ordination under a Detrended Correspondence Analysis (DCA) was performed to find major gradients in species composition. However, due to reduction of the environmental gradient (0.237), Principal Component Analysis (PCA) was then applied to search for a general pattern of environmental variables. In this analysis, the distribution graph of plant communities in relation to soil properties are shown on the coordinate axes (Zare Chahouki, 2006).

Results

According to outcomes of TWINSPAN and eigen-values, the vegetation communities were categorized into five groups (Table 1).

Table 1. Species composition of *Salvia officinalis.*

Vegetation Type	Cover (%)	Composition (%)
Agropyron intermedium	6.38	12.96
Agropyron intermedium Astragalus gossypinus	2.00	7.38
Astragalus gossypinus- Salvia officinalis	4.54	19.32
Bromus dantoniae	3.75	10.36
Sophora alopecuroides- Astragalus paralogues	3.30	10.90

Group I: *Sophora alopecuroides- Astragalus paralogues* (So.al-As.pa)

Group II: *Bromus dantoniae* (Br.da)

Group III: *Astragalus gossypinus- Salvia officinalis* (As.go-Sa.of)

Group IV: *Agropyron intermedium* (Ag.in)

Group V: *Agropyron intermedium- Astragalus gossypinus* (Ag.in-As.go)

Ecological classes obtained by classification under TWINSPAN were confirmed to area vegetation types where showed the reduced eigen-values of each plant groups (Fig. 1).

Evaluation of quantitative traits of S.officinalis within vegetation types

Analysis of variance was conducted to evaluate quantitative traits of *S.officinalis* among habitats including cover percentage, density, species height, stands mean distances, volume, and short and long diameter. (Table 2), shows results of analysis of variance and comparison of means between vegetation types.

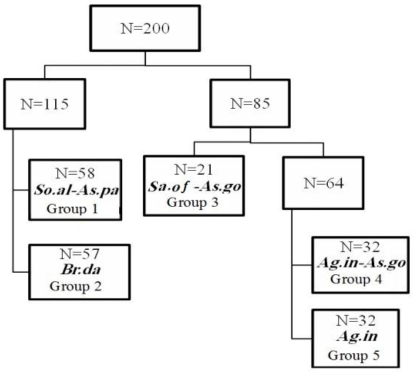

Fig. 1. Classification chart of vegetation types under TWINSPAN.

In addition, Duncan's test was performed to evaluate the significant differences among the groups.

Determining the factors affecting characteristic variations of Salvia

As shown the outcomes of principle components analysis in (Table 3), the first and second components address 88.81% of all variations of vegetation. The former shows more importance undertaking 48.11% of total variations while the later reveals 27.9% of variations. Furthermore, eigen-vectors of soil variables in relation to axis are shown in (Table 4).

Table 2. Comparison of quantitative characteristics of *S.officinalis* in the study sites.

Vegetation Type	Cover (%)	Density (/m2)	Diameter Min (cm)	Diameter Max (cm)	Volume (cm3)	Height (cm)	Distance between ind.(cm)
Ag.in	6.38^{a}	2.92^{a}	9.30^{a}	24.50^{a}	2453.20	11.40^{a}	22.50
Ag.in-As.go	2.00^{c}	0.92^{b}	7.00^{b}	22.35^{ab}	1578.00	11.10^{a}	39.50
As.go- Sa.of	4.54^{ab}	2.23^{ab}	4.80^{b}	16.60^{c}	291.80	6.70^{c}	22.70
Br.da	3.75^{ab}	2.20^{ab}	5.50^{b}	18.90^{bc}	750.57	9.20^{b}	27.50
So.al -As.pa	3.30^{ab}	1.75^{ab}	5.10^{b}	20.90^{abc}	479.43	8.00^{b}	35.80
F value	2.49*	2.87*	6.48**	2.94*	3.23*	18.65**	1.39$^{n.s}$

* and ** = Different is significant at the 0.05 and 0.01 probability levels, respectively

Table 3. The variance of each axis.

