

## Correspondence

## Geographic variation in *Mesalina watsonana* (Sauria: Lacertidae) along a latitudinal cline on the Iranian Plateau

SEYYED SAEED HOSSEINIAN YOUSEFKHANI<sup>1</sup>, ESKANDAR RASTEGAR-POUYANI<sup>1,2</sup> & NASRULLAH RASTEGAR-POUYANI<sup>1</sup>

<sup>1</sup>) Iranian Plateau Herpetology Research Group (IPHRG), Faculty of Science, Razi University, 6714967346 Kermanshah, Iran

<sup>2</sup>) Department of Biology, Faculty of Science, Hakim Sabzevari University, Sabzevar, Iran

Corresponding author: SEYYED SAEED HOSSEINIAN YOUSEFKHANI, email: mesalina.watsonana@gmail.com

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Iran is geologically structured by several major mountain ranges, plateaus and basins, including the Zagros and Elburz Mountains, the Central Plateau, and the Eastern Highlands (BERBERIAN & KING 1981). *Mesalina watsonana* (STOLICZKA, 1872) is one of the 14 species of the genus *Mesalina* GRAY, 1838 and has a wide distribution range in Iran, Afghanistan, Pakistan, NW India and some parts of Turkmenistan (ANDERSON 1999, RASTEGAR-POUYANI et al. 2007, KHAN 2006). It is well known that size and morphological adaptations of a species are closely linked to its habitat selection, determine its capability of colonising an area, and play an important role in the organisation of ecological communities (PETERS 1983, CALDER 1984, SCHMIDT-NIELSEN 1984). Body size and morphology are often associated with latitude according to Bergmann's rule (BERGMANN 1847, MAYR 1956). Squamates can be described as largely following an inverted Bergmann's rule, with the larger animals preferably colonising the warmer environments of lower latitudes (ASHTON et al. 2000, ASHTON & FELDMAN 2003, BLANCKENHORN & DEMONT 2004), although there are exceptions, e.g., at intraspecific level amongst the lizards of genus *Sceloporus*, where larger individuals inhabit higher latitudes (SEARS & ANGILLETTA 2004). *M. watsonana* is widespread, occurring virtually at all altitudes represented within its range. Our study aimed at quantifying the variability of its morphological patterns within Iran by analysing the metric and meristic characters of individuals from two different latitudinal zones (26°N to 32°N and 32°N to 38°N; Fig. 1). To this end, we examined a total of 60 individuals from 34 localities (grouped into three geographical units, i.e., Zagros, East, and South; Tab. 1) for 28 morphological characters (Tab. 2). The collected specimens were fixed in 96% ethanol and are now deposited in the Sabzevar University Herpetological Collection (SUHC).

We also examined the extent of sexual dimorphism as evident in the 28 metric and meristic characters examined between the 39 adult males (15 Zagros; 10 South; 14 East) and 21 adult females (Tab. 3) by means of statistical analysis. The analyses were run using ANOVA and with SPSS 16.0 for a Principal Component Analysis (PCA) based on the correlation matrix of seven characters to identify groups that were possibly clustered. While 21 of the character states examined proved to show no significant variation between the two latitudinal zones, the seven that had P-values of < 0.05 (Tab. 4; HH, HL, TD, IOR, LV, LBT and LWB; see Tab. 2 for explanation of abbreviations used) in-

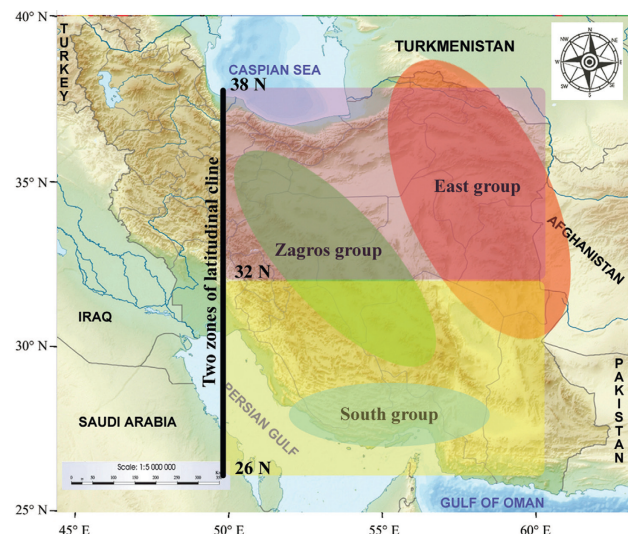


Figure 1. Iran, showing the two ranges of latitudes that were sampled and the three sampled geographical groups.

