Scorpion Envenomation in Naama, Algeria

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Abstract—**In Algeria scorpion envenomation represents a real public health problem with a population at risk of scorpion stings estimated at 68% of the national population. A total of $903,461$ scorpion sting cases and 1996 deaths were recorded by health services between 1991 and 2012.**
The physical-geographic and climate conditions make the province of Naama a conducive environment for scorpion species and an endemic zone for scorpion envenomation. A total of $22,498$ scorpion stings and 66 deaths were recorded by the Department of Public Health of the province between 1999 and 2013.
An early warning system is an essential tool for preparedness and effectiveness of scorpion stings control; it could help determine the appropriate number of antivenom vials necessary in health facilities and anticipate the demand for antivenoms and symptomatic drugs so that they can be distributed in advance. To this end, we performed a regression analysis to estimate the relationship between scorpion sting cases and climate conditions. The obtained results showed that the scorpion activity in Naama province is climate dependent phenomenon; the temperature and precipitation are the main factors; they were used to derive the best predictive model for scorpion sting cases. If we know beforehand the change on climate variables, we can use regression model to predict the number of scorpion sting cases using those climate variables.

Index Terms—**Climate, Correlation, Naama province, Precipitation, Regression analysis, Scorpion, Scorpion Sting, Temperature.**

I. Introduction

SCORPION stings represent a public health problem in many tropical and subtropical regions. North Saharan Africa, Sahelian Africa, South Africa, Near and Middle-East, South India, Mexico and South Latin America, East of the Andes are identified as at risk areas involving 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. They are grouped into six families, 70 genera and more than 1500 species. Only 25 species are deadly to humans, and most potentially lethal to human belong to the family Buthidae which primarily is distributed in Africa and Southeast Asia. Scorpions are easily recognizable because of their morphological structures; they are of 13 to 220 mm length. They are primarily nocturnal, fearful of nature, not aggressive and lucifugous. They withstand aggressive environmental factors either cold or hot. They are active in the spring and summer. The longevity of the adult varies from 2 to 10 years or even twenty years. They feed essentially on insects and on spiders, preferring the alive or freshly killed prey. The big scorpions eat invertebrates, small lizards, snakes and even small mice. Scorpions are cannibals inter/intra species and even the mother can eat its young. They can stay almost two years without food and water. 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 neighborhood of houses, take place between sheets, in shoes, in kitchens and bathrooms. They detect their prey by senses of contact and sound, and similar to the way seismologists locate earthquakes. They use their venom to kill or paralyze 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. Scorpion stings should always be treated as a medical emergency that requires treatment as soon as possible [1], [14].

In Algeria scorpion envenomation is a real public health problem. Twenty-eight species and fourteen genera of scorpions were identified in the country and the most important health threatening scorpions found belong to the Buthidae family. They include Androctonus australis and Leiurus quinquestriatus, and are found mostly in the southern highlands and in the Atlas and Hoggar mountain ranges [14]. The population at risk of scorpion stings is estimated at 68% of the total national population. Among the 48 provinces of the country, 39 provinces are affected by the scorpion envenomation accidents. Fourteen provinces belonging to Highlands and Sahara account together for almost 90% of patients stung and the entire deaths. The incidence varies between less than 7 scorpion stings per $100,000$ inhabitants in the northern provinces and more than 1000 scorpion stings per $100,000$ inhabitants in those of the South [11].

Naama ranks among the endemic provinces of the country and records every year a high incidence of scorpion stings. A total of $22,498$ scorpion stings and 64 deaths were recorded by the Department of Public Health of the province between 1999 and 2013. The public health authorities of the province are faced to scorpionism, and consequently, they are required to establish prevention and control strategies. An early warning system is an essential tool for preparedness and effectiveness of scorpion stings control; it could help determine the appropriate number of antivenom vials necessary in health facilities and anticipate the demand for antivenoms and symptomatic drugs so that they can be distributed in advance in this endemic province.

As far as we know the first mathematical approach on predicting scorpion sting incidence is due to Chowell and al; they analyzed the significance of climate variables to predict the incidence of scorpion stings in humans in the state of Colima (Mexico) using multiple linear regression [2]. Other studies on other regions on the influence of climate factors on scorpion envenomation following the statistical approach conducted by Chowell and al have been performed using

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simple statistical analysis and correlation between scorpion stings and climate variables [6], [13].

The scorpion envenomation surveillance in Algeria is based on a passive system. Neither the analysis nor interpretation of data were undertaken; the only performed statistical approach to scorpionism is due to Selmane and El hadj [12].

