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Geographic variation in the morphology of *Macrovipera lebetina* (Linnaeus, 1758) (Ophidia: Viperidae) in Iran

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Abstract. The Levantine viper, *Macrovipera lebetina*, has an extensive geographical range being distributed in central Asia and the Middle East. The species exhibits high levels of polymorphism, especially in colouration and pattern. Recent studies revealed significant morphological differences between the two subspecies from northeastern and western portions of Iran. However, considering limited geographic samplings, taxonomic status of Iranian *Macrovipera* are controversial. In this study, uni- and multivariate statistical techniques were used to analyze geographic variation in 31 morphological characters measured in 117 specimens of *Macrovipera lebetina* covering its entire range in Iran. Sexual dimorphism was obvious in number of scales across the head and subcaudals. Univariate analyses detected substantial geographic variation in several meristic characters. Pholidosis exhibits a general north-south pattern of variation and most scale counts averaged higher in southern regions. Colouration displayed a pattern of strong clinal variation among three broad areas consisting of the combined western and northwestern, northeastern, and southern highland regions. Also, morphometric characters exhibited a general north-south pattern of geographic variation and some characters averaged lower in southern regions. Populations from the southern regions remained clearly distinct in Principal Component, Cluster and Discriminant analyses. In the light of these differences, it is concluded that the southern Iranian populations should not be identified as belonging to *Macrovipera lebetina obtusa* (Dwigubsky, 1832), which occurs in northwestern and western regions of the Iranian Plateau.

Keywords. Viperidae, *Macrovipera lebetina*, geographic variation, morphology, statistical analyses, Iranian Plateau.

INTRODUCTION

The genus *Macrovipera* has been described by Reuss in 1927, and then resurrected by Herrmann et al. (1992). According to Lenk et al. (2001), just two species are known: *Macrovipera schweizeri* (Werner, 1935), which is endemic to a few islands in the western Cyclades (Nilson and Andrén, 1988) and *Macrovipera lebetina* (Linnaeus, 1758). The Levantine viper, *Macrovipera lebetina* is distributed from Central Asia to the Middle East (Nilson and Andrén, 1988; Nilson et al., 1988; Böhme and Wiedl, 1994; Göçmen et al., 1996; David et al., 1999; Atatür and Göçmen, 2001; Ananjeva et al., 2006; Göçmen et al., 2006). Traditionally, up to six distinct subspecies were recognized of *M. lebetina*: *M. l. chernovi* (Chikin and Szczerbak, 1992), *M. l. lebetina* (Linnaeus, 1758), *M. l. obtusa* (Dwigubsky, 1832), *M. l. peilei* (Murray, 1892), *M. l. transmediterranea* (Nilson and Andrén, 1988) and *M. l. turanica* (Terentiev and Chernov, 1940). Recently, Stümpel and Joger (2009) and Stümpel (2012) in their molecular analysis showed that haplotypes of *Macrovipera lebetina* are subdivided into five major lineages which support the validity of the allopatric subspecies *lebetina*, *euphratica, obtusa*, *turanica* and *chernovi*

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with no samples available from *peilei* (southern Afghanistan and Pakistan) and *transmediterranea* (north Africa). One more *lebetina*-like taxon from south-central Iran (Jiroft/Baft Mts.) is genetically very distinct from all other *Macrovipera lebetina* taxa (Stümpel, 2012). *Macrovipera lebetina obtusa* (Dwigubsky, 1832) has a southernmost range from Turkey south to N Jordan, eastwards through the Caucasus to Kashmir and N India (Sindaco et al., 2013). *Macrovipera lebetina chernovi* (Chikin and Szczerbak, 1992) occurs in north-eastern Iran, south Turkmenistan, and parts of northern Afghanistan, Tadjikistan, and northern Pakistan (Phelps, 2010; Stümpel, 2012) and is replaced by *Macrovipera lebetina turanica* in central Asia.

The body colour of blunt-nosed vipers can be virtually any shade of brown, even pinkish, dark or light grey. Specimens from Cyprus tend to be paler. The blunt-nosed viper can possess faint or bold markings and many seem uniform in colour. Markings, however distinct, take the form of cross bands, dorsal blotches, and vertical lateral bars of a darker hue than the ground colour. Some handsome specimens have a more contrasting colour pattern (Mermer et al., 2012). The ventral surface is usually a paler version of the ground colour with or without darker stippling (Phelps, 2010).

In recent years, Iranian researchers such as Afroosheh and Kazemi (2011), Rajabizadeh et al. (2011) and Oraie et al. (2012) have done valuable surveys on the taxonomic status of *Macrovipera lebetina* in Iran. All of the previous researches have focused on the western and northeastern populations of *M. lebetina*, whereas southern populations were not investigated. In order to clarify their taxonomic status, in this paper geographic variation in morphology of all populations of *Macrovipera lebetina* across the whole distribution range in Iran is discussed.

MATERIALS AND METHODS

Specimens and sampling

In this study, 117 specimens of *M. lebetina* were examined across the entire range of species distribution in Iran (see Appendix). Of these, 77 mature and intact individuals (29 males and 41 females) were selected for analysis of metric and meristic characters used in morphological studies of vipers, and 99 specimens were investigated in non-parametric analysis of colour pattern. Because of the immaturity or lack of revealed colour pattern, 65 specimens among them were selected for parametric analysis. Thirty specimens were captured from June 2012 to late October 2013; more than twenty were released subsequent to measuring morphological characters in the field, whereas the remainders according to Pisani (1973) were preserved in ethanol 96% and deposited at the Razi University Zoological Museum (RUZM), Museum of Shahid Bahonar University of Kerman (ZMSBUK), and Sabzevar University Herpetological Collection (SUHC). Additional specimens subject of this study come from the herpetological collections (Table 1). Also, six pictures were selected for analyzing the colour pattern.

Characters

Characters used in this research are listed in Table 2. All of the specimens were examined for eight metric, seventeen meristic, and six colour pattern characters (Table 2). Metric characters were evaluated with a digital caliper to the nearest 0.01 mm.

Because expressing body measurements as a percentage of Snout-Vent Length (SVL) does neutralize allometry, we calculated the residual values of each body measurements as a function of SVL (Babocsay, 2003). All mensural characters as compared to SVL were analyzed.

Table 1. Number of specimens subject of present study come from the herpetological collections and used for meristic, mensural, and color pattern analysis.

Type of analysis	Herpetological collections					
	ZCRI	ZMSBUK	SUHC	RUZM	SUZM	FDOI
Meristic	43	4	6	4	2	4
Mensural	43	4	6	4	2	4
Colour pattern	55	7	6	6	3	4
Total	61	8	9	8	3	4

ZCRI: Zoological Collection of the Department of Venomous Animals and Antiserum Production, Razi Vaccine and Serum Research Institute, Hesarak, Karaj

ZMSBUK: Zoological Museum of Shahid Bahonar University of Kerman

SUHC: Sabzevar University Herpetological Collection

RUZM: Razi University Zoological Museum

SUZM: Shiraz University Zoological Museum

FDOI: Species Diversity Museum of Department of Environment, Fars

Table 2. Morphological characters used in this study.