Table 1. Collection localities of *Mesalina watsonana* in Iran.

| N°            | E°             | Altitude (m) | Locality                                      |
|---------------|----------------|--------------|-----------------------------------------------|
| 28° 37' 02.4" | 054° 20' 29.7" | 1103         | Fars province, Darab-Tol rigi village         |
| 28° 27' 56.5" | 054° 14' 25.4" | 1111         | Fars province, Lar                            |
| 26° 58' 35.3" | 054° 34' 27.4" | 285          | Hormozgan province, Bastak                    |
| 29° 14' 45.4" | 054° 22' 59.1" | 1689         | Fars province, Neyriz                         |
| 27° 47' 33.6" | 053° 47' 17.0" | 939          | Fars province, Evaz                           |
| 26° 48' 43.1" | 054° 10' 35.0" | 37           | Hormozgan province, Parsian                   |
| 35° 09' 14.7" | 059° 23' 39.6" | 1382         | Khorasan Razavi province, Roshtkhar           |
| 34° 56' 44.6" | 059° 42' 51.3" | 1249         | Khorasan Razavi province, Khaf                |
| 34° 24' 23.1" | 060° 16' 02.7" | 969          | Khorasan Razavi province, Sangam              |
| 34° 12' 24.6" | 060° 16' 10.4" | 741          | Khorasan Razavi province, Chah gaz kohne      |
| 34° 59' 59.9" | 058° 03' 26.4" | 1176         | Khorasan Razavi province, Bardaskan           |
| 33° 50' 32.5" | 056° 22' 24.6" | 1079         | Yazd province, Tabas                          |
| 36° 39' 16.1" | 059° 19' 40.9" | 1280         | Khorasan Razavi province, Chenaran            |
| 34° 46.99'    | 057° 22.27'    | 1080         | Khorasan Razavi province, Chah mosafer        |
| 33° 15.29'    | 058° 51.64'    | 1401         | South Khorasan province, Arian Shahr          |
| 33° 49.40'    | 058° 19.66'    | 1306         | South Khorasan province, Ferdows              |
| 33° 37.68'    | 060° 04.08'    | 955          | South Khorasan province, Qaien                |
| 27° 17.57'    | 056° 28.977'   | - 8          | Hormozgan province, Bandar-e-abbas            |
| 27° 08.16'    | 055° 48.64'    | 12           | Hormozgan province, Bandar-e-khamir           |
| 26° 46.59'    | 056° 04.17'    | - 9          | Hormozgan province, Qeshm                     |
| 27° 02.65'    | 053° 15.11'    | 0            | Hormozgan province, Neyrom                    |
| 34° 17' 03.3" | 051° 40' 42.0" | 870          | Isfahan province, Kashan                      |
| 36° 32' 15.7" | 058° 08' 15.1" | 1330         | Khorasan Razavi province, Mashkan             |
| 36° 36' 59.8" | 057° 16' 42.4" | 1367         | Khorasan Razavi province, Joqatai             |
| 34° 32' 49.9" | 060° 11' 07.0" | 1061         | Khorasan Razavi province, Salami              |
| 35° 46' 41.5" | 060° 36' 00.9" | 1306         | Khorasan Razavi province, Torbat-e-Jam        |
| 35° 10' 21.7" | 060° 58' 23.6" | 814          | Khorasan Razavi province, Doab-Torbatjam      |
| 34° 44' 01.9" | 060° 48' 50.0" | 795          | Khorasan Razavi province, Taybad              |
| 35° 32' 12.8" | 059° 11' 51.9" | 1711         | Khorasan Razavi province, Torbat-e-Heydariyeh |
| 33° 08' 12.6" | 056° 17' 11.1" | 1267         | Sistan region, Zabol                          |
| 32° 55' 41.3" | 055° 31' 11.1" | 1544         | Yazd Province, Robat-e-Posht badam            |
| 30° 51' 33.8" | 052° 50' 33.7" | 2316         | Fars province, Eghlid-                        |
| 29° 59' 49.4" | 051° 17' 27.7" | 1183         | Fars province, Nourabad-Babameydan            |
| 30° 18' 53.3" | 053° 54' 48.8" | 2065         | Fars province, Bavanat-Toot Syiah area        |

