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Some Ecological Conditions of *Amygdalus scoparia* Spach in Nehbandan, Eastern Iran

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ABSTRACT The effect of soil and topographic features on distribution of *Amygdalus scoparia* in Nehbandan (Iran) was investigated. Slope, aspect and altitudinal maps were overlaid to prepare a working map unit. Quantitative and qualitative traits, including height, number, collar diameter of sprout with the highest diameter, crown diameter and trunk health were recorded in 1000 m^2 plots (27 plots). In each plot, soil was sampled at depth 0-30 cm. The regression model of the traits with topographical and edaphic factors showed that 70% of variations of *A.scoparia* sprout height was explained with calcium carbonate, 50% variations of the number of sprouts was explained with clay, and 77% variations of the crown diameter was explained with calcium carbonate. Correlation results revealed that some soil properties such as clay, potassium, organic matter, sand, acidity and lime accounted for *A.scoparia* distribution. Future work on other indicating factors will help us to determine the optimum range of these factors for this plant species.

Key words: *Amygdalus, Distribution, Environmental features, Growth parameters, Nehbandan*

1 INTRODUCTION

The form of propagation and the presence of plants are not accidental, but the composition, structure, and distribution pattern of plant communities in different habitats are largely controlled by various environmental factors, including water, climate, soil and topographic characteristics (Naseri *et al.*, 2009; Zhang and Dong, 2010; Fattahi and Ildoromi, 2011; Rouhi-Moghaddam *et al.*, 2015). Plant communities are inherently dynamic and change with changing environmental factors, like climate, topography and soil (Burke, 2001; Wright *et al.*, 2003). The change in plant communities is gradual and occurs over time. The distribution of plant communities and effective environmental factors are important issues that must be taken into consideration in the management of a forest ecosystem (Canter *et al.*, 2003). Moradi (2014) found that plant communities in a rangeland were mainly correlated with soil and soil water content, while Masoodipour (2014) indicated that slope, altitude, and soil texture were effective in homogeneity of the plant communities in Sanib Taftan basin region.

In understanding the limiting factors of ecological niches and the relationship between effective environmental factors, there is a need for statistical and mathematical analyses (Leps and Smilauer, 2003). The relationship between vegetation and environmental factors is linear

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(McCune *et al.*, 2002). Multivariate analysis is a branch of statistics that tests numerical quantities and data together with different factors. When examining plant community ecology, the data are related to the number and percentage of the vegetation crown. The final aim of multivariate analysis is to show the significance or insignificance of the effect of environmental factors and to determine the type and level of the effect of the environmental factors on species and different plant communities (Gauk, 1981; Leps and Smilauer, 2003). Ordination means ordering different vegetation in relation to each other and in terms of similarity of the species composition and their controlling factors (Leps and Smilauer, 2003; Mesdaqhi, 2005).

Amygdalus scoparia Spach is a branching shrub in the *Rosaceae* family with upright, green and cylindrical branches reaching a height up to 6 m that bear leaves in linear form. The plant's flowering season is from March to April (Mozafarian, 2004). *A. scoparia* grows well in alluvial soils in the hillsides and resists well in hard and rocky grounds as well as in arid areas. It can tolerate the active limestone in the soil using its strong root system, so the soil in its natural habitats is often light and somewhat limy with good permeability (Alvaninezhad, 1999). This plant grows in many regions of Iran such as Zagros forests (Salarian *et al.*, 2008), Kerman (Irannezhad Parizi, 1995), Fars (Alvaninezhad, 1999), Khorasan (Torabian, 2008), Markazi (Goudarzi, 2008) and Qom (Tavakoli Neko *et al.*, 2011).

Thiswork was conducted in Ebrahimabad region of Nehbandan, where *A. scoparia* is its most important plant species with widespread distribution, to study (1) the growth characteristics of *A. scoparia* (height, number of sprouts, crown diameter and collar diameter), and (2) to find the most effective factors contributing to its distribution.

2 MATERIALS AND METHODS

2.1 Study area

The study area is located in an arid region 20 km north of Nehbandan (between 31° 41' 2", 31° 42' 58" N, and 59° 56' 2", 60° 01' 23" E), covering an area of 1877 ha in South Khorasan province (Figure 1). The average rainfall is 124 mm (the highest being in winter and the lowest in summer), the annual average temperature is 19.9°C and the number of frost days is 37; the average altitudeis 1950 mabove sea level. General soil texture is sandy loam (Report of Sustainable Management of Hori mountain, Nehbandan, Iran, 2010).