	Abbreviation	Characters
Meristic characters	PreV	Number of preventrals + small gular scales along the midline of the ventral side of the head
	Ven	Number of ventral scales
	Scd	Number of subcaudal scales
	Dors1	Number of dorsal scale rows, counting across the forepart of the body [one head length behind the posterior end of head][1]
	Dors2	Number of dorsals, counted across mid-body (at mid-SVL length)
	Dors3	Number of dorsals, counted across the hind part of the body, one head length before the anal plate[1]
	Ap	Number of apical scales
	Blspl	Number of scales between last supralabial scales across the head
	Can	Number of canthal scales
	Interocular	Number of scales across head, between the dorsal parts of two eyes
	Spl*	Number of supralabials scales
	Ifl*	Number of sublabial (infralabial) scales
	inCir*	Number of inner circumocular scales
	outCir*	Number of outer circumocular scales (around eye and supraocular scales)
	Lor*	Number of loreal scales
	Supraoc	Number of supraocular scales
	bESpl	Number of scales between eye and supralabials
Mensural characters (mm)	SVL	Snout-vent length
	TaL	Tail length
	HL	Head length (from anterior tip of snout to the angle of jaws)
	HW	Head width
	HH	Head height
	DbN	Distance between nostrils
	IOD	Inter ocular distance
	SL	Snout length (distance between rostrum to the anterior edge of eye)
Colour pattern characters	SCN	The area of the black or dark pigmentation in and around the dorsal blotch, in number of scales. A scale was counted half if it was pigmented over < 50% and one if > 50% of its area (mean of three blotches, halfway between the rostrum and the anus)[2]
	L/WdbR	Length to width ratio for a dorsal blotch at mid-SVL.
	L/DdbR	Length of dorsal blotch to distance between two blotches at mid-SVL
	L/DlbR	Length of lateral blotch to distance between two blotches at mid-SVL
	DbC	Dorsal base colour: G) gray; GB) grayish brown; B) brown; R) reddish brown
	VentP	Ventral pattern: D) scattered dots on the entire ventral surface; DD) ventral surface densely dotted; S) scattered dots on the entire ventral surface with a trapezoid splotch

* Meristic characters were recorded from both sides and analyzed separately.
[1] Campbell et al., 2004.
[2] Babocsay, 2003.

Statistical analyses

The Principal Components Analysis (PCA) based on a correlation matrix of meristic data was used to determine whether distinct geographic units exist within *Macrovipera lebetina*. Independent multivariate analyses were conducted on combined sexes.

In addition, the Cluster observation method was used to explore the population's groupings, based on significant characters which had $r^2 > 50\%$. Also Discriminant Analysis was used for meristic characters, in order to evaluate the actual degree of discrimination among the *a priori* groups as well as to predict their group membership. Moreover, generalized squared distances between groups were computed to show the distance between each pair of groups.

To describe dispersal pattern among morphological characters of different localities, descriptive statistical parameters including Minimum, Maximum, Mean and Standard devia-

tion were employed separately for each group. Data normality was checked by drawing residual plots: Residual versus fits and Main effects plot for each character to carrying out the analyses. The existence of sexual dimorphism was checked in all mature specimens using independent sample t-test. Because some data was missing, the General linear model ANOVA was used to explore the significant differences by gender, but also sexes combined. Statistical analyses for all meristic and colour pattern characters were performed using one-way ANOVA followed by Fisher's LSD method comparison *post hoc* test to explore the patterns of morphological variation among combined sexes. Also, considering that DbC and VentP are qualitative characters, non-parametric analyses for these characters were performed using Kruskal-Wallis test. The significance level for all the statistical tests was set at $P < 0.05$. Statistical analyses were performed using the MINITAB® (Ver. 16) for the Windows.

RESULTS

Descriptive statistics

Ranges and Mean ± SD for studied characters in each group are provided in Table 3. The specimens were classified according to the different colour patterns and recent studies (Oraie et al., 2012), and the distribution of each pattern in Iran was mapped (Fig. 1). Specimens were grouped in four geographic samples based on geographic units: I. Khorasan Province (Kopet Dagh Mts.); II. Golestan Province (area between Kopet Dagh Mts. and Alborz Mts.); III. Alborz Mts. along with the northern part of Zagros Mts.; IV. Southern part of Zagros Mts. (Latitude 33°N) extended south to the Persian Gulf coast and continuing southeast to Sistan Mts. (Longitude 58°E).

Results of ANOVA analyses for meristic characters

Analysis of meristic data indicated that nine characters in males [Ven, AP, Blspl, Spl(L), Spl(R), Ifl(L), Ifl(R), outCir(L) and Supraoc], ten characters in females [Ven, Scd, Spl(L), Ifl(L), Ifl(R), inCir(L), inCir(R), outCir(L), Lor(R) and Supraoc] and thirteen characters when sexes were combined [PreV, Ven, Scd, Can, Interocular, Spl(L), Spl(R), Ifl(L), Ifl(R), inCir(L), outCir(L), Lor(L) and Lor(R)] showed statistically significant differences ($P < 0.05$).

Results of ANOVA for meristic characters in combined sexes show that PreV in group III was significantly lower ($P < 0.05$) compared to other groups. The number of Ven in group IV are significantly ($P < 0.0001$) higher than in other groups, whereas Scd in group II are significantly lower compared to other groups. Characters of Ifl(L) and Ifl(R) in group IV show significant higher values ($P < 0.0001$) in comparison with groups II and III, whereas respective values form group IV overlap with those of group I. Lor(L) in group II were significantly higher in comparison with group IV. Scale counts of Lor(R) and Spl(L) in groups I and IV are significantly increased compared to groups II and III and separated from them, whereas, scale counts of Supraoc in these groups (I and IV) was significantly decreased with respect to groups II and III. Also, scale counts of Spl(R) in group IV shows a significant increase ($P < 0.05$) in comparison with groups II and III and separated from them, whereas this group overlaps with group I.

Results of ANOVA analyses for metric characters

Results of ANOVA analyses showed that IOD in males, Tal in females, IOD and DbN in combined sexes showed significant differences ($P < 0.05$). Results for mensural characters in combined sexes indicated that vipers from eastern populations have broader heads than those from western and northwestern populations.

Results of ANOVA and non-parametric analyses for colour patterns

Analysis of colouration indicates that three characters (SCN, L/WdbR and L/DdbR) in combined sexes show statistically significant differences ($P < 0.05$) among groups. In four groups, results of ANOVA for colour pattern show that SCN in group IV has significantly lower number than in group III, but it overlaps with values from groups I and II. Character of L/WdbR in groups I and IV were significantly decreased ($P < 0.05$) with respect to groups II and III. Character of L/DdbR in groups I and IV were significantly lower ($P < 0.05$) with respect to group III.

Analysis of two non-parametric characters among 99 individuals indicated that both dorsal base colour (DbC) and ventral pattern (VentP) in combined sexes showed powerful significant differences ($P < 0.0001$) among groups. The median of DbC among four groups was 74.07% R for group I; 50% B for group II; 72% GB for group III and 75.67% G for group IV. Also, the median of VentP among groups was 100% DD for group I; 70% B for group II; 56% D for group III and 86.48% S for group IV. These results indicated that each geographical group have a particular pattern, however, some individuals were difficult to classify with an ambiguous colour patterns such as uniform ground colour without recognizable pattern.

According to these results and our observations, three different colour patterns existed among the Iranian populations (Fig. 2).

Table 3. Descriptive statistics of meristic, mensural, and colour pattern characters in four groups of *Macrovipera lebetina*. All Mensural characters as compared to SVL were analyzed.