indicated a cline between low and high latitudes in that they increased from south to north.

Results from the Principal Component analysis (Tab. 5) indicated that the first PC explained more than 66% of the total variation in seven character states, and the second PC explained more than 77% of the total variation in the same seven character states. PC1 is heavily weighted by LBT and IOR, and PC2 is heavily weighted by TD (see PCA scatter-plot in Fig. 2). Variation in precipitation was approximately equally distributed across the first three PCs. Furthermore, a Principal Component Analysis yielded a primary axis that suggests LBT to be very significant. The PCA analysis also produced a secondary axis that is negative for most characters.

According to a Discriminant Function Analysis (DFA) head height predicted the originally grouped samples almost correctly (80.0% for the latitudinal range 26–32°, and 79.3% for 32–38°). Also based on this analysis, head length classified the original grouped cases almost correctly, so that 70% for range latitude between 26–32° and 69% for range latitude between 32–38° were correctly classified into their relevant groups.

Regression plots drawn from these statistics for seven characters (Figs. 3, 4), show a fairly marked positive relationship between increased latitude and character expression.

ORAEI et al. (2011) demonstrated that sexual dimorphism was also evident in other meristic characters of *Mes-*

Table 2. Morphometric characters analysed in the present study.

| Character | Definition                                                  |
|-----------|-------------------------------------------------------------|
| SVL       | Snout-vent length                                           |
| TL        | Tail length                                                 |
| LHF       | Trunk Length                                                |
| HL        | Head Length                                                 |
| HH        | Head Height                                                 |
| HW        | Head width                                                  |
| LFL       | Length of forelimb                                          |
| LHL       | Length of hindlimb                                          |
| LFO       | Length of femur                                             |
| LA        | Length of tibia                                             |
| EL        | Horizontal diameter of eye                                  |
| RED       | Snout length                                                |
| EED       | Distance between posterior edge of eye and tympanum         |
| NL        | Length of neck                                              |
| TD        | Tympanum diameter                                           |
| IOR       | Interorbital distance                                       |
| LV        | Length of cloacal opening                                   |
| LBT       | Maximum width of tail base                                  |
| LWB       | Maximum width of belly                                      |
| NSL       | Number of labial scales anterior to the centre of eye       |
| NIL       | Number of scales on the Infralabials                        |
| NGS       | Number of gular scales in a straightedian series            |
| NCS       | Number of collar scales                                     |
| NEE       | Number of scales between posterior edge of eye and tympanum |
| NVS       | Number of transverse series of ventral scales               |
| NDS       | Number of dorsal scales acrossidbody                        |
| SDLT      | Number of subdigital lamellae (4 <sup>th</sup> toe)         |
| NFP       | Number of femoral pores                                     |

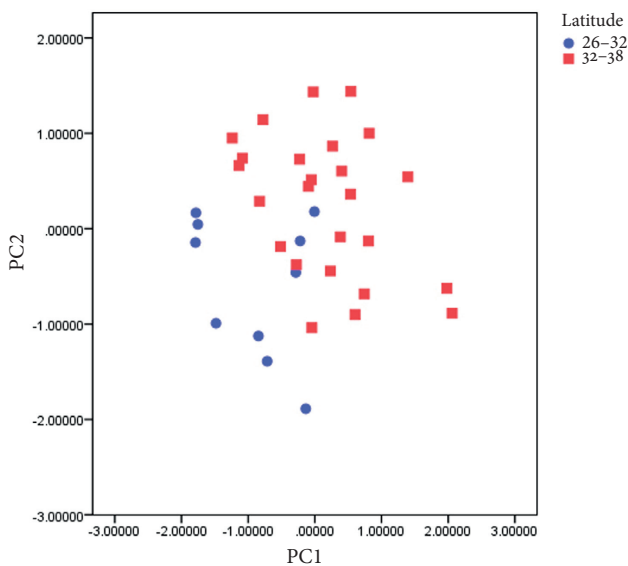


Figure 2. Principal components of seven characters as per collection sites.