2.2 Sampling method

There were differences between topography, soil type, and spatial heterogeneity in the study area. Since the distribution of *A. scoparia* within the area was uneven, a unit work map was prepared as a homogenous unit for the study (Shokrollahi *et al.*, 2014). For this purpose, stream lines and topographic digital maps were prepared with the scale of 1:25000 and in using these maps, Digital Elevation Model (DEM) was provided with the pixel size 5×5 m. In order to investigate the vegetation cover, a field survey was done, then the altitude (Figure 2), slope (Figure 3) and aspect (Figure 4) maps were prepared using ArcGIS 9.3 package. By combining these three maps, land units map was built (Figure 5).

Some traits of *A. scoparia* shrubs was recorded in a systematic-random manner with 1000 m^2 circular plots (27 samples), where the growth parameters were measured, including the total height, crown diameter, number of sprouts, collar diameter of the sprout with the highest diameter, and the trunk health. The regeneration status was examined with 100 m^2 micro plots at the center of each plot.

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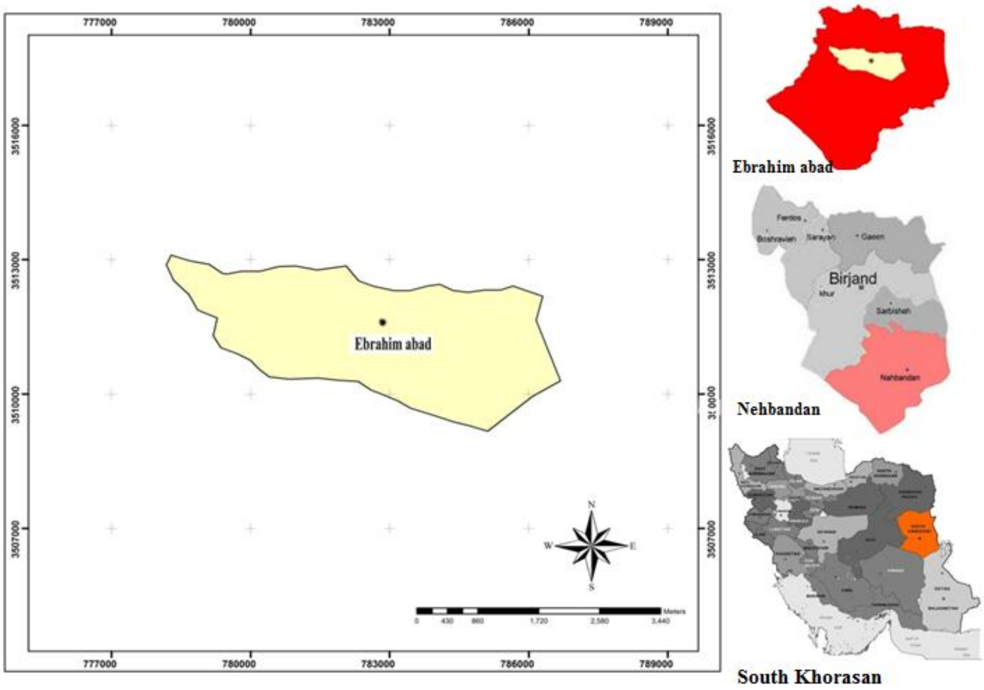