Character	Sex	I Mean ± SD (n) (range)	II Mean ± SD (n) (range)	III Mean ± SD (n) (range)	IV Mean ± SD (n) (range)
PreV	M	4.60 ± 0.54 (5) 4-5	4.50 ± 0.57 (4) 4-5	4.00 ± 0.00 (4) 4-4	4.70 ± 0.58 (18) 3-5
	F	4.75 ± 0.50 (4) 4-5	4.71 ± 0.48 (7) 4-5	4.18 ± 0.60 (11) 3-5	4.57 ± 0.60 (19) 3-5
Ven	M	170.20 ± 1.79 (5) 168-172	167.25 ± 5.12 (4) 162-173	170.50 ± 2.52 (4) 168-174	173.35 ± 2.00 (18) 171-178
	F	168.75 ± 2.63 (4) 165-171	167.29 ± 2.69 (7) 164-172	169.09 ± 2.59 (11) 165-173	174.00 ± 2.98 (19) 169-179
Scd	M	46.80 ± 3.11 (5) 44-52	44.5 ± 3.11 (4) 42-49	46.00 ± 2.45 (4) 43-49	47.25 ± 3.99 (18) 35-53
	F	44.25 ± 4.03 (4) 40-49	39.86 ± 5.46 (7) 29-46	45.60 ± 3.75 (11) 37-49	45.78 ± 3.06 (19) 42-52
Dors 1	M	24.20 ± 1.09 (5) 23-25	25.00 ± 0.00 (4) 25-25	24.50 ± 1.00 (4) 23-25	24.11 ± 1.23 (18) 21-25
	F	25.00 ± 0.00 (4) 25-25	24.14 ± 1.06 (7) 23-25	24.45 ± 0.93 (11) 23-25	23.94 ± 1.54 (19) 21-27
Dors 2	M	25.40 ± 0.89 (5) 25-27	25.00 ± 0.00 (4) 25-25	25.00 ± 0.00 (4) 25-25	25.22 ± 0.64 (18) 25-27
	F	25.00 ± 0.00 (4) 25-25	25.00 ± 0.00 (7) 25-25	25.18 ± 0.60 (11) 25-27	25.21 ± 0.63 (19) 25-27
Dors 3	M	19.00 ± 0.00 (5) 19-19	18.50 ± 1.00 (4) 17-19	19.00 ± 0.00 (4) 19-19	18.77 ± 0.64 (18) 17-19
	F	19.00 ± 0.00 (4) 19-19	19.00 ± 0.00 (7) 19-19	19.18 ±0.60 (11) 19-21	19.00 ± 0.00 (19) 19-19
Ap	M	6.80 ± 0.44 (5) 6-7	7.00 ± 0.00 (4) 7-7	6.00 ± 0.00 (4) 6-6	6.38 ± 0.50 (18) 6-7
	F	7.00 ± 0.81 (4) 6-8	6.28 ± 0.48 (7) 6-7	6.81 ± 0.87 (11) 6-9	6.31 ± 0.58 (19) 6-8
Blspl	M	23.80 ±0.83 (5) 23-25	25.25 ± 0.50 (4) 25-26	26.00 ± 0.81 (4) 25-27	25.20 ± 1.20 (18) 23-28
	F	25.25 ± 1.70 (4) 23-27	25.71 ± 0.75 (7) 25-27	25.36 ± 1.28 (11) 23-27	26.12 ± 1.02 (19) 24-28
Can	M	2.20 ± 0.44 (5) 2-3	2.00 ± 0.00 (4) 2-2	2.50 ± 0.57 (4) 2-3	2.18 ± 0.40 (18) 2-3
	F	2.25 ± 0.50 (4) 2-3	2.00 ± 0.00 (7) 2-2	2.50 ± 0.52 (11) 2-3	2.15 ± 0.37 (19) 2-3
Interocular	M	12.00 ± 0.70 (5) 11-13	10.50 ± 0.57 (4) 10-11	11.75 ± 1.25 (4) 10-13	11.11 ± 0.67 (18) 10-12
	F	11.75 ± 0.95 (4) 11-13	11.28 ± 0.75 (7) 10-12	12.09 ± 1.22 (11) 10-14	11.21 ± 0.97 (19) 9-13
Spl(L)	M	10.40 ± 0.54 (5) 10-11	10.00 ± 0.81 (4) 9-11	9.75 ± 0.50 (4) 9-10	10.72 ±0.57 (18) 10-12
	F	10.50 ± 0.57 (4) 10-11	9.85 ± 0.37 (7) 9-10	10.27 ± 0.64 (11) 9-11	10.73 ± 0.65 (19) 10-12
Spl(R)	M	10.60 ± 0.54 (5) 10-11	9.75 ± 0.50 (4) 9-10	9.50 ± 0.57 (4) 9-10	10.83 ± 0.61 (18) 10-12
	F	10.50 ± 0.57 (4) 10-11	10.28 ± 0.75 (7) 9-11	10.45 ± 0.52 (11) 10-11	10.52 ± 0.61 (19) 10-12

Table 3. (Continued).

Character	Sex	I Mean ± SD (n) (range)	II Mean ± SD (n) (range)	III Mean ± SD (n) (range)	IV Mean ± SD (n) (range)
Ifl(L)	M	13.80 ± 0.44 (5) 13-14	12.25 ± 0.50 (4) 12-13	13.00 ± 0.81 (4) 12-14	14.27 ± 0.89 (18) 13-16
	F	13.75 ± 0.50 (4) 13-14	13.28 ± 0.75 (7) 13-15	13.36 ± 0.67 (11) 13-15	14.42 ± 1.01 (19) 13-17
Ifl(R)	M	13.80 ± 0.83 (5) 13-15	12.50 ± 0.57 (4) 12-13	13.00 ± 0.00 (4) 13-13	14.16 ± 0.85 (18) 13-16
	F	13.50 ± 0.57 (4) 13-14	13.57 ± 0.78 (7) 12-14	13.45 ± 0.68 (11) 13-15	13.42 ±0.83 (19) 13-16
inCir(L)	M	15.60 ± 1.51 (5) 14-17	14.50 ± 1.00 (4) 13-15	16.00 ± 1.55 (4) 15-17	15.11 ± 1.07 (18) 14-17
	F	14.50 ± 1.29 (4) 13-16	16.14 ± 0.69 (7) 15-17	15.90 ± 1.04 (11) 14-17	14.78 ± 1.08 (19) 13-17
inCir(R)	M	15.60 ± 2.70 (5) 13-19	14.25 ± 0.95 (4) 13-15	15.50 ± 1.29 (4) 14-17	15.61 ± 1.09 (18) 14-18
	F	14.75 ± 1.25 (4) 13-16	16.71 ± 0.75 (7) 16-18	16.18 ± 1.66 (11) 13-19	14.94 ± 1.12 (19) 13-17
outCir(L)	M	23.20 ± 0.83 (5) 22-24	22.25 ± 1.50 (4) 21-24	20.75 ± 1.70 (4) 19-23	22.88 ± 1.27 (18) 21-25
	F	20.75 ± 1.70 (4) 19-23	21.71 ± 0.95 (7) 20-23	21.36 ± 1.69 (11) 20-26	22.89 ± 1.15 (19) 21-25
outCir(R)	M	22.80 ± 1.30 (5) 21-24	22.00 ± 2.16 (4) 20-25	22.75 ± 2.87 (4) 19-26	22.88 ± 1.67 (18) 20-25
	F	21.50 ± 2.38 (4) 19-24	22.14 ± 1.77 (7) 20-25	22.72 ± 2.19 (11) 19-27	22.94 ± 1.90 (19) 18-25
Lor(L)	M	16.40 ± 1.51 (5) 14-18	13.00 ± 1.41 (4) 12-14	14.50 ± 0.57 (4) 14-15	15.46 ± 2.29 (18) 12-20
	F	14.25 ± 3.20 (4) 11-17	13.14 ± 1.67 (7) 11-16	14.00 ± 2.79 (11) 9-19	15.62 ± 1.74 (19) 12-18
Lor(R)	M	16.80 ± 2.16 (5) 14-20	14.00 ± 1.41 (4) 13-15	14.75 ± 1.89 (4) 12-16	14.92 ± 1.97 (18) 12-19
	F	15.25 ± 2.75 (4) 12-18	13.42 ± 1.90 (7) 11-16	13.81 ± 2.52 (11) 9-17	15.75 ± 1.43 (19) 13-18
Supraoc	M	1.40 ± 0.89 (5) 1-3	2.00 ± 0.81 (4) 1-3	2.75 ± 0.50 (4) 2-3	1.33 ± 0.68 (18) 1-3
	F	1.50 ± 1.00 (4) 1-3	2.71 ± 0.48 (7) 2-3	2.81 ± 0.40 (11) 2-3	1.15 ± 0.50 (19) 1-3
bESpl	M	3.00 ± 0.00 (5) 3-3	3.00 ± 0.00 (4) 3-3	3.00 ± 0.00 (4) 3-3	2.94 ± 0.23 (18) 2-3
	F	3.00 ± 0.00 (4) 3-3	3.00 ± 0.00 (7) 3-3	3.00 ± 0.00 (11) 3-3	2.89 ± 0.31 (19) 2-3
Tal/SVL	M	0.13 ± 0.00 (5)	0.13 ± 0.01 (4)	0.13 ± 0.00 (4)	0.13 ± 0.01 (17)
	F	0.13 ± 0.01 (4)	0.12 ± 0.00 (7)	0.13 ± 0.01 (11)	0.13 ± 0.01 (19)
HL/SVL	M	0.04 ± 0.00 (5)	0.04 ± 0.00 (4)	0.04 ± 0.00 (4)	0.04 ± 0.00 (15)
	F	0.04 ± 0.00 (4)	0.04 ± 0.00 (7)	0.04 ± 0.00 (11)	0.04 ± 0.00 (16)
HW/SVL	M	0.02 ± 0.00 (5)	0.02 ± 0.00 (4)	0.0 ± 0.00 (4)	0.02 ± 0.00 (17)
	F	0.02 ± 0.00 (4)	0.02 ± 0.00 (7)	0.02 ± 0.00 (11)	0.02 ± 0.00 (19)
HH/SVL	M	0.01 ± 0.00 (5)	0.01 ± 0.00 (4)	0.01 ± 0.00 (4)	0.01 ± 0.00 (18)
	F	0.01 ± 0.00 (4)	0.01 ± 0.00 (7)	0.01 ± 0.00 (11)	0.01 ± 0.00 (19)
DbN/SVL	M	0.01 ± 0.00 (5)	0.00 ± 0.00 (4)	0.00 ± 0.00 (4)	0.00 ± 0.00 (15)
	F	0.01 ± 0.00 (4)	0.00 ± 0.00 (7)	0.00 ± 0.00 (11)	0.00 ± 0.00 (16)