*alina watsonana*. The ANOVA analysis of our material showed that most of the characters considered were significantly sexually dimorphic ( $P < 0.05$ ) for each group separately (Tab. 3).

Latitude is often one of the determining factors of climate, affording animals at lower latitudes with warmer conditions for longer periods of time that in turn facilitate longer periods for reproduction (PINCHEIRA-DONOSO et al. 2008).

According to our ANOVA analysis, seven characters (Tab. 4) are significantly different between specimens from the two latitudinal zones examined ( $P$ -values  $< 0.05$ ), which means that these character states display two different patterns of variation corresponding to the two selected latitudinal zones (Fig. 1). The PCA scatterplot shows their separation clearly, with the samples from higher latitudes being located near the maximum ranges (Fig. 2). The subsequent regression plots then show that these character states vary with latitude. According to ASHTON et al. (2000), Bergmann's rule is true for mammals and birds (endotherms). Our results confirm Bergmann's rule for *M. watsonana* to a

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Table 3. The ANOVA-based intrasexual comparison of meristic and morphometric character states in three different population groups of *Mesalina watsonana*. Degrees of freedom = 1. Significant characters in each group are emphasised in bold. Abbreviations: F = F value, Sig. = Significance as P-value.

| Char-<br>acter | Eastern and Northeastern group |                 |        |              | Zagros group      |                 |       |              | South group       |                 |        |              |
|----------------|--------------------------------|-----------------|--------|--------------|-------------------|-----------------|-------|--------------|-------------------|-----------------|--------|--------------|
|                | Sum of<br>Squares              | Mean<br>Squares | F      | Sig.         | Sum of<br>Squares | Mean<br>Squares | F     | Sig.         | Sum of<br>Squares | Mean<br>Squares | F      | Sig.         |
| SVL            | 48.989                         | 48.989          | 2.358  | 0.138        | 73.342            | 73.342          | 8.697 | <b>0.007</b> | 0.686             | 0.686           | 0.156  | 0.703        |
| TL             | 404.609                        | 404.609         | 1.737  | 0.217        | 203.075           | 203.075         | 3.477 | 0.095        | 16.465            | 16.465          | 0.037  | 0.854        |
| LHF            | 0.008                          | 0.008           | 0.001  | 0.974        | 13.279            | 13.279          | 1.925 | 0.179        | 5.402             | 5.402           | 1.121  | 0.321        |
| HL             | 12.046                         | 12.046          | 14.251 | <b>0.001</b> | 0.762             | 0.762           | 0.697 | 0.412        | 1.176             | 1.176           | 8.683  | <b>0.019</b> |
| HH             | 3.871                          | 3.871           | 10.992 | <b>0.003</b> | 3.397             | 3.397           | 3.116 | 0.091        | 0.090             | 0.090           | 1.014  | 0.344        |
| HW             | 5.176                          | 5.176           | 9.045  | <b>0.006</b> | 1.049             | 1.049           | 0.820 | 0.375        | 0.365             | 0.365           | 7.626  | <b>0.025</b> |
| LFL            | 18.553                         | 18.553          | 9.573  | <b>0.005</b> | 0.001             | 0.001           | 0.001 | 0.979        | 1.537             | 1.537           | 1.678  | 0.231        |
| LHL            | 104.995                        | 104.995         | 18.547 | <b>0.000</b> | 20.803            | 20.803          | 6.182 | <b>0.021</b> | 16.978            | 16.978          | 7.056  | <b>0.029</b> |
| LFO            | 2.697                          | 2.697           | 4.230  | 0.051        | 0.674             | 0.674           | 1.829 | 0.189        | 0.955             | 0.955           | 0.912  | 0.368        |