In the aim to estimate the effects of climate variables on scorpion envenomation in Naama, we performed a regression analysis to estimate the relationship between scorpion sting cases (the dependent variable) and climate conditions (the independent variables). The obtained results showed that the scorpion activity in Naama province is climate dependent phenomenon; the temperature and precipitation are the main factors; they were used to derive the best predictive model of scorpion sting cases.

II. Materials and Methods

A. Scorpionism in Algeria

Scorpion stings are common in Algeria and represent an actual public health problem. Health services have recorded between 1991 and 2012 a total number of $903,461$ scorpion stings and 1996 related deaths. The number of stings doubled between 1996 and 1999 and from 1999 to 2012 a weak fluctuation of this number is perceived (Fig. 1.). Unlike, the number of deaths have halved. The geographical distribution of the incidence per $100,000$ inhabitants of scorpion stings for the year 2012 (Fig. 2.) mapped using MapInfo Professional 11.0, shows that the incidence predominate in Highlands and Sahara, which together account for almost 90% of patients stung [11].

B. Study Area : Naama Province

Naama is one of the 48 provinces of Algeria. It is situated in the west between the Tell Atlas and the Saharan Atlas at $33^o\ 16'\ N$ and $0^o\ 19'\ W$ of the equator and more than $1,000$ meters above sea level. The province is made up of seven districts gathering twelve municipalities over a land size of about $29,950\ km^2$ with an estimated population of $238,087$ as 2013, that is, a population density of 8 inhabitants per km^2 [9]. The climate is split into two main seasons; cold and relatively wet season which extends from November to April and a hot and dry season which extends from May to October. However, this climate is marked by irregularities. This is significant not only from one year to another, but also in the distribution between the different months. Rainfalls remain low and irregular; it is heterogeneous in time and space [8].

C. Data

The study period comprises 96 months from January 2003 to December 2010 and consists of two different monthly data sets : epidemiological data and meteorological data; the climates conditions being assumed to be of great influence on scorpion distribution and activity. Monthly scorpion sting cases were obtained from the Department of Public Health of the province of Naama, and monthly mean temperature (in ^oC), period of sunshine (in $hours$), precipitation amount (in mm), wind

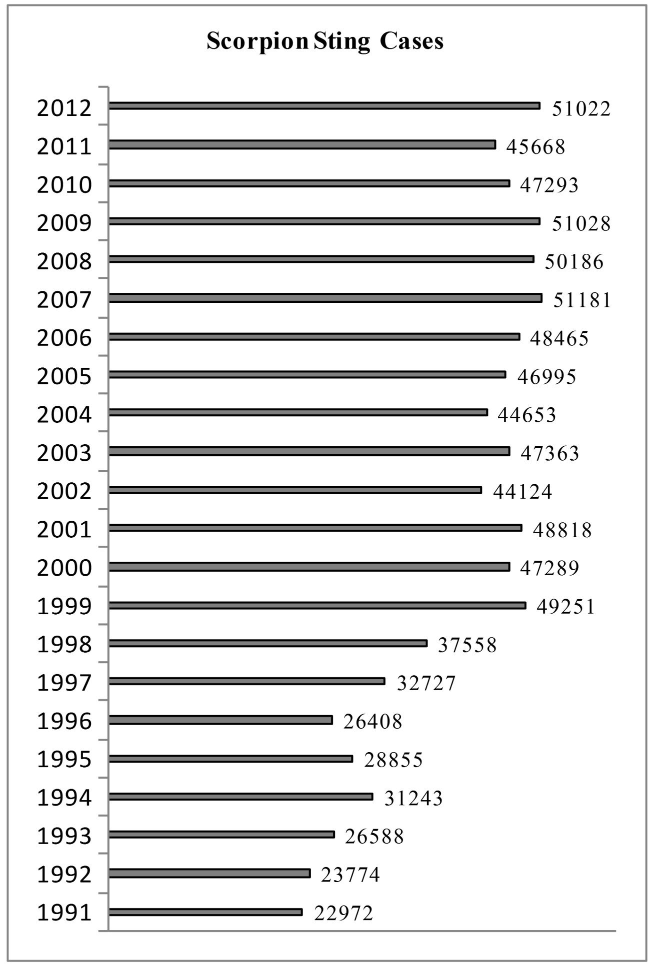

Fig. 1. The annual evolution of recorded scorpion sting cases in Algeria.