Table 3. (Continued).

Character	Sex	I Mean ± SD (n) (range)	II Mean ± SD (n) (range)	III Mean ± SD (n) (range)	IV Mean ± SD (n) (range)
IOD/SVL	M	0.01 ± 0.00 (5)	0.01 ± 0.00 (4)	0.01 ± 0.00 (4)	0.01 ± 0.00 (15)
	F	0.01 ± 0.00 (4)	0.01 ± 0.00 (7)	0.01 ± 0.00 (11)	0.01 ± 0.00 (16)
SL/SVL	M	0.01 ± 0.00 (5)	0.01 ± 0.00 (4)	0.01 ± 0.00 (4)	0.01 ± 0.00 (15)
	F	0.01 ± 0.00 (4)	0.01 ± 0.00 (7)	0.01 ± 0.00 (11)	0.01 ± 0.00 (16)
SCN		16.66 ± 7.35 (7) 6.33-27.33	17.83 ± 3.62 (4) 12.66-21.00	19.82 ± 4.80 (11) 12.00-25.66	13.47 ± 4.95 (25) 7.00-27.00
L/WdbR		0.37 ± 0.12 (7) 0.21-0.52	0.69 ± 0.11 (4) 0.53-0.75	0.68 ± 0.22 (11) 0.34-1.07	0.37 ± 0.12 (25) 0.10-0.61
L/DdbR		0.86 ± 0.38 (7) 0.36-1.25	1.44 ± 0.22 (4) 1.14-1.67	1.61 ± 0.70 (11) 0.65-3.10	0.78 ± 0.41 (25) 0.32-1.97
L/DlbR		0.82 ± 0.32 (7) 0.48-1.38	0.95 ± 0.31 (4) 0.63-1.24	0.93 ± 0.32 (12) 0.52-1.78	0.64 ± 0.37 (26) 0.31-2.07

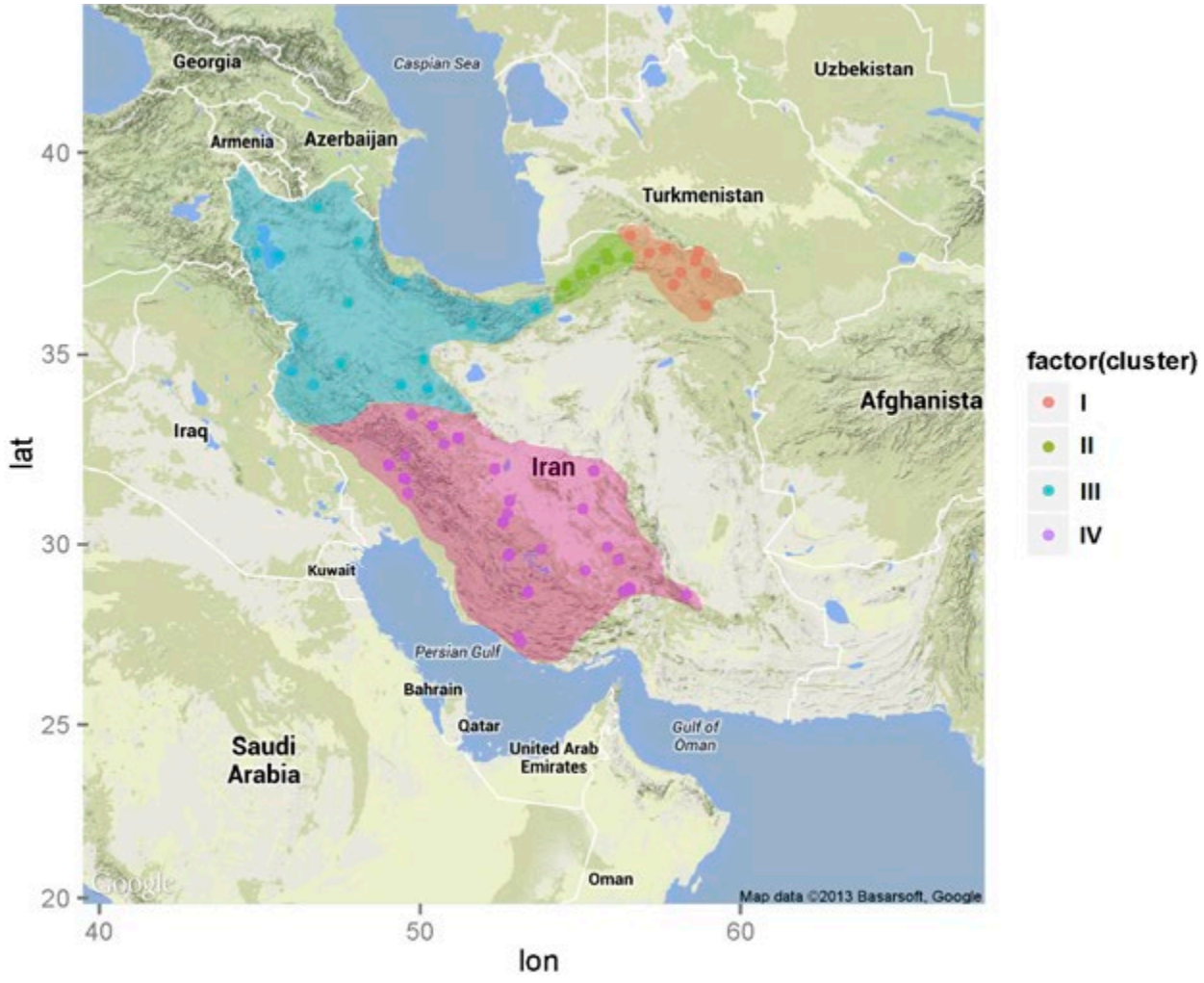

Fig. 1. Distribution map of *Macrovipera lebetina* in Iran, each coloured region represents a studied group. Each circle on the map represents a location from which at least one snake was examined.