| LA             | 7.762                          | 7.762           | 13.503 | <b>0.001</b> | 0.164             | 0.164           | 0.313 | 0.581        | 0.497             | 0.497           | 2.284  | 0.169        |
| EL             | 0.697                          | 0.697           | 3.833  | 0.063        | 0.082             | 0.082           | 0.355 | 0.557        | 0.876             | 0.876           | 4.321  | 0.071        |
| RED            | 2.569                          | 2.569           | 8.436  | <b>0.008</b> | 0.282             | 0.282           | 1.078 | 0.310        | 0.557             | 0.557           | 1.413  | 0.269        |
| EED            | 0.420                          | 0.420           | 1.201  | 0.285        | 0.432             | 0.432           | 3.357 | 0.080        | 0.096             | 0.096           | 0.732  | 0.417        |
| NL             | 0.603                          | 0.603           | 0.939  | 0.343        | 3.683             | 3.683           | 7.284 | <b>0.013</b> | 0.835             | 0.835           | 1.045  | 0.337        |
| TD             | 0.272                          | 0.272           | 8.529  | <b>0.008</b> | 0.179             | 0.179           | 2.340 | 0.140        | 0.059             | 0.059           | 0.986  | 0.350        |
| IOR            | 0.957                          | 0.957           | 2.755  | 0.111        | 0.287             | 0.287           | 2.958 | 0.099        | 0.055             | 0.055           | 6.879  | <b>0.031</b> |
| LV             | 5.816                          | 5.816           | 7.611  | <b>0.011</b> | 2.863             | 2.863           | 3.137 | 0.090        | 3.600             | 3.600           | 13.516 | <b>0.006</b> |
| LBT            | 7.278                          | 7.278           | 5.492  | <b>0.028</b> | 2.786             | 2.786           | 4.632 | <b>0.042</b> | 1.384             | 1.384           | 18.025 | <b>0.003</b> |
| LWB            | 5.093                          | 5.093           | 1.599  | 0.219        | 7.480             | 7.480           | 6.997 | <b>0.014</b> | 0.967             | 0.967           | 4.504  | 0.067        |
| NSL            | 0.935                          | 0.935           | 4.246  | 0.051        | 0.250             | 0.250           | 0.742 | 0.398        | 0.900             | 0.900           | 2.250  | 0.172        |
| NIL            | 0.000                          | 0.000           | 0.001  | 0.982        | 0.250             | 0.250           | 0.418 | 0.524        | 0.400             | 0.400           | 0.889  | 0.373        |
| NGS            | 0.416                          | 0.416           | 0.155  | 0.697        | 1.210             | 1.210           | 0.503 | 0.485        | 0.400             | 0.400           | 0.081  | 0.783        |
| NCS            | 3.617                          | 3.617           | 2.906  | 0.102        | 5.760             | 5.760           | 4.665 | <b>0.041</b> | 0.400             | 0.400           | 0.276  | 0.614        |
| NEE            | 0.000                          | 0.000           | 0.000  | 1.000        | 0.810             | 0.810           | 0.841 | 0.369        | 0.000             | 0.000           | 0.000  | 1.000        |
| NVS            | 13.149                         | 13.149          | 9.206  | <b>0.006</b> | 7.840             | 7.840           | 6.092 | <b>0.021</b> | 0.100             | 0.100           | 0.125  | 0.733        |
| NDS            | 1.877                          | 1.877           | 0.098  | 0.758        | 6.760             | 6.760           | 0.393 | 0.537        | 2.500             | 2.500           | 0.079  | 0.785        |
| SDLT           | 0.998                          | 0.998           | 0.517  | 0.479        | 4.410             | 4.410           | 1.806 | 0.192        | 28.900            | 28.900          | 14.821 | <b>0.005</b> |
| NFP            | 0.458                          | 0.458           | 0.276  | 0.604        | 0.040             | 0.040           | 0.026 | 0.873        | 0.400             | 0.400           | 0.400  | 0.545        |

