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The Impact of Climate Variables on the Incidence of Scorpion Stings in Humans in M'Sila's Province in Algeria

S. Selmane, H. El Hadj, and L. Benferhat

***Abstract*—Scorpion stings represent a public health problem in many tropical and subtropical regions of the world, especially in north Africa, Latin America, India, and the middle East, due to suitable climate and environmental conditions for these arthropods. In Algeria and due to its geographical location, its climate and its socio-economic structure, scorpions are common in southern areas and central highlands and scorpion envenomation represents a real public health problem. Despite the creation of a national committee of control of scorpion envenomation in 1986, and the several steps taken to deal with this problem, a total of 815,217 scorpion sting cases and 1870 deaths were recorded by health services between 1991 and 2010.**

In the aim to help determine the appropriate number of antivenom vials necessary in health facilities of the province of M'sila (Algeria) which is faced each year with serious health problems; we undertook a research study on the significance of climatological variables to predict the incidence of scorpion stings in humans. From the data of the present study for the period 2008-2012, it is concluded that the scorpion activity in M'Sila province is an environmental climatology dependent phenomenon; the temperature and sunshine are the essential factors; they were used to derive a predictive model of scorpion sting incidence.

***Index Terms*—Climate, correlation, multiple linear regression, scorpion.**

I. Introduction

SCORPION stings remain a serious public health menace in many tropical and subtropical and desert habitats worldwide. Scorpions have large horizontal distribution (longitudes and latitudes) and vertical (elevation). Horizontally, no species exceeds both to the North and to the South, 50° latitude where the living conditions of these animals thermophilic easily explain this distribution. According to the most recent studies, seven areas were identified as at risk : north-Saharan Africa, Sahelian Africa, South Africa, Near and Middle-East, South India, Mexico and South Latin America, east of the Andes. These involve 2.3 billion at risk population. The annual number of scorpion stings exceeds 1.2 million leading to more than 3250 deaths worldwide [1].

Scorpions are venomous arthropods of the class Arachnida, relatives of spiders, mites, and ticks. They are grouped into six families, 70 genera and more than 1500 species. Only 25 of 1500 species of scorpions are deadly to humans, and most potentially lethal belong to the family Buthidae which primarily is distributed in Africa and Southeast Asia. In Algeria, 28 species and 14 genera of scorpions, classified under three families Buthidae, Chactidae (Euscorpiidae) and Scorpionidae were identified. The most important health-threatening scorpions found in Algeria include Androctonus australis and Leiurus quinquestriatus, and are found mostly in the southern highlands and in the Atlas and Hoggar mountain ranges. Other species also causing fatalities or threats to life are Androctonus aeneas, Buthus occitanus and Buthacus arenicola, found respectively in the southern highlands, in the northern Sahara, Hoggar and in the Tassili. All these species belong to the Buthidae family [1].

Scorpions are easily recognizable because of their morphological structures; they are of 13 to $220\,mm$ length. They are sensitive to light, so they are primarily nocturnal. They are fearful of nature, not aggressive and lucifugous. Scorpions walk slowly and gropingly and possess a low weak vision. Scorpions withstand aggressive environmental factors either cold or hot. Active in the spring and summer, they go into hibernation in early autumn. Some species may retain their potential activity during the cold season. The longevity of the adult is not yet well determined; it varies from 2 to 10 years or even twenty years. They feed essentially on insects (locusts, grasshoppers, flies, larvae of the butterflies ...) and of spiders, preferring the alive or freshly killed prey. They rarely absorb vegetable substances. The big scorpions eat invertebrates, small lizards, snakes and even small mice. Scorpions are cannibals inter/intra species (may eat other scorpion species and the smallest of its kind) and even the mother can eat its young. They can stay almost two years without food and water. In general, scorpions live in groups. They are found in diverse habitats: under stones, rocks, tree bark and old buildings. They look dark corners where they dig burrows. On the other hand certain scorpions affect the neighbourhood of houses, take place between sheets, in shoes, in kitchens and bathrooms. They detect their preys by senses of contact and sound, and similar to the way seismologists locate earthquakes, scorpions determine the size and location of a meal by measuring subsurface vibrations. They use their venom to kill or paralyse their prey so it can be eaten. The sting of most scorpions can be very painful, like a bee sting, although most are not lethal. The effects of scorpion venom on people are highly variable with severity ranging from localized, self-resolving pain to death. Additionally, the response to scorpion envenomation may vary with the general health and age of the victim, their physiology and genetics, and emotional condition. Further variability may be attributed to the site and depth of sting penetration, quantity of the injected venom, and the proportion of the venom reaching the