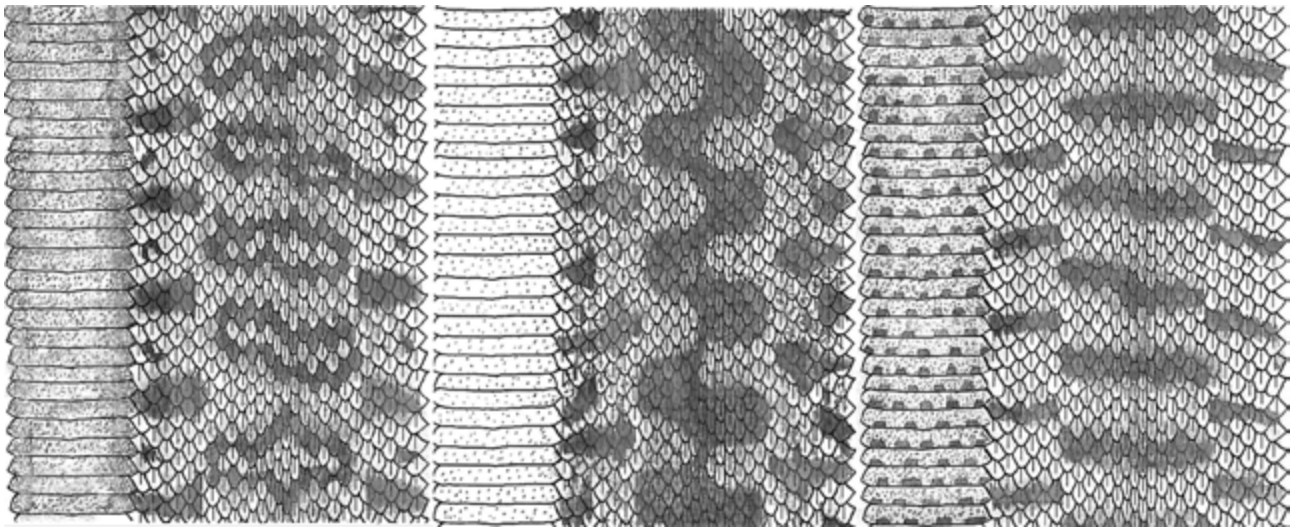

Fig. 2. Typical pattern of *Macrovipera lebetina* from northeastern populations (Left); northern, western and northwestern populations (Middle); and southern populations (Right) (Sketch by: Naeim Moradi).

Principal Component Analysis

Multivariate analysis of the meristic characters was carried out to determine whether distinct geographic units exist within *Macrovipera lebetina* populations. Five Principal Components (PCs) explained 55.8%, and the first eight Principal Components revealed 73.5% of the total variation. Of this total, 18.9% explained by PC1 in which Supraoc, Ven, and Ifl were mainly responsible for this variation; 31.8% explained by PC2 which is mainly attributed to Interocular and inCir; 41.6% explained by PC3 mainly attributed to outCir; and 49.1% explained by PC4 in which Scd and Dors3 were more important. These results showed that the Supraoc, Ven and Interocular are most important characters in separating populations (Table 4). The magnitude and sign of the loadings on PC1 and PC2 showed significant separation among groups and the high degree of separation of southern populations (group IV) from other groups. Also, group I tends to separate from two residual groups (Fig. 3).

Cluster analysis

A Pearson distance dendrogram based on two meristic characters (Ven and Supraoc) with $P < 0.05$ and $r^2 > 50\%$ clusters all four geographic groupings used in this study. Males and females are treated together because there is no sexual significant difference between them in these two characters. In Figure 4, the first major dichotomy separates the southern populations (cluster IV) with a considerable distance from all other clusters. The second major dichotomy separates the northeastern populations (cluster I) with a distance from clusters II and III, which, in turn, constitute two major branches; one branch encompasses Gorgan populations (cluster II) from northern Iran, whereas the other branch is composed of all the other localities in northwest, west and western parts of Alborz Mts., approaching cluster IV in the south.

Discriminant analysis

The reclassifications were compared to the original cluster designations to determine how well the original model was supported by the Discriminant Analysis. Due to existence of missing values, twelve cases were removed from the multivariate analyses. Discriminant Analysis was performed on the 58 remaining snakes with sexes combined. Classification results and predicted group membership showed that 98.3% of the original allocations were correctly classified. Though vipers from the northeastern population (group I) were correctly classified to 88.9%, this value is 100% for other three groups. However, classification results with Cross-validation indicated that a total of 72.4% of the original groupings were correctly classified. Proportions correctly classified are 66.7% for group I, 77.8% for group II, 46.2% for group III, and 85.2% for group IV. The generalized squared distances among groups were computed to show the distance between each pair of groups as follow: 17.37 between group II and III; 22.63 between group I and II; 19.69 between group I and IV; 31.32 between group II and IV; 19.49 between group I and III; and 28.03 between group III and IV (Table 5).

Table 4. Factor loadings on the first eight Principal Components extracted from a correlation matrix of 22 meristic characters in *Macrovipera lebetina* from Iran.

Characters	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
PreV	0.214	-0.009	0.048	-0.298	0.361	0.068	-0.008	0.013
Ven	0.323	-0.127	0.192	0.169	-0.307	0.182	0.156	0.059
Scd	0.172	-0.104	-0.018	0.426	-0.076	-0.216	0.042	-0.263
Dors 1	-0.024	0.196	0.065	0.150	0.085	-0.213	0.101	0.613
Dors 2	0.106	0.269	0.265	0.104	-0.021	-0.368	0.139	-0.300
Dors 3	-0.062	0.292	0.155	0.302	-0.096	0.034	0.097	-0.360
Ap	0.032	0.188	0.095	0.207	0.563	-0.178	0.011	-0.057
Blspl	-0.010	0.167	-0.109	0.264	-0.259	0.118	-0.550	0.092
Can	-0.093	0.244	0.003	0.322	0.218	0.399	-0.248	-0.066
Interocular	0.028	0.425	-0.033	0.032	0.167	-0.080	0.281	0.154
Spl(L)	0.267	0.056	0.135	0.051	0.096	-0.085	-0.498	0.032
Spl(R)	0.230	0.139	0.023	-0.354	0.138	-0.080	-0.330	-0.049
Ifl(L)	0.304	0.172	0.345	-0.079	-0.189	0.193	0.085	0.155
Ifl(R)	0.304	0.230	0.236	-0.176	-0.146	-0.025	-0.135	0.024
inCir(L)	-0.124	0.389	-0.234	-0.209	-0.199	0.015	-0.005	-0.023
inCir(R)	-0.112	0.349	-0.083	-0.204	-0.372	-0.115	0.076	-0.074
outCir(L)	0.302	0.022	-0.368	-0.020	-0.018	-0.287	0.030	0.011
outCir(R)	0.175	0.017	-0.494	-0.023	-0.003	-0.194	-0.106	-0.248
Lor(L)	0.340	0.139	-0.253	0.030	0.061	0.277	0.237	0.027
Lor(R)	0.289	0.074	-0.330	0.163	0.065	0.383	0.163	0.048
Supraoc	-0.368	0.263	-0.105	-0.030	0.062	0.131	-0.048	0.058
bESpl	-0.035	0.044	0.147	-0.283	0.135	0.312	0.080	-0.435
Eigenvalue	4.1650	2.8393	2.1580	1.6449	1.4744	1.4230	1.3280	1.1291
Proportion	0.189	0.129	0.098	0.075	0.067	0.065	0.060	0.051
Cumulative	0.189	0.318	0.416	0.491	0.558	0.623	0.683	0.735

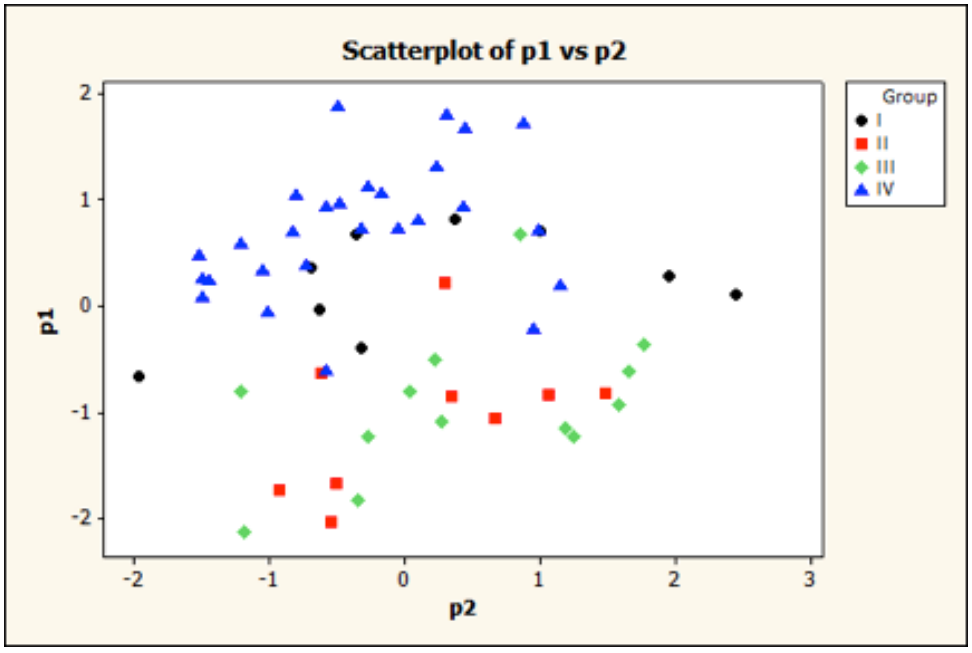

Fig. 3. Scatterplot of individuals on the first two Principle Components.