Table 4. Results of ANOVA-based intragroup comparisons of morphometric and meristic character states of Iranian *Mesalina watsonana* collected for the present study. Degrees of freedom = 1. Significant characters in each group are emphasised in bold. Abbreviations: F = F value, Sig. = Significance as P-value.

| Character | Sum of<br>Squares | Mean<br>Squares | F      | Sig.         |
|-----------|-------------------|-----------------|--------|--------------|
| SVL       | 65.037            | 65.037          | 4.389  | 0.053        |
| TL        | 346.234           | 346.234         | 1.914  | 0.186        |
| LHF       | 13.866            | 13.866          | 1.826  | 0.185        |
| HL        | 3.740             | 3.740           | 4.717  | <b>0.036</b> |
| HH        | 6.039             | 6.039           | 17.410 | <b>0.000</b> |
| HW        | 2.457             | 2.457           | 3.559  | 0.067        |
| LFL       | 1.179             | 1.179           | 0.553  | 0.462        |
| LHL       | 3.752             | 3.752           | 0.812  | 0.373        |
| LFO       | 0.221             | 0.221           | 0.393  | 0.535        |
| LA        | 1.561             | 1.561           | 2.792  | 0.103        |
| EL        | 0.119             | 0.119           | 0.484  | 0.491        |
| RED       | 0.841             | 0.841           | 2.402  | 0.130        |

| Character | Sum of<br>Squares | Mean<br>Squares | F     | Sig.         |
|-----------|-------------------|-----------------|-------|--------------|
| EED       | 0.363             | 0.363           | 1.891 | 0.177        |
| NL        | 0.122             | 0.122           | 0.175 | 0.678        |
| TD        | 0.370             | 0.370           | 4.952 | <b>0.032</b> |
| IOR       | 1.233             | 1.233           | 4.862 | <b>0.034</b> |
| LV        | 7.537             | 7.537           | 9.772 | <b>0.003</b> |
| LBT       | 6.763             | 6.763           | 7.341 | <b>0.010</b> |
| LWB       | 11.991            | 11.991          | 6.028 | <b>0.019</b> |
| NSL       | 0.102             | 0.102           | 0.325 | 0.572        |
| NIL       | 0.385             | 0.385           | 0.694 | 0.410        |
| NGS       | 0.085             | 0.085           | 0.032 | 0.859        |
| NCS       | 0.580             | 0.580           | 0.399 | 0.531        |
| NEE       | 1.129             | 1.129           | 0.742 | 0.395        |
| NVS       | 0.096             | 0.096           | 0.087 | 0.770        |
| NDS       | 28.929            | 28.929          | 1.575 | 0.217        |
| SDLT      | 6.256             | 6.256           | 1.813 | 0.186        |
| NFP       | 0.732             | 0.732           | 0.452 | 0.506        |

Table 5. Factor loadings on first three principal components elicited from a correlation matrix of seven morphological characters of 39 male *Mesalina watsonana* used in the present study.

| Character     | PC1    | PC2    | PC3    |
|---------------|--------|--------|--------|
| HH            | 0.827  | -0.027 | 0.287  |
| HL            | 0.838  | 0.062  | -0.446 |
| TD            | 0.580  | 0.794  | 0.117  |
| IOR           | 0.884  | -0.058 | -0.140 |
| LV            | 0.793  | -0.152 | 0.504  |
| LBT           | 0.885  | -0.271 | 0.061  |
| LWB           | 0.858  | -0.092 | -0.304 |
| Eigen values  | 4.651  | 0.743  | 0.665  |
| % of variance | 66.443 | 10.616 | 9.503  |
| Cumulative    | 66.443 | 77.059 | 86.559 |

certain extent in that they provide clear evidence that some metric character states increase with latitude, while snout-vent length (SVL) remains relatively constant.

In Iran, increasing latitudes correspond with decreasing average temperatures (DASTORANI & POORMOHAMMADI 2012). According to OUFIERO et al. (2011), lizards have larger scales in warmer environments to reduce the risk of overheating and smaller ones in cooler environments to improve heat retention. In Iranian *M. watsonana*, the size of the head gradually increases with latitude, and we assume that this change in head size is related to environmental conditions.