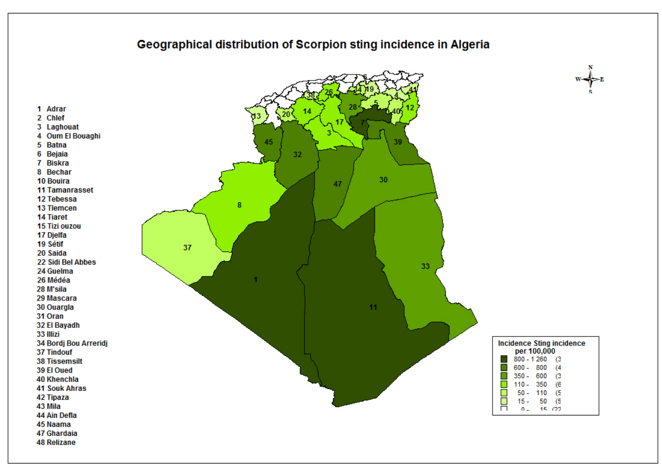

Fig. 2. Geographical distribution of scorpion sting incidence in Algeria.

speed (in m/s), and relative humidity (in %) recorded by the weather station of Naama (Latitude : $33^o\,16'\,N$, Longitude : $0^o\,18'\,W$, Altitude: $1166\,m$) were extracted from the National Office of Meteorology [8].

D. Statistical Modeling Method

Descriptive statistics are performed to quantitatively describe the main features of the data. Time series analysis of scorpion sting cases and climate factors are also performed in order to extract meaningful statistics and other characteristics of the data and also to analysis of temporal trends of the variables. To find any significantly relationship between the scorpion sting variable and the climate variables, first, the scatterplots and Pearson product-moment correlation coefficient are drawn up, then a regression analysis is undertaken.

Regression analysis is a statistical process for estimating the relationships among variables. It includes many techniques for modeling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables. More specifically, regression analysis helps one understand how the typical value of the dependent variable changes when any one of the independent variables is varied, while the other independent variables are held fixed. A regression model relates the dependent variable, Y to a specified function of independent variables, X, and unknown parameters, β :

$$Y \approx f(X, \beta).$$

The approximation is usually formalized as

$$E(Y|X) = f(X, \beta)$$

where $E(Y|X)$ is the average value of the dependent variable when the independent variables are fixed. One method of parameter estimation is ordinary least squares; which consists to minimize the sum of squared residuals [3].

A best regression model has to fulfil the following features :

- The value of R-square should be more than 60 percent. Higher the R-square value, better the data fitted.
- Most of the independent variables should be individually significant to influence the dependent variable (this matter can be checked using t-test).
- The independent variables should be jointly significant to influence or explain dependent variable (This can be checked using F-test).
- No serial correlation in the residual (can be tested using Bruesch-Godfrey serial correlation LM test).
- No heteroscesticty in the residual (can be tested using Bruesch-Pegan-Godfrey Test).
- Residuals should be normally distributed (can be tested using Jarque Bera statistics).

When all these features are met; the model can be used for forecasting [3].

All performed computations and generated figures were carried out with Eviews 7 software.

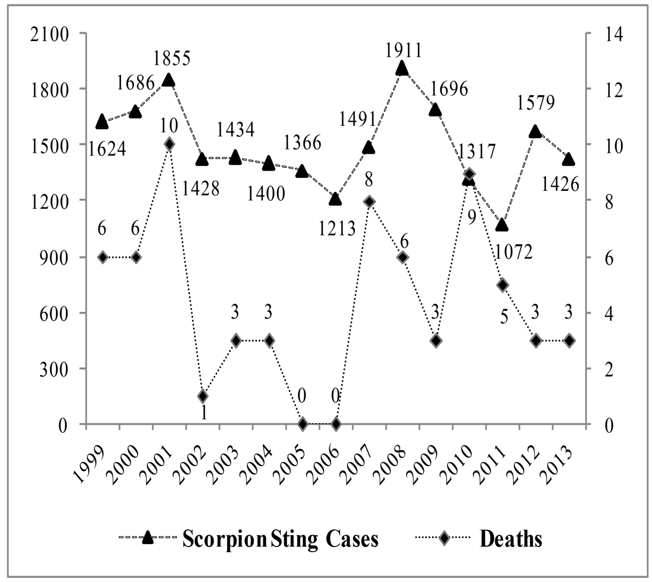

Fig. 3. Evolution of annual recorded scorpion sting cases and deaths in Naama province from 1999 to 2013.

III. Data Analysis and Results

A. Annual evolution of recorded scorpion sting cases

A total of $22,498$ scorpion stings and 66 deaths were recorded by the Department of Public Health of the province of Naama between 1999 and 2013; the yearly distribution is plotted in Fig. 3. The highest total yearly scorpion sting cases occurred in the years 2001 and 2008 with 1851 and 1911 respectively and the highest number of deaths were notified in 2001 with 10 deaths and in 2010 with 9 deaths [11]. We note pronounced fluctuations on the yearly evolution; this is to be expected due the fact that scorpion activity is related to climate and the latter is marked by irregularities.