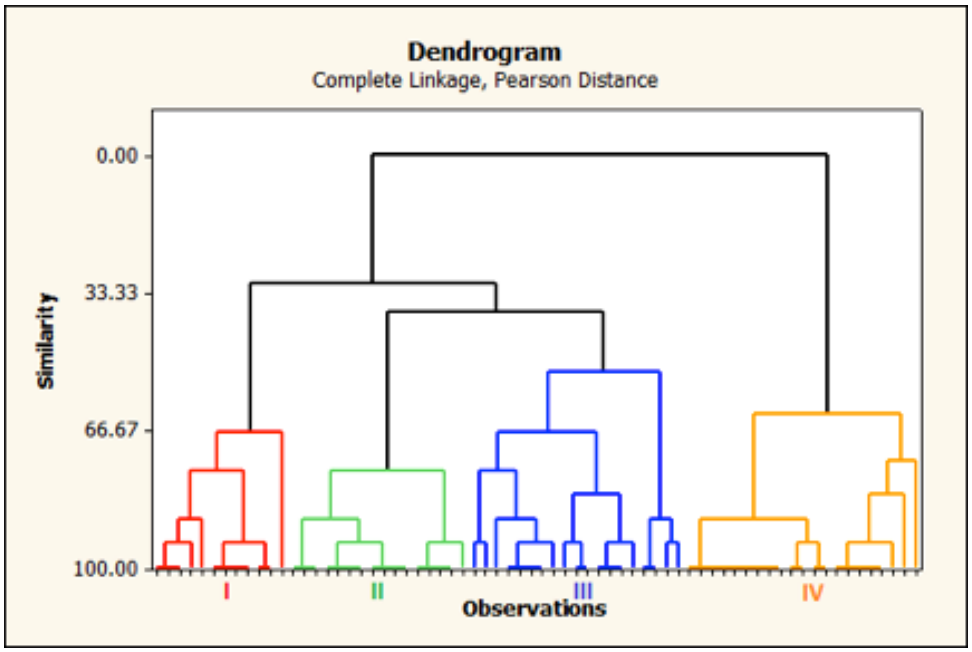

Fig. 4. Pearson distance dendrogram resulting from the Cluster Analysis based on two meristic characters (Ventral and Supraocular scales) of *Macrovipera lebetina* in Iran.

Table 5. Linear Discriminant Function for groups.

Characters	I	II	III	IV
PreV	119	125	120	121
Ven	88	88	88	90
Scd	-22	-23	-22	-23
Dors 1	48	49	48	49
Dors 2	61	62	58	59
Dors 3	242	246	243	244
Ap	-15	-16	-16	-19
Blspl	78	81	79	80
Can	-24	-29	-20	-17
Interocular	-41	-43	-40	-43
Spl(L)	72	70	73	72
Spl(R)	64	62	61	66
Ifl(L)	-162	-164	-159	-164
Ifl(R)	-56	-58	-59	-55
inCir(L)	39	40	41	39
inCir(R)	-0	0	-1	-1
outCir(L)	131	133	130	134
outCir(R)	-56	-56	-53	-56
Lor(L)	-11	-12	-11	-10
Lor(R)	-32	-33	-35	-34
Supraoc	39	45	44	38
bESpl	371	384	376	368
Constant	-12071	-12320	-12210	-12495

Table 6. Standardized Coefficients for determining differences among four groups of *Macrovipera lebetina*.

Characters	Function		
	1	2	3
PreV	0.070	-0.421	0.447
Ven	-0.234	0.755	-0.001
Scd	-0.045	0.151	-0.204
Dors 1	-0.001	-0.097	0.175
Dors 2	0.142	-0.261	-0.022
Dors 3	0.135	-0.067	0.001
Ap	0.135	-0.422	-0.490
Can	-0.345	0.546	0.049
Interocular	0.121	0.651	-0.567
Spl(L)	-0.219	0.061	-0.347
Spl(R)	-0.228	0.108	-0.131
Ifl(L)	-0.208	0.012	0.077
Ifl(R)	-0.369	0.198	0.444
inCir(L)	0.115	0.131	-0.141
inCir(R)	0.098	-0.472	0.188
outCir(L)	-0.059	0.179	0.391
outCir(R)	0.163	0.249	0.282
Lor(L)	2.340	7.021	2.551
Lor(R)	-2.137	-6.654	-2.474
Supraoc	0.874	0.267	0.195
bESpl	0.418	-0.082	-.295

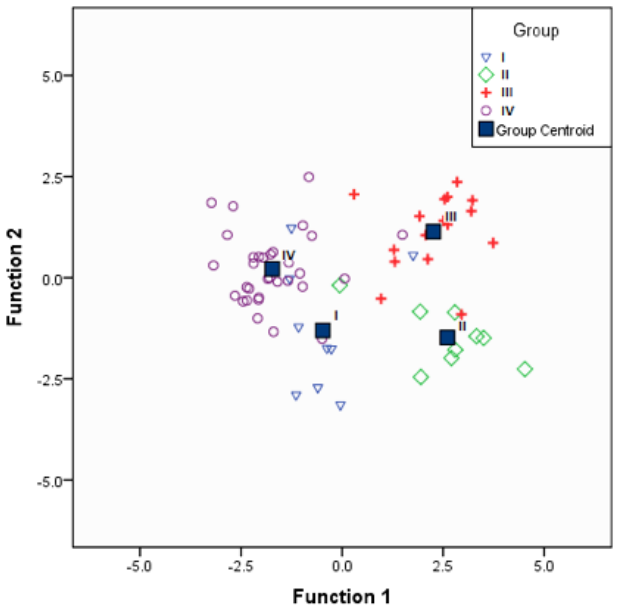

Fig. 5. Patterns of variation expressed by the two Discriminant Functions (Function 1 against Function 2) for four groups of *Macrovipera lebetina*.

Based on additional Discriminant Function analysis (DFA) of meristic characters using SPSS® Ver. 20, the first three functions yielded 100% of total information in which, the first function explained 73% of the total variance with characters Supraoc, Ifl, Spl and inCir having the highest values. The loadings of each character on a particular function are shown in Table 6. Function 1 is heavily weighted by numbers of supraocular scales (Supraoc) and the number of loreal scales (Lor). Function 2 is weighted by ventral (Ven), canthal (Can), Loreal (Lor) and Interocular scales, while function 3 is weighted by loreal scales count (Lor). Totally, loreal scale count was the most powerful character to separate four groups.

Based on this analysis, with the ordination of four groups along the first two functions (Function 1 against Function 2), the centroids of each geographic group is well separated from any other group (Fig. 5).

Results of sexual dimorphism analyses

Firstly, two sample t-tests using all meristic data showed significant sexual dimorphism ($P < 0.05$) in Scd and Blspl. This indicates that males have more subcaudal scales (Scd) and females have more scales across the head. A Principal Component Analysis (PCA) for sexes was performed; the magnitude and sign of the loadings on PC1 and PC2 showed apparent sexual dimorphism pattern between males and females. Although, the scatterplot did not show a clear separation between the sexes, but a weak pattern of sexual dimorphism is apparent (Fig. 6).