AXIS	Eigenvalues	Variance (%)	Cum.of Var (%)	Broken–Stick Eigenvalue
PCA1	7.216	48.107	48.107	3.318
PCA2	4.185	27.899	76.006	2.318
PCA3	1.921	12.808	88.814	1.818
PCA4	1.678	11.186	100.00	1.485

Table 4. Eigenvector values of the variables in each axis of the PCA technique.

Variable	Eigenvector			
	PCA 1	PCA 2	PCA 3	PCA 4
Silt (%)	0.3532	0.0363	-0.1598	0.1642
Caco3 (%)	0.3319	0.2080	-0.1103	0.0150
Organic Matter (%)	-0.3208	0.1707	-0.1227	-0.2521
Slop (%)	-0.3374	-0.1139	-0.0317	0.2700
Ph	0.3602	0.0180	-0.1096	0.1532
Elevation (m)	-0.2976	-0.2603	0.1203	0.1718
Sand (%)	-0.2466	0.3310	-0.0267	-0.2457
Clay (%)	-0.0378	-0.4589	0.1936	0.1470
Nitrogen (%)	-0.2956	0.2961	-0.0319	0.0215
Phosphorus (ppm)	-0.0551	0.2155	0.5716	0.3050
Depth (cm)	0.0706	0.0965	0.6849	-0.1196
Gravel (%)	-0.1933	-0.2840	-0.2247	0.4198
EC	-0.0787	0.2825	-0.1531	0.4307
Potassium (ppm)	-0.2153	0.2930	-0.0543	0.4233
Aspect	0.2872	0.1720	0.0890	0.3980

* The bold and underline coefficients have significant correlation with the relevant axes

Given the coefficient modulus, the first component involves variables including slope, elevation, organic matter percentage, lime content, and silt content whereas the second one denotes the percentage of clay, sand, and nitrogen content. According to variations of the main environmental factors on the first and second axes, the plant habitat is categorized into four separate classes involving one or more vegetation types in each class.

Likewise, the first and second components graph in Fig. 2, reveals that vegetation types are distributed as a function of environmental factors and soil characteristics. The classified plant habitat groups are as follows:

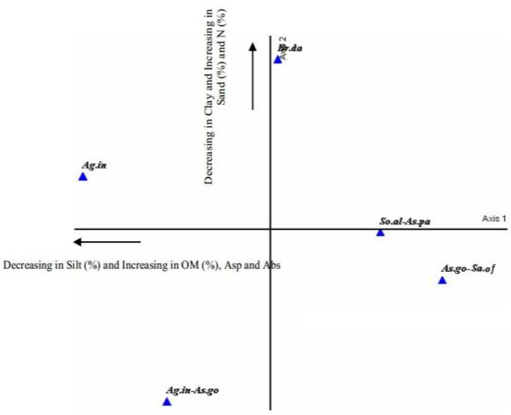

Fig. 2. The scatter plot of grassy habitats in relation to environmental factors in the study area using PCA analysis.

Group I: Involves two vegetation types including *A.gossypinus* - *S.officinalis* and *S.alopecuroides* - *Astragalus paralogues*. In this group, vegetation cover, volume, and density of *S.officinalis* were estimated 3.97%, 478 cm^3, and 2.1 per m^2 respectively.

Since *S.officinalis* forms the main part of vegetation structure, it makes vegetation type As.go-Th.ko in the third region. Although, altitude and slope contributed in improvement of the vegetation cover, soil texture, lime and organic matter contents are the main factors responsible for establishment and distribution of the vegetation types.

Group II: Involves a vegetation type known as two species *A.intermedium- A.gossypinus*. In this group, vegetation cover, volume, and density of *S.officinalis* were estimated 2%, 1578 cm^3 and 0.9 per m^2 respectively. The percentage of *S.officinalis* cover was reduced while there was considerable degradation in the stand population. Therefore, some factors involving in establishment of *S.officinalis* reduce the vegetation cover and density. Overall, the main factors contributing in creation of this type are increase in slope, elevation, organic matter content, as well as low lime content.

Group III: Involves a species *A.intermedium*. In this group, the vegetation cover, volume, and density of *S.officinalis* were estimated 6.83%, 2453 cm^3 and 2.9 per m^2 respectively. The main factors forming this vegetation type include altitude, slope, organic matter content, lime content, and soil texture. In this type, the vegetation cover and density of *S.officinalis* remarkably tend to increase than other types.