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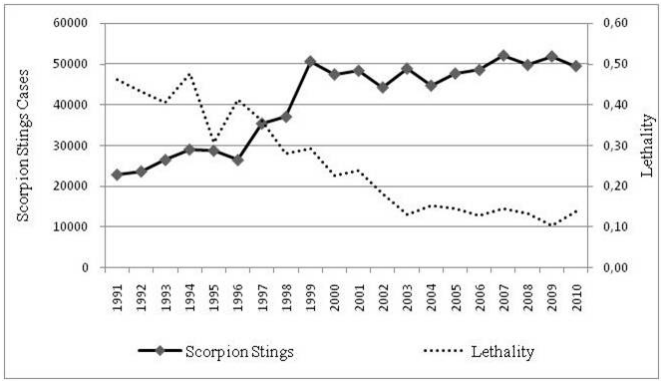

Fig. 1. Evolution of annual recorded scorpion sting cases and lethality in Algeria (1991 -2012).

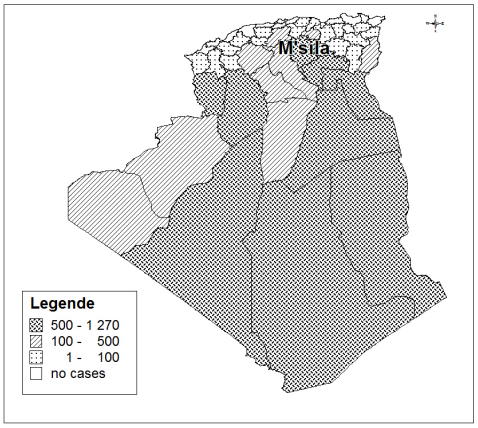

Fig. 2. Geographic distribution of the annual incidence of scorpion stings in Algeria (2001-2010).

circulatory system. Scorpion stings should always be treated as a medical emergency that requires treatment as soon as possible, especially when young children are concerned. Victims of scorpion sting, particularly if known dangerous species are involved, should be closely observed for at least 24 hours. Children and other high-risk patients should be hospitalized [5].

In Algeria, scorpion envenomation is a real public health problem. Since the creation of the National Committee of Control of Scorpion envenomations in 1986, several steps have been taken to deal with this problem. In the aim to help determine the appropriate number of antivenom vials necessary in health facilities of the province of M'sila; we undertook a research study on the significance of climatological variables to predict the incidence of scorpion stings in humans. The Pearson product-moment correlation coefficient was calculated to find any significant linear relationship between the scorpion sting variable and the climate variables, including mean of temperature, relative humidity, mean wind speed, sunshine, and precipitation amount. We carried out a multiple linear regression analysis on all the climatological independent variables and scorpion sting dependent variable, and derived a predictive model of scorpion sting incidence.

II. Materials and Methods

Scorpions and scorpion sting cases are common in Algeria due to its geographical location, its climate and its socio-economic structure. Health services have recorded $815,217$ scorpion sting cases and 1870 deaths between 1991 and 2010. In Figure 1, the recorded scorpion sting cases and the lethality are plotted from 1991 to 2010, where lethality is defined as the ratio of the number of deaths due to scorpion envenomation over the number of cases stung during the same period and expressed in percentage. The incidence predominate in Highlands and Sahara, which together account for almost 90% of patients stung, as shown in the incidence geographical distribution (Figure 2).