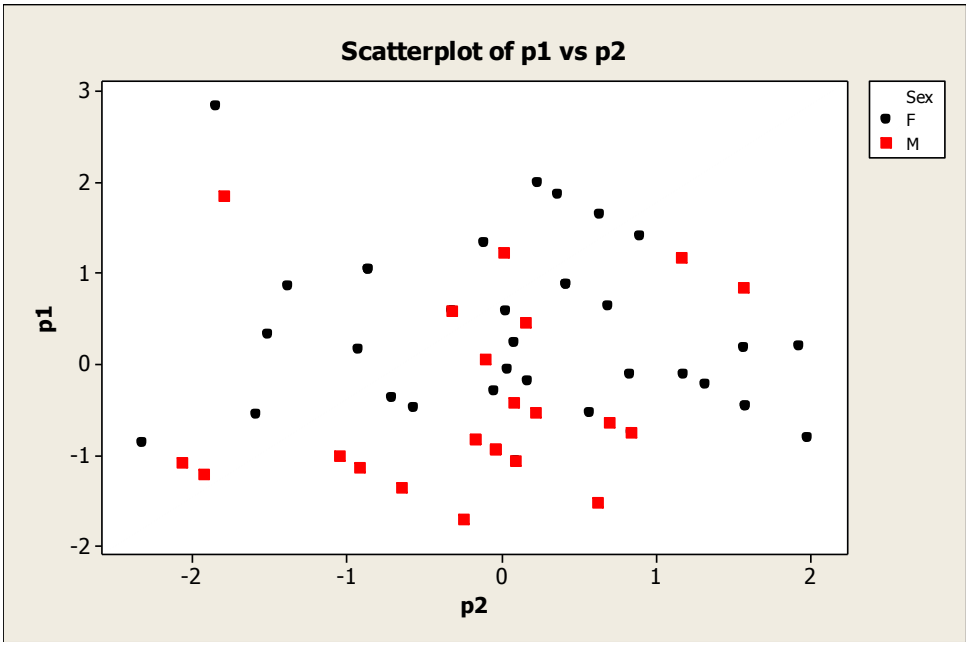

Fig. 6. Scatterplot of Principal Component Analysis for males and females of *Macrovipera lebetina.*

DISCUSSION

Latifi in 1983 assigned the Iranian *Macrovipera* to the subspecies of *Macrovipera lebetina obtusa* (Dwigubsky, 1832). However, Chikin and Szczerbak in 1992 described a new subspecies from Khorasan Province. Until now, the Iranian *Macrovipera* consisted of two subspecies: *Macrovipera lebetina obtusa* (Dwigubsky, 1832) (Fig. 7) distributed in west, northwest, and north of Iran, and *Macrovipera lebetina chernovi* (Chikin and Szczerbak, 1992) (Fig. 8) occurring in northeastern Iran. Our results indicated that the separation of the northeastern populations of *M. lebetina* from the northwestern and western populations could be corroborated by morphological characters, as previously suggested by Chikin and Szczerbak (1992), Ananjeva et al. (2006), Rajabizadeh et al. (2011), and Oraie et al. (2012). However, the character expression in southern populations likely amounts to another taxonomic status in the Iranian *Macrovipera* taxa.

M. lebetina populations from southern region of the Iranian Plateau showed significant differences to all northern populations regarding several morphological characters. For example, pholidosis showed a general north-south pattern of geographic variation for most meristic characters. Ventral, infralabial, outer circumocular and supralabial scales averaged higher, and interocular, inner circumocular and supraoculars averaged lower in the southern regions.

Many ophidians display latitudinal pattern of geographic variation in Pholidosis. Christman (1980) examined 15 species of snakes in Florida and founded a latitudinal pattern of geographic variation in two characters, ventral and subcaudal scales, both of which increased in number from north to south in most species. Higher scales count in the southern regions could also be the result of selection for larger body sizes, which in turn may reflect longer annual growing periods in southern regions.

Substantial geographic variation in colouration was observed among the Iranian *Macrovipera* as well. Vipers from the southern populations have the narrowest crossbars on dorsum with high distances between them. They also entail lower scale counts compared to northwestern and northeastern populations. The general pattern of body crossbars and blotches in *Macrovipera lebetina* appeared to be influenced by latitudinal pattern and elevation. The Alborz Mts. of the northern and northwestern regions combine high latitude and high elevation, and consequently annual temperatures there are among the coldest in the species' range. High number of dark pattern elements would be expected to increase the ability of a snake to thermoregulate at high elevations. Integumentary colour and reflectance are known to exert a strong influence on the thermal biology of snakes (Peterson et al., 1993).

Also, according to non-parametric analysis, there was a clinal difference between northern and southern populations, so that with toward the southern latitudinal, dorsal body colour become brighter and ventral dots pattern become denser and dots form a trapezoid-shaped spots and belly will have a mottled appearance.

Geographic variation in pattern may be strongly related to habitat. The differences between the northeastern and western regions may be due to the lower elevations and warmer summers of the northeastern regions and different landscape features in Kopet Dagh Mts.

In addition, the southern populations remained clearly distinct in all multivariate analyses and the cluster analyses showed that the southern populations were distinguishable with a considerable distance from all the other clusters. Multivariate statistical analyses are the

Fig. 7. An adult specimen of *Macrovipera lebetina obtusa* from Takab, western Azerbaijan Province, Iran (Photograph by Omid Mozaffari).

Fig. 8. An adult specimen of *Macrovipera lebetina chernovi* from Khorasan Province, Iran (Photograph by Hasan Moghimi).

most comprehensive when applied to morphological data, inasmuch as the rely upon multiple aspects of the phenotype. The formal recognition of distinct geographic units within *Macrovipera lebetina* in supported by this study.

Gorgan populations (cluster II) in the multivariate analyses virtually separated from other northeastern and northern-western populations, however, existence of overlapping in pholidosis and colour pattern in some characters can be a sign of a hybrid zone between two major northeastern and northern-western populations, this confirms the existence of two subspecies of *M. l. obtusa* and *M. l. chernovi*. In spite of that cannot be recognized a distinct border between ranges of two northern subspecies, individuals of Gorgan populations have more similar to the northern-western subspecies.

Eventually, individual characters often showed clear patterns of variation. In all of multivariate analyses, characters of Ventral and Supraocular scales were identified as important and significant variables and were used for mapping geographic variation.

Differences in dorsal and ventral scale counts are often diagnostic for different species of *Macrovipera* (Nilson and Andrén, 1988; Joger, 1984; Göçmen et al., 1999; Phelps, 2010) and Chikin and Szczerbak, 1992 early reliance on supraoculars to delineate subspecies of Iranian *Macrovipera lebetina*. Most recently, Stümpel (2012) in molecular analyses on mtDNA sequences mentioned that the specimen from southeastern Iran were completely distinct from other specimens of *M. lebetina*. However, studies of reptiles have demonstrated the early classification based on a few specimens or single morphological characters often do not agree with more comprehensive molecular and morphological analyses.

Nevertheless, we accept, provisionally, considering the some morphological evidences, the hypothesis of the specific status of the southern Iranian populations as *Macrovipera* sp. (Fig. 9). However, complementing phylogenetic investigation is required to gain a deeper understanding of the evolution of this species complex.

New combinations of morphological characters are used to device a key for identification of Iranian *Macrovipera*, partly based on diagnostic characteristics gathered from Chikin and Szczerbak (1992), David et al. (1999), Joger (1984) and Oraie et al. (2012).

Fig. 9. An adult male, *Macrovipera* sp. from Masjed Soleyman, Khuzestan Province, Iran (Photograph by Naeim Moradi).

IRANIAN *MACROVIPERA* IDENTIFICATION KEY

1a- Ventral scales 156-188 (less than 171 in 81.08% of specimens) 2

1b- Ventral scales 169-179 (more than 172 in 83.78% of specimens), supraocular entire, and infralabials 13-17, dorsum brownish gray with narrow crossbars with distinguishable distance between them, each crossbar includes 13.47 ± 0.99 pigmented scales at mid snout-vent length. Belly covered with dark blotch (3-5 trapezoid spots in posterior part of each ventral scales). Some southeastern specimens' uniform glazy black ..... *Macrovipera* sp.