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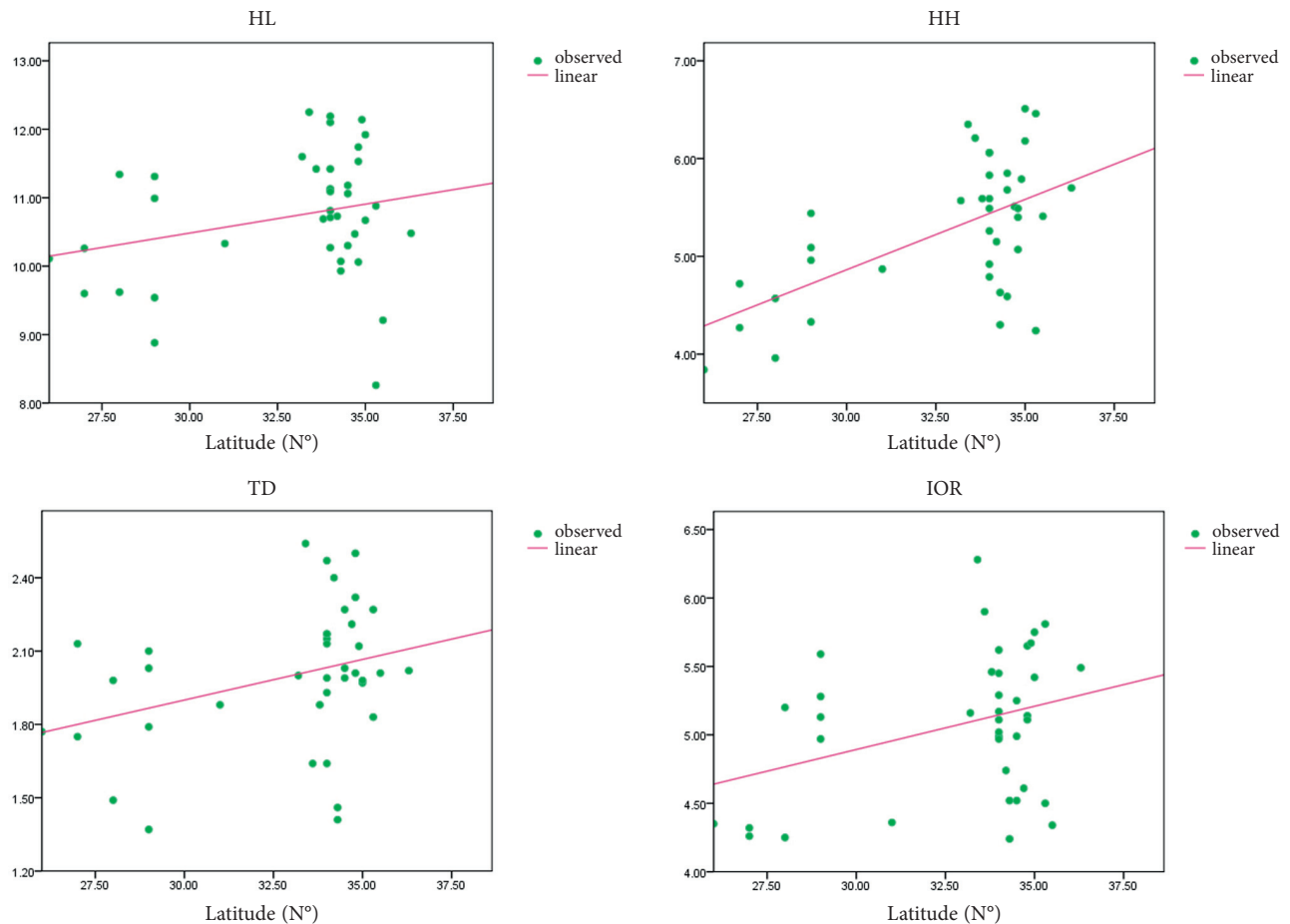


Figure 3. ANOVA-significant regression plots of four characters (HL, HH, TD and IOR).