A. Study area : M'Sila Province

M'Sila, a province in Algeria, lies between the Tell and the Sahara and is situated at $35^o42'7''N$ and $4^o32'49''E$ of the equator. The province is made up of 47 municipalities distributed between 15 districts over a land size of about 18175 square kilometres. As 2012, the province accommodates a population of 1073000 with an annual growth rate of 2.1%. Its climate is continental, semi-arid, subjected partly to Saharan influences with an annual average temperature of 21^oC (average temperature of 34^oC in summer and 10^oC in winter), and a low and irregular rainfall not exceeding $250\ mm$ per year. M'Sila experiences high temperature between June and September, and rainfalls between September and December.
M'Sila ranks among the poor provinces in Algeria, it is faced each year with serious health problems; the region records every year a high incidence of scorpion envenomation and a very high incidence of cutaneous leishmaniasis; both related to climate.

B. Data collection

Over a period of 11 years (2000-2010), the annual incidence of scorpion in the province of M'Sila has experienced weak fluctuations (Figure 3) with mean incidence 537 per $100,000$ inhabitants [4]. Monthly scorpion sting cases from 2008 to 2012 were obtained from INSP [4], and monthly mean temperature, sunshine hours, precipitation amount, wind speed, and relative humidity recorded by the weather station M'SILA 604670 (Latitude: 35.66, Longitude: 4.5, Altitude: 442) for the period $2008-2012$ were extracted from the National Office of Meteorology [3]. The epidemiological year for scorpion stings starts from March to April (lowest incidence) with a peak in July-August, to resume its lowest rate toward November-December (Figure 4). The scorpion sting cases, temperature, and sunshine follow the same trends, while scorpion sting cases and relative humidity have opposite trends.

C. Statistical Methods

The Pearson product-moment correlation coefficient was calculated to find any significant linear relationship between the scorpion stings dependent variable and the climate independent variables, including mean of temperature (^oC), relative humidity (percentage), mean wind speed (Km/h), sunshine hours, and precipitation amount (mm). The data

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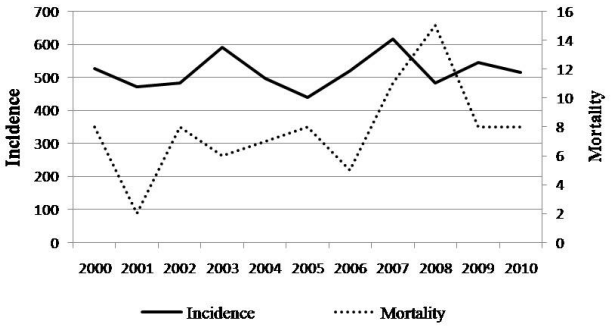

Fig. 3. Evolution of annual incidence per $100,000$ inhabitants of scorpion stings and mortality in M'Sila province (2000 -2010).

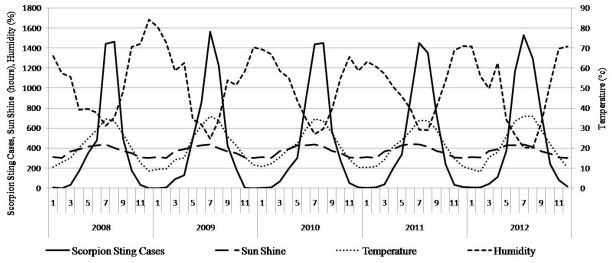

Fig. 4. Monthly scorpion sting cases, mean temperature, sunshine, and humidity in M'Sila province.

comprise 60 months (2008-2012) with month one corresponding to January for each year. The following are the main observations :

- The climatological variables with strong positive correlation coefficients are the temperature (r=0.92), and sunshine (r=0.75). This confirms the increasing activity of scorpion with increasing the environment temperature; when the rate of sunshine hours increases the environment temperature will go up.
- There is strong negative correlation between scorpion sting cases and relative humidity (r=-0.85).
- The correlation between precipitation amount and the scorpion sting cases was moderate negative (r=-0.42), and almost zero with wind speed (r=-0.17) which is against the stories of local residents who believe that with wind blows increase the scorpion stings cases.