2a- Supraocular entire or divided and larger than circumoculars, snout dark (one third of anterior part of the head). Dorsum reddish brown or dark with large unfilled blotch which sometimes connected together, each dorsum blotch includes 16.66 ± 2.78 pigmented scales at mid snout-vent length. The ratio of interocular distance to head length is 0.39 ± 0.02. Belly often light and splotched by dark dots..... *Macrovipera lebetina chernovi* (Chikin and Szczerbak, 1992)

2b- Three supraoculars present and same as the other circumoculars, head uniform, with narrow strips between the corner of the mouth and the posterior part of the eyes, and also between the eye and fourth supralabial scale. Dorsum brown or dark brown with rectangular dark marking and arrange in zigzag pattern, each dorsum blotch includes 19.29 ± 1.16 pigmented scales at mid snout-vent length. The ratio of interocular distance to head length is 0.36 ± 0.01. Belly often light and splotched with dark dots ....*Macrovipera lebetina obtusa* (Dwigubsky, 1832)

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Appendix. Herpetological collections, locality, and collection numbers (No.) of the specimens of *Macrovipera lebetina* used in present study.

Specimens	Locality	No.
ZCRI	Kalat, near Mashhad, Khorasan Razavi Prov.	2349
	Kalat, near Mashhad, Khorasan Razavi Prov.	2350
	Kalat, near Mashhad, Khorasan Razavi Prov.	2363
	Kalat, near Mashhad, Khorasan Razavi Prov.	2351
	Kalat, near Mashhad, Khorasan Razavi Prov.	2346
	Kalat, near Mashhad, Khorasan Razavi Prov.	2342
	Kalat, near Mashhad, Khorasan Razavi Prov.	2344
	Gorgan, Golestan Prov.	1313
	Gorgan, Golestan Prov.	2154
	Gonbad e Kavoos, Golestan Prov.	2158
	Tang-e-Rah (Gonbad e Kavoos), Golestan Prov.	2260
	Tang-e-Rah (Gonbad e Kavoos), Golestan Prov.	2261
	Gonbad e Kavoos, Golestan Prov.	2256
	Gonbad e Kavoos, Golestan Prov.	2259
	Tang-e-Rah (Gonbad e Kavoos), Golestan Prov.	2262
	Gorgan, Golestan Prov.	2151
	Rahmat Abad (Rasht), Gilan Prov.	2143
	Rudbar, Gilan Prov.	2150
	Arak, Markazi Prov.	2267
	Alajigh, Between Tehran & Saveh	2292
	Ashk Island, Orumie Lake	129382
	Mahallat, Markazi Prov.	1314
	Orumie Lake Island	129381
	Rezaeie, West Azarbaijan Prov.	129380
	Alajigh, Between Tehran & Saveh	2180
	Arezu Island, Orumie Lake	129386
	Bijar, Kordistan Prov.	1249
	Ashk Island, Orumie Lake	129383
	Kermanshah, Kermanshah Prov.	972
	Semirom, Esfahan Prov.	2274
	Khansar, Esfahan Prov.	2237
	Khansar, Esfahan Prov.	2238
	Meymahe, Esfahan Prov.	2280
	Semirom, Esfahan Prov.	2159
	Eghlid (Aso pas), Fars Prov.	2144
	Albaji, Ahvaz, Khuzistan Prov.	2309
	Tang-e-Karun, Eghlid, Fars Prov.	2210
	Albaji, Ahvaz, Khuzistan Prov.	2142
	Tang-e-Karun, Eghlid, Fars Prov.	2212
	Shushtar, Khuzistan Prov.	2248
	Abadeh, Fars Prov.	2298
	Albaji, Ahvaz, Khuzistan Prov.	2234
	Masjed soleyman, Khuzistan Prov.	2299
	Albaji, Ahvaz, Khuzistan Prov.	2195
	Aligudarz, Lorestan Prov.	2208
	Tang-e-Karun, Eghlid, Fars Prov.	2211
	Masjed-Soleyman, Khuzistan Prov.	2170
	Mamasani, Fars Prov.	119204
	Masjed-Soleyman, Khuzistan Prov.	2168
	Ramhormoz, Khuzistan Prov.	121817
	Kalat, near Mashhad, Khorasan Razavi Prov. (Picture)	426
	Kalat, near Mashhad, Khorasan Razavi Prov. (Picture)	979
	Kalat, near Mashhad, Khorasan Razavi Prov.	969
	Mashhad, Khorasan Razavi Prov.	1385
	Mashhad, Khorasan Razavi Prov.	1272
	Mashhad, Khorasan Razavi Prov.	1273
	Dare Gaz, Khorasan Razavi Prov.	608

Specimens	Locality	No.
	Dare Gaz, Khorasan Razavi Prov.	2228
	Dare Gaz, Khorasan Razavi Prov.	1304
	Masjed-Soleyman, Khuzistan Prov.	2171
	Masjed-Soleyman, Khuzistan Prov.	2166
SUHC	Khorasan Razavi Prov.	ERP 986
	Khorasan Razavi Prov.	ERP 987
	Babmaran, Kerman Prov.	ERP 143
	Bahrame gur Protected area, Fars Province	ERP 1531
	Bakhtegan National park, Fars Prov.	ERP 1518
	Pariz, Kerman Prov.	ERP 3732
	Balvard, Sirjan, Kerman Prov.	ERP 1941
	Sabzevar, Khorasan Razavi Prov.	ERP 666
	Shimbar Protected area, Khuzistan Prov.	ERP 1741
RUZM	Kermanshah, Kermanshah Prov.	VV.31.3
	Kermanshah, Kermanshah Prov.	VV.31.1
	Kermanshah, Kermanshah Prov.	VV.31.2
	Kermanshah, Kermanshah Prov.	VV.31.5
	Asmari Mts, Masjed soleyman, Khuzistan Prov	VV.31.6
	Asmari Mts, Masjed soleyman, Khuzistan Prov	VV.31.7
	Abdanan, Ilam Prov.	unlabeled
	Abdanan, Ilam Prov.	unlabeled
ZMSBUK	Khabr National Park, Kerman Prov.	A3
	Khabr National Park, Kerman Prov.	A18
	Khabr National Park, Kerman Prov.	A12
	Sirjan, Kerman Prov.	A46
	Sirjan, Kerman Prov.	A57
	Khabr National Park, Kerman Prov.	A58
	Pariz, Kerman Prov.	A110
	Baft, Kerman Prov.	A32
SUZM	Shiraz, Fars Prov.	unlabeled
	Bamoo National Park, Fars Prov.	unlabeled
	Bamoo National Park, Fars Prov.	unlabeled
FDOI	Sarvestan, Fars Prov.	unlabeled
	Seyf Abad, Fars Prov.	unlabeled
	Seyf Abad, Fars Prov.	unlabeled
	Sarvestan, Fars Prov.	unlabeled
Picture	Abdanan, Ilam Prov.	--
	Khojir protected area, Tahran Prov.	--
	Bazman, Siatan Prov.	--
	Tangestan, Bushehr Prov.	--
Capture & Release	Golestan National Park, Golestan Prov.	--
	Golestan National Park, Golestan Prov.	--
	Golestan National Park, Golestan Prov.	--
	Damghan, Semnan Prov.	--
	Shimbar Protected area, Khuzistan Prov.	--
	Shimbar Protected area, Khuzistan Prov.	--
	Golgir, Masjid-Soleyman, Khuzistan Prov.	--
	Balvard, Sirjan, Kerman Prov.	--
	Balvard, Sirjan, Kerman Prov.	--
	Balvard, Sirjan, Kerman Prov.	--
	Pariz, Kerman Prov.	--
	Pariz, Kerman Prov.	--
	Ghatruye National park, Fars Prov.	--
	Bamoo National Park, Fars Prov.	--
	Bamoo National Park, Fars Prov.	--
	Gorm protected area, Jahrom, Fars Prov.	--
	Turan National Park, Semnan Prov.	--
	Shahrud, Semnan Prov.	--
	Shahrud, Semnan Prov.	--
	Rudbarak Protected area, Semnan Prov.	--

ZCRI: Zoological Collection of the Department of Venomous Animals and Antiserum Production, Razi Vaccine and Serum Research Institute, Hesarak, Karaj
ZMSBUK: Zoological Museum of Shahid Bahonar University of Kerman
SUHC: Sabzevar University Herpetological Collection
RUZM: Razi University Zoological Museum
SUZM: Shiraz University Zoological Museum
FDOI: Species Diversity Museum of Department of Environment, Fars