Figure 1 Location of the study area in South Khorasan, Iran

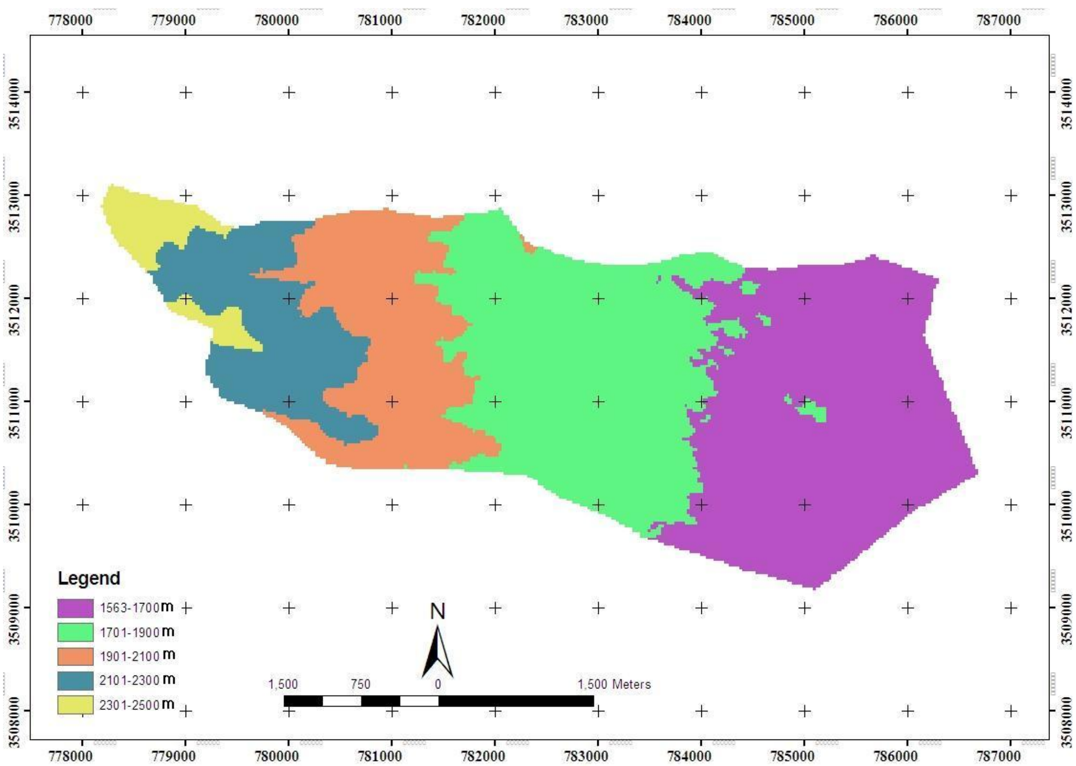

Figure 2 Hypsometric map of the study region

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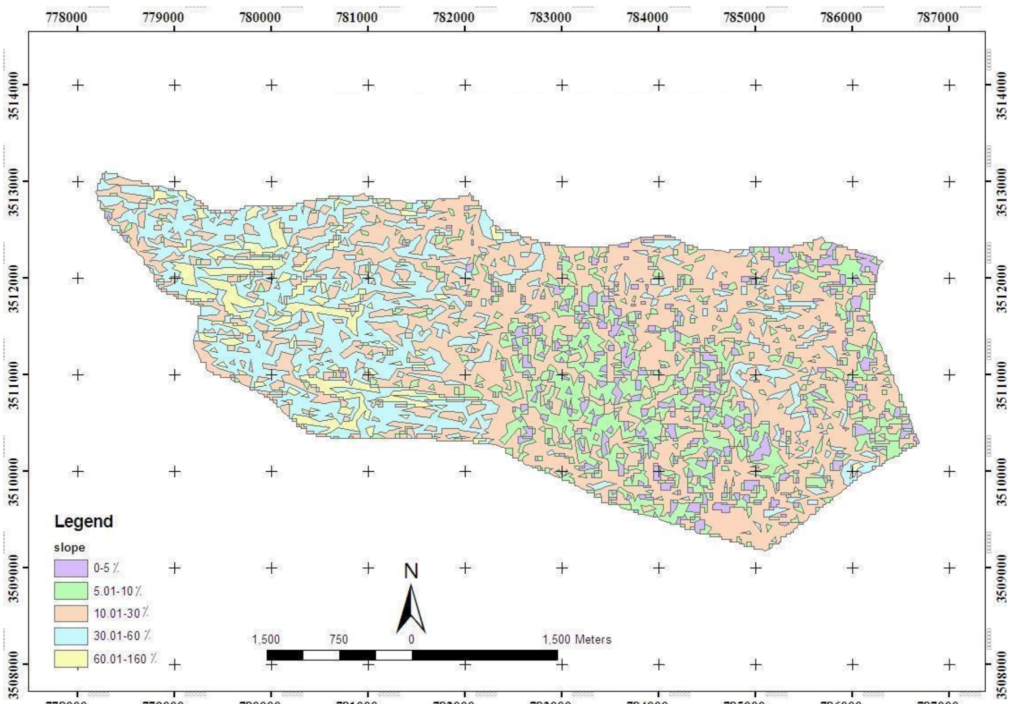