D. Model and Forecast of scorpion stings cases

As climate variables have linear relationships to scorpion sting cases (the scatterplot pairwise between each of the climatological variables and scorpion sting cases is linear), and given the instantaneous effect of climate variables on scorpion envenomation, the multiple linear regression is therefore appropriate.

We applied a log-linear regression by first introducing all variables at the same time, and selecting those who have a statistically significance of 95%, then we proceeded by removing variables that had no significance in the model. And thereafter, we have chosen among the models (Table 1), the best regression model, a choice based on the coefficient of determination R^2, the Akaike information criterion (AIC), and Standard Error (SE) of regression.

Table 1. Models

Independent variables	R^2	(AIC)	SE
C, T, Sun	0.865	2.60	0,864
T, P, H, Sun	0.866	2.63	0,869
T, Sun, H	0.851	2.70	0,907

The selected model (Table 2) corresponds to the model incorporating the constant (C), the variables temperature (T) and sunshine (Sun) to explain the dependent variable Lscor (logarithm of scorpion sting cases) :

$$Lscor = -4.379 + 0,167\,T + 0,015\,Sun \qquad (1)$$

The coefficient of determination, R^2, the key output of regression analysis, is equal to $R^2 = 0.86$, that is, 86 percent of the variance in scorpion sting cases is predictable from temperature and sunshine. As the standard error $(SE = 0,864)$ is lower and the coefficient of determination is higher, therefore predictions are likely to be more accurate. To ensure that analysis has proceeded within the bounds of the basic assumptions, we test the normality of the residuals by applying statistical Jarque Berra. Jarque-Bera value : $5,32$ $(< 5,99)$ and P.value : $0,06 > 0,05$ that is, H0 of normal distribution of residuals is accepted.

Table 2. The selected Model

Variable	Coefficient	Std.Error	t-Statistic	Prob
C	-4,379	1,336	-3,278	0,002
T	0,167	0,028	5,902	0,000
Sun	0,015	0,005	3,049	0,004

In figure 5, we plotted the reported versus the fitted Lscor values for the period $2008 - 2012$. In spite of a difference in the extreme values observed between the predictive model and reported scorpion sting cases, this model approach to reality and appears acceptable for the amount of variance explained. The unexplained part could be due to the presence of other factors that affect the scorpions. Finally, the correlation coefficient of the monthly fitted and actual Lscor for the period 2008-2012 is strong positive (r=0.94).

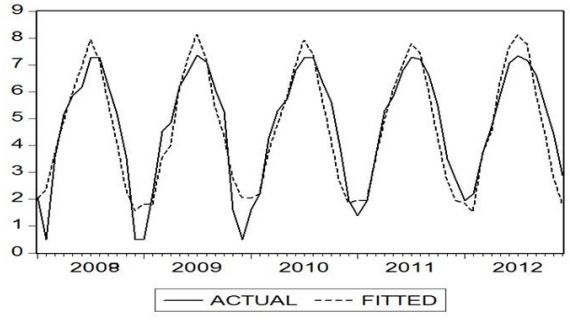

Fig. 5. Forecasted versus reported Lscor in 2008-2012.

III. Conclusion

This study showed that is helpful for forecasting the scorpion sting incidence to understand how weather conditions affect the scorpion envenomation. From the data of the present study it is concluded that the scorpion activity in

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M'Sila province is an environmental climatology dependent phenomenon. However, the temperature and sunshine are the essential factors, which were used in the prediction modelling of scorpion sting incidence. Equation (1) predicts that for every 1^oC increase in the temperature, there will be an increase of 0.18 scorpion stings per month per $100,000$ people in M'Sila province. This result could be used to help determine the appropriate number of antivenom vials necessary given appropriate climatological information.

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