On the other hand, the higher the slope and elevation and the lower the lime content of soil, the greater the vegetation cover, density and diameter of *T.kotschyanus*.

Group IV: Involves a species *B.dantoniae*. In this group, the vegetation cover, volume, and density of *S.officinalis* were estimated 3.3%, 516.5 cm^3 and 1.75 per m^2 respectively. Meanwhile, the vegetation cover and density of *S.officinalis* are reduced than groups I and III. Soils with high sand and nitrogen contents and low clay content provide a suitable environment to form this type of vegetation.

Discussion

According to the ecological groups obtained by TWINSPAN analysis, some groups are common in dominant species. The index species of groups IV and V was *Agropyron intermedium* while the index species of groups III and IV was *Astragalus gossypinus*. The similarity in index species of groups implies the similar habitats on which they grow. Moreover, the first group is characterized *Sophora alopecuroides* and *Astragalus* *paralogues* while the group II is haracterized with index species *Bromus dantoniae* that show the difference in habitat conditions. Due to similarity of some ecological groups, it was possible to get a less numbers of groups through extending the threshold distinguishing the ecological group. However, in order to get a higher accuracy, it was decided to conduct the analysis in the present level that generated five vegetation groups. Consequently, comparing the outcomes of TWINSPAN analysis with the map of vegetation types verified the classification of vegetation groups.

Identifying the vegetation communities successfully demonstrated the differences in environmental requirements of the five main vegetation types. The results show that besides observing *S.officinalis* as a common species within all habitats, the species is seen either dominant or second dominant species in the vegetation communities. Analysis of variance of quantitative characteristics of *S.officinalis* showed that except the distances of stands, there are significant differences between other quantitative traits in the study sites. Furthermore, the quantitative characteristics of *S.officinalis* including vegetation cover, density, volume, and the diameter show the highest amount in groups II and IV representing high adaptation of the species to the habitats. However, vegetation cover and density of *S.officinalis* represent the least value at group III representing less adaptation of the species to the habitats. Results of this research reveal that distribution of *S.officinalis* is highly affected by soil characteristics as well as topographical factors. However, in elevations, topographical factors show higher influence on vegetation cover and density variations than the other variables.

Davies (2007) stated that structural attributes of *Artemisia tridentata* including height, volume and crown cover are less affected by environmental factors. Therefore, in low elevated areas, the quantitative parameters of species vary as a function of edaphic factors. Likewise, Mohtashamnia *et al.* (2007) reported that in elevations, edaphic factors show less effect on the quantitative parameters of species than topographical factors. Topographical factors play an important role in association with precipitation towards increasing the crown cover, and density as well as establishment of *S.officinalis* while other quantitative parameters such as species height, diameter and volume are not changed significantly. Under these circumstances, plant size (diameter, height and volume) is probably affected by some other ecological factors related to interspecies competition. According to findings of Hasani (2004) and Jamshidi *et al.* (2006), *S.officinalis* is highly tolerated to elevation due to its extensive distribution in different elevations and diverse soil types. Most of the conducted researches on *Salvia* genus demonstrate remarkable resistance of the species against abiotic and biotic environmental stress. In line with findings of Hasani (2004), this study did not find a significant impact of aspect of slope on development of *S.officinalis* communities. Hasani (2004) demonstrated that the best habitats of *S.officinalis* societies in terms of vegetation cover, density, diameter, height, and volume are developed in elevations ranging between 2300 - 2500 m and slopes ranging between 20%- 40%.

According to the obtained results, *S.officinalis* grows rapidly in sandy loam, light textured, high nitrogen content, rich in organic matter content, and the non-calcareous soils. In addition, evaluation of habitat of *S.officinalis* reveals that although the species forms some communities in low elevated areas as the dominant one, its crown cover is much less than those developed in the elevations ranging between 2300 - 2500 m. *S.officinalis* is frequently seen along with species *Agropyron intermedium*, *Astragalus gossypinus*, *Bromus dantoniae*, *Achillea millefolium* and *Astragalus paralogues* in the studied habitats.

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