Figure 3 Slope map of the study region

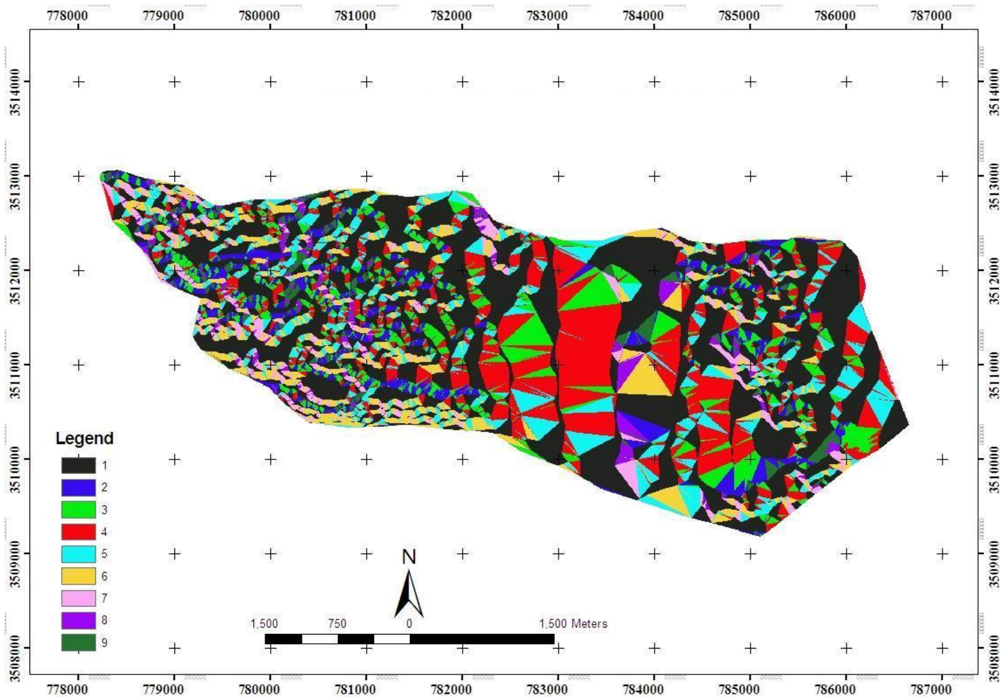

Figure 4 Aspect map of the study region

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Using a hand corer, soil samples were taken from the surface layer (0–30 cm) of a totally 9 randomly selected points in each working units. The samples were taken to the laboratory upon labeling them in plastic bags to determine the physical and chemical properties. The soil's texture was determined using laser diffractometry (Wang *et al.*, 2012); the soil pH was determined using a digital pH-meter (Model 691, Metrohm AG Herisau Switzerland) after one hour agitationof1:5 soil to distilled water slurry (Thomas, 1996); the $CaCO_3$ equivalent was determined by neutralizing with HCl and back titration with NaOH (Black *et al.*, 1965). Available phosphorus (AP) and potassium were, respectively, determined by the method of Bray and Kurtz (1954) and flame photometry method (Knudsen *et al.*, 1982). Organic carbon (OC) was measured by the Walkley-Black method (Nelson and Sommers, 1996). The available calcium was also measured using atomic spectrometry method, ICP/OES (Du Laing *et al.*, 2003).

2.3 Data analysis

Principal components analysis (PCA) was employed using PC-ORD version 4 software to determine the most important factors affecting the plant's qualitative and quantitative properties. For the analysis, data were standardized with a zero mean and a unit variance. Moreover, General Linear Model (GLM) was used to examine the effect of environmental factors (edaphic and physiography factors) on plant characteristics and their entry to the model was examined using stepwise regression (SPSS version 16) software in order to determine the most important variables. One-way analysis of variance (ANOVA) with unequal repeats was used to examine the significant differences between plant characteristics being studied and edaphic factors and direction of data, and duncan test was used to compare the means.