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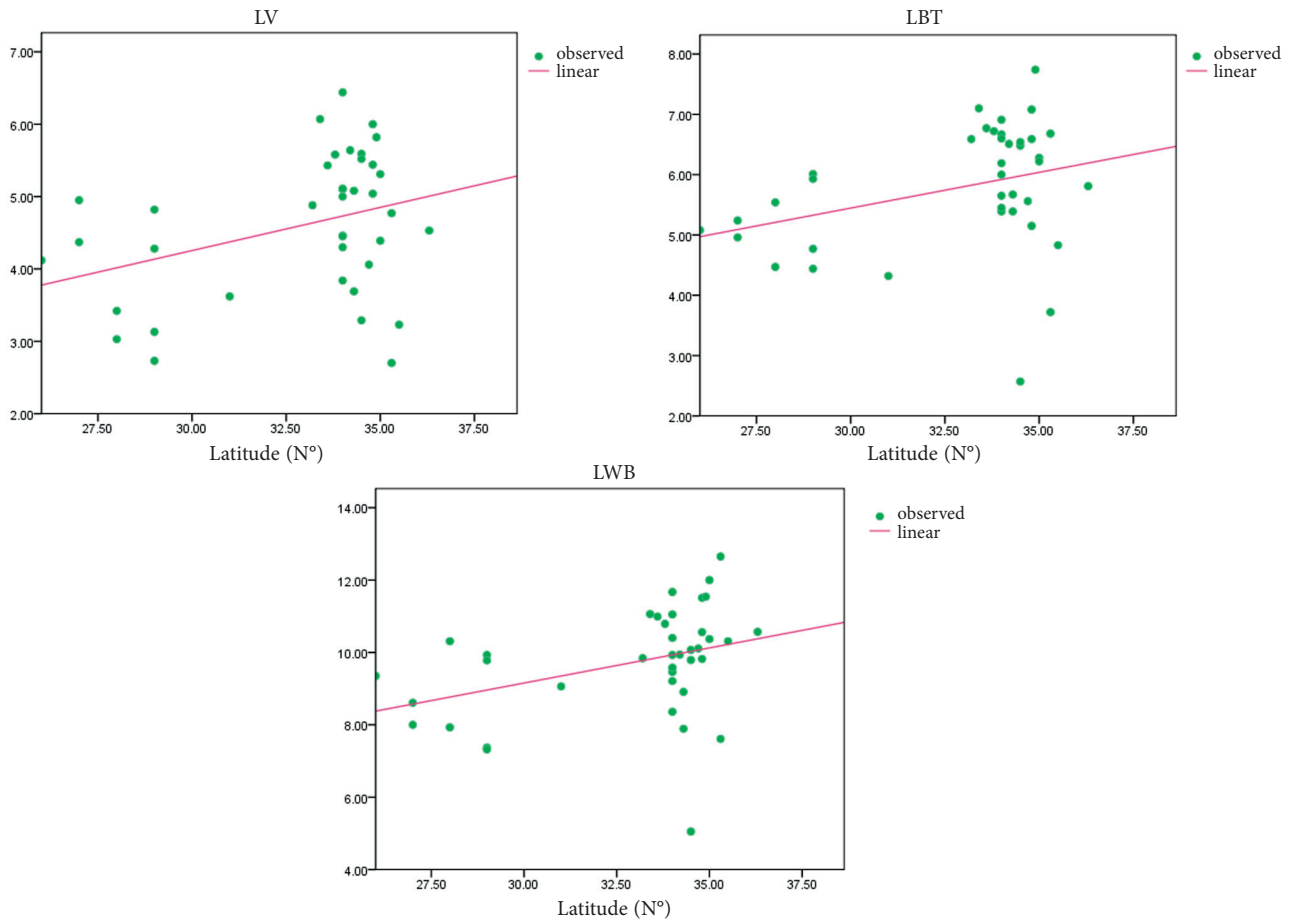


Figure 4. Regression plotted for three characters, LV, LBT and LWB, and their ANOVA significance.

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