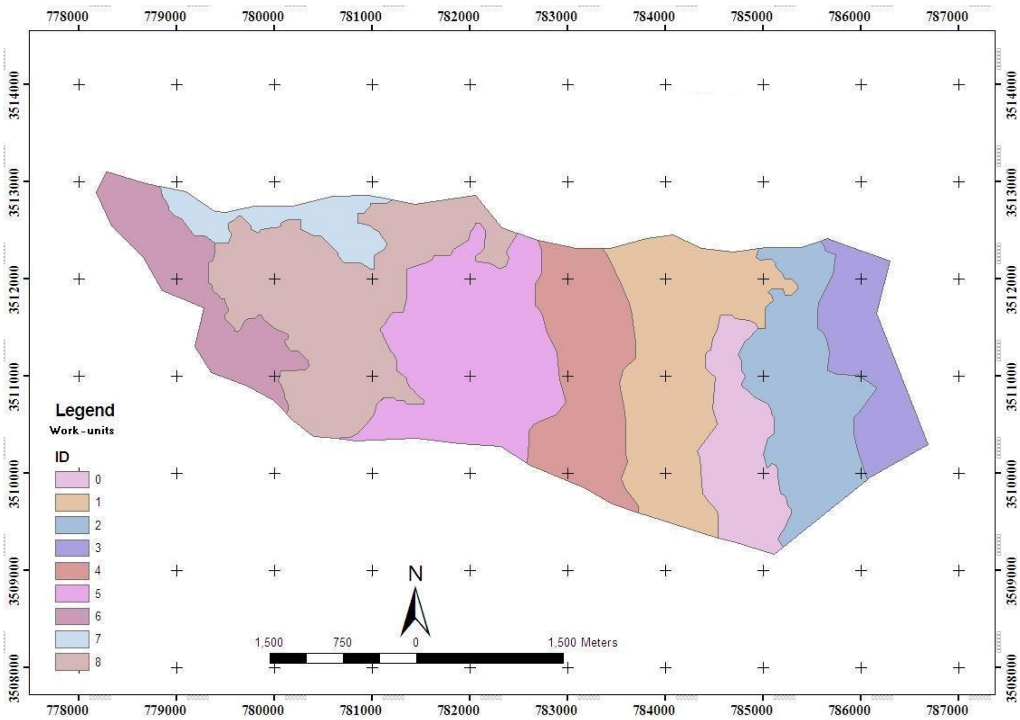

Figure 5 Working unit map of the study region

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3 RESULTS

The characteristics of each working unit are shown in Table 1, including the geographical direction and soil parameters. The average growth parameters of *A. scoparia* are shown in Table 2. The average height of the shrubs was up to 2.41 m, the average collar diameter of the sprout with the highest diameter of any tree was up to 66 cm and the average density of the shrubs was from 56 to 193 shrubs ha^{-1} in the working units. Due to the successive droughts in the region, natural regeneration was not observed in the habitat (number of regenerations=0, Table 2).

The regression model of *A. scoparia* traits, edaphic and direction factors are shown in Table 3. As observed, the equation of the plant height accounts for 70% (R^2adj) of the changes with calcium carbonate, the plant's number of sprouts accounts for 50% (R^2adj) of the changes with clay, and the plant crown diameter accounts for 77% (R^2adj) of the changes with calcium carbonate.

Table 1 Soil factors in the working units

Working unit no.	Domain direction	Sand (%)	Silt (%)	Clay (%)	pH	$CaCO_3$ (%)	P (mg kg^{-1})	K (mg kg^{-1})	Organic matter (%)	Ca (meq l^{-1})	Working unit (ha)
1	Northeast	55	37	8	7.74	9.18	7.00	280	0.30	8.00	131.45
2	Eastern	55	31	14	7.88	18.87	3.00	310	0.66	7.00	221.77
3	Western	59	33	8	7.87	10.45	4.60	400	0.20	5.00	132.69
4	Eastern	48	22	30	7.93	9.18	6.00	290	0.30	10.00	296.90
5	Flat	49	33	18	7.95	12.75	7.60	236	0.07	5.00	205.97
6	Southwest	55	39	6	8.14	10.71	4.00	195	0.40	6.00	311.90
7	Northern	61	27	12	7.84	8.41	7.60	221	0.70	6.00	348.82
8	Western	57	35	8	8.12	14.28	8.600	300	0.67	7.00	148.49
9	Eastern	55	33	12	7.96	12.24	7.000	340	0.17	6.00	74.69

Table 2 Average growth characteristics of *A. scoparia* at each working unit

Working unit	Height (cm)	Number of sprouts	Crown diameter (cm)	Collar diameter (cm)	Number of regenerations	Trunk health (%)	Number of bases in plots
1	87.08	6.79	71.42	5.76	0	98.0	16.3
2	140.73	6.75	112.70	9.96	0	82.70	19.3
3	152.67	6.41	132.47	66.37	0	100.00	11.3
4	101.84	5.23	106.62	7.07	0	76.60	10.0
5	163.21	9.12	139.83	24.87	0	94.70	6.30
6	157.09	6.50	106.21	15.32	0	91.90	12.30
7	123.16	6.08	90.44	14.84	0	94.30	17.7
8	241.54	6.46	234.45	35.89	0	100.0	5.60
9	178.55	7.38	156.71	26.31	0	96.80	10.30

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The results of the correlation between *A. scoparia* growth traits and edaphic and geographical direction factors showed that the maximum correlation of the number of sprouts of the plant had the highest correlation with clay (75%) and silt (62%), respectively (Table 4). The crown diameter showed the highest correlation with soil organic matter (89%) and slop (81%), respectively. The plant height showed the highest correlation with the soil organic matter (86%) and slop (57%), respectively. The results show that collar diameter had the maximum correlation (66%) with the amount of potassium.

Table 3 The results of the General Linear Model (GLM) regression analysis of *A. scoparia* traits with environmental factors

R^2adj	R^2		
70	73	Y= 69.70+21.05$caco_3$	The equation of plant height with environmental factors
50	56	Y= 0.69+0.66$clay$	The equation of number of sprouts with environmental factors
77	80	Y= 152.63+26.12$caco_3$	The equation of crown diameter with environmental factors

Table 4 Correlation coefficients between *A. scoparia* traits, and edaphic and direction vectors

Correlation	Clay	Silt	Sand	P	K	Ca	pH	Caco3	OM	Slop
Height	-0.01	0.15	-0.15	0.27	0.20	-0.17	0.74*	0.21*	0.86*	0.57*
Number of sprouts	0.75**	0.62*	-0.55	-0.17	0.04	0.46	-0.36	-0.16	0.01	-0.38
Crown diameter	0.001	0.14	-0.16	0.31	0.39	-0.02	0.62*	0.05	0.89**	0.81**
Collar diameter	-0.14	0.22	-0.01	-0.15	0.66*	-0.50	0.15	-0.22	0.32	0.52

*significance at the level 5%, **significance at the level 1%

Table 5 Factors affecting *A. scoparia* distribution using PCA

Component	Eigenvalue	Variance (%)	Cumulative variance (%)	Broken-stick eigenvalue
1	3.55	35.54	35.54	2.93
2	1.83	18.32	53.86	1.93
3	1.49	14.88	65.74	1.43
4	1.32	13.17	81.92	1.10
5	1.02	10.25	92.17	0.85
6	0.43	4.29	96.45	0.65
7	0.26	2.56	99.01	0.48
8	0.01	0.98	100.00	0.34
9	0.00	0.00	100.00	0.21
10	0.00	0.00	100.00	0.10

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The results of PCA indicate that the first, second, third and the fourth axes account for 35.53%, 18.32%, 14.88% and 13.17% of the changes, respectively (Table 5). In total, the four axes accounted for 81.91% of the changes. Clay in the first axis, potassium and organic matter in the second axis, and acidity and lime in the third axis accounted for the distribution of *A. scoparia* (Table 6). Among significant principal components of the first axis, clay was positive in the working units 5 and 2, and negativein the working units 4 and 6. Also, since among the significant components of the second axis, the percentage of potassium and organic matter are negative, the habitat of *A. scoparia* stands in the working units 3 and 9 is also in the positive side of the axes in direct relation with potassium percentage and is inversely related to organic matter percentage. But the working unit 7 in the negative side is inversely related to potassium percentage and is directly related to organic matter. About 92.78% of the examined total bases of *A.scoparia* were in working units 9 and 7.22% had unhealthy trunks.

Table 6 Correlation between environmental variables and principal components (R) in PCA

Variable	Component (axis)					
	First	**Second**	**Third**	**Fourth**	**Fifth**	**Sixth**
	0.4639	-0.1700	-0.2863	-0.0675	0.1339	0.2633
Clay (%)	-0.3932	0.2137	0.0168	-0.0173	-0.5625	0.0051
Sand (%)	-0.3270	0.0403	0.4632	0.1299	0.4141	0.0561
P (mg kg^{-1})	-0.0662	-0.4201	0.0864	0.6508	-0.1070	0.2406
K (mg kg^{-1})	0.0539	0.4829	-0.1570	0.4810	0.4411	0.0561
Ca (%)	0.4022	-0.2798	-0.1383	0.0405	0.0197	-0.6755
pH	-0.2975	0.0289	-0.0897	-0.5004	-0.1683	-0.3623
OM (%)	-0.2085	-0.4135	0.1833	0.0432	0.0990	0.1121
$CaCO_3$ (meq l^-)	-0.2541	-0.0143	-0.5664	0.4204	-0.0820	-0.1328
Slope	-0.3390	-0.1160	-0.2173	-0.3102	0.5201	0.2998

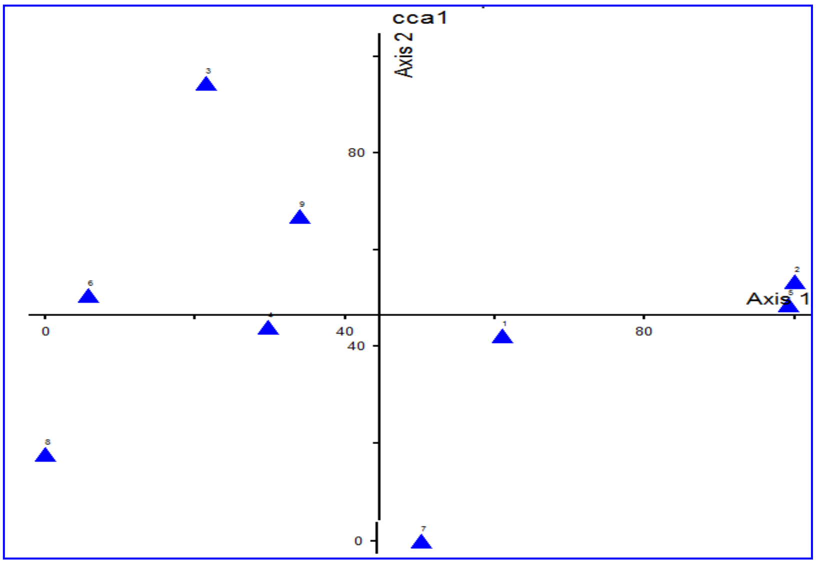

Figure 6 PCA ordination diagram of *A. scoparia* distribution in relation to environmental factors and soil characteristics in the study area

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4 DISCUSSION

A. scoparia is distributed in many regions of Iran, especially in Irano-Turanian phytogeographical region. The establishment of the plant in Nehbandan, where climate is dry and has been experiencing successive droughts, show the species' high compatibility with hard environmental conditions. The soil in most habitats of almond genera is light and somewhat limy with good permeability (Alvaninezhad, 1999). Soil characteristics, especially its texture were determined as important factors affecting *A. scoparia* distribution, which is also consistent with an earlier result in Qom habitats (Tavakoli Neko *et al.*, 2011). It is also consistent with the results by Salarian *et al.* (2008) who stated that edaphic factors were important for the development and growth of *A. scoparia* in different height classes when examining itshabitat requirements in Zagros forests. In the present research, there was also a correlation between height, number of sprouts, crown diameter and collar diameter of the sprout with the highest diameter and soil characteristics. Soil texture affects the establishment and distribution of different species through its moisture, ventilation and accessible foods. In this regard, Heydari *et al*. (2009) considered soil texture as effective factors in rangeland separation of a protected zone. Soil texture is reported as an effective factor in water penetration and storage as well as plant's accessibility to water and foodstuff. In addition to the impacts on plant group determinations, soil texture is also effective in plant species distribution (Sperry and Hacke, 2002). For example, Davies *et al.* (2007) documented positive association of soil texture content with plant species composition in a semiarid environment. The soil texture is one of the stable physical properties of the soil and affects the other soil properties including soil bulk density, moisture storage, soil penetrability, cation exchange capacity (CEC), saturation percentage and amount of organic matter (Jafari-Haghighi, 2003; Ebrahimi *et al.,* 2016). Masoodipour *et al*. (2014) addressed the soil texture as an effective factor in *A. lycoides* communities in Taftan rangelands. Salarian *et al*. (2008) considered $CaCo_3$ and soil texture as effective factors in distribution of *A. scoparia* in a habitat.

The correlation test between the environmental variables and the PCA on the importance of edaphic and direction factors revealed that clay, acidity and lime accounted for the distribution of *A. scoparia* in the first axis, while sand had the highest effect on distribution in the third axis. Since the clay percentage was positive among the significant principal components of the first axis, the mass of *A. scoparia* in the working units 5, 2 and 1 were directly related to the clay percentage and those in the working units 4 and 6 that were in the negative side of the first axis, were inversely related to the clay percentage. Alvaninezhad (1999) stated that *A. scoparia* habitats were mountainous and rocky areas having alkaline and erosive soils with loamy, clay and loamy-clay textures. Salarian *et al.* (2008) also reported the existence of the species on calcareous formations. Goudarzi (2008) reported a correlation between the existence of the species and the frequency of the soil's silt, sand, potassium and acidity in moist environments and also between the existence of the species and active limestone, organic carbon and nitrogen in warmer environments.

The results showed that potassium and organic matter had the highest importance to justify *A. scoparia* distribution. Number of sprouts in working units 3 and 9 and in the positive side of the axes was directly related to the potassium percentage and inversely related to the organic matter percentage. Examining the effect of topographical, climate and soil factors on the diversity of the central European meadows, Wellstein *et al.* (2007) indicated that the soil's nutrients played an important role in the plants' diversity and wheat's freshness. Potassium is one of the macronutrients of plants being largely consumed after nitrogen and phosphorous (Mahmodi and Hakymian, 2007). Jafari *et al.* (2002) found potassium as an effective factor in species diversity of rangelands in Yazd province.

Lime was another important edaphic factor affecting *A. scoparia* distribution and there was a correlation between $CaCo_3$ and the species distribution in the third axis, which was also consistent with the results by Moradi (2014) on distribution of some plants in Kakan basin. $CaCO_3$ is the most important variable in soil affecting acidity and controlling other forms of nutrients (Hardtle *et al.*, 2003). $CaCO_3$ largely affects the growth and distribution of plants, which is also reported as an effective factor of vegetative distribution (Jafari *et al.*, 2002; Monier *et al.*, 2006). It is also a mineral with low solubility in water and if it is soluble, a strong alkali is produced that limits the growth of the plants needing acidic pH. Hence, $CaCO_3$ is a growth inhibitor for limestone-demanding plants and reduces the capability of using micronutrients, such as zinc and manganese, by plants (Mahmodi and Hakymian, 2007).

The geographical direction, as an important factor of plants' establishment, was found to have norelationship with the distribution of *A. scoparia* in the study region; this factor was, therefore, not included in the regression model. However, a correlation between geographical direction and *A. scoparia* height was evident. The number of the plants' bases was more in the east than the other directions, which was not consistent with the results by Salarian *et al.* (2008), reporting direction as an important factor in *A. scoparia* distribution in Zagros forests.

5 CONCLUSION

In this research, the soil characteristics was found to be an important factor in the distribution and growth of *A. scoparia* and the hillside directions had no effect.

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برخی ویژگی‌های اکولوژیکی رویشگاه بادامک در نهبندان، شرق ایران

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چکیده نقش خصوصیات خاک و توپوگرافی در پراکنش گونه بادامک، *Amygdalus scoparia* در منطقه ابراهیم آباد شهرستان نهبندان با در نظر گرفتنصفات کمی و کیفی شامل ارتفاع، تعداد جست، قطر یقه، قطورترین جست، قطر تاج و سلامت تنه در قطعات نمونه ۱۰۰۰ مترمربعی بررسی شد. نقشه طبقات ارتفاعی، شیب و جهت جغرافیایی تهیه و با تلفیق این نقشه‌ها، نقشه واحد کاری تهیه گردید. در هر قطعه، نمونه خاک از عمق ۰- ۳۰ سانتی‌متری تهیه گردید. مدل رگرسیونی خصوصیات گونه بادامک با خصوصیات خاک و جهت نشان داد که برای معادله ارتفاع گیاه با کربنات کلسیم ۷۰ درصد تغییرات و معادله تعداد جست گیاه با رس ۵۰ درصد تغییرات و معادله قطر تاج بادامک با کربنات کلسیم ۷۷ درصد تغییرات را توجیه می‌کند. مطابق نتایج جدول همبستگی، برخی از خصوصیات خاک از قبیل مقدار رس، پتاسیم، ماده آلی، مقدار شن، اسیدیته و آهک بیشترین اهمیت را در توجیه پراکنش این گونه داشتند. بطور کلی با یافتن عوامل موثر در پراکنش گونه بادامک می‌توان دامنه شرایط مطلوب برای این گونه گیاهی را مشخص نمود.

کلمات کلیدی: بادامک، پراکنش، ویژگیهای محیطی، پارامترهای رویشی، نهبندان