B. Geographical distribution of scorpion envenomations in Naama

The geographical distribution of the incidence per $100,000$ inhabitants of scorpion stings for the year 2013 by municipality for Naama province is mapped using MapInfo Professional 11.0 (see Fig. 4.). Almost half of scorpion sting cases occurred in Mechria (27.1%) and Ain Sefra (21.9%); the incidence per $100,000$ inhabitants is 517.08 for Mechria and 487.33 for Ain Sefra. The highest incidence was recorded in Mekmen Ben Amar (1304) and Sfissifa (1501).

C. Scorpion sting cases and population size by municipality

To estimate the importance of the heterogeneity of the province, we analyzed the correlation between the total number of scorpion stings, the population size, the population density, and the incidence per municipality for the year 2013. The number of scorpion stings showed a high degree of correlation with the population size ($r = 0.943$) (Fig. 5.) and a high degree of correlation with population density ($r = 0.909$).

For all municipalities, the total number of recorded scorpion

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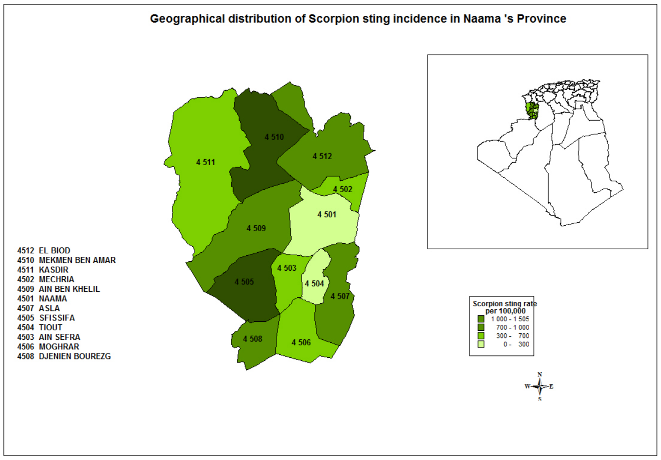

Fig. 4. Geographical distribution of scorpion sting incidence in Naama's province.

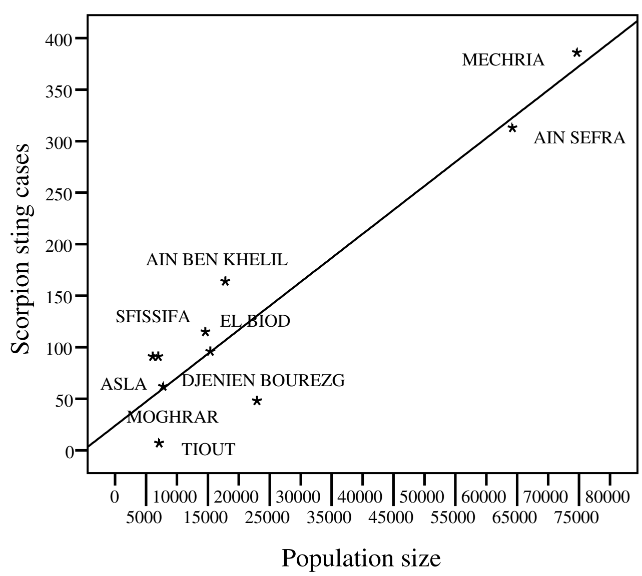

Fig. 5. The scatterplot of the total number of recorded scorpion stings and the total population size by municipality. The straight line represents the linear regression equation (1).

stings (S_{Mun}) and the population size (P_{Mun}) are related as follows :

$$S_{Mun} = 0.005\, P_{Mun} \tag{1}$$

an equation that explains 86.5% of the observed variance.

D. Descriptive statistics of the variables

The descriptive statistics of the monthly data for the study period $(2003 - 2010)$ and the Pearson product-moment correlation coefficient (r) between scorpion sting cases (S) and climate variables are displayed in Table I. The climate variables with strong positive correlation coefficient with scorpion sting cases are mean temperature (T), mean maximum temperature ($MaxT$) and mean minimum ($MinT$). This confirms the increasing activity of scorpion with increasing the environment temperature. There is strong negative correlation between scorpion sting cases and relative humidity (RH), maximum relative humidity ($MaxRH$) and minimum relative humidity ($MinRH$). The correlation between sunshine time (I) (resp. maximum wind speed ($MaxW$)) and the scorpion sting cases is mild ($r = 0.609$) (resp. $r = 0.530$). The correlation between accumulated precipitation (P) amount (resp. wind speed (W)) and the scorpion sting cases is very weaker ($r = -0.153$) (resp. ($r = 0.182$)).
The coefficient of variation CV ($CV = SD/Mean = 1,22$ where SD is the standard deviance) is closer to 1, which means the greater the variability of scorpion data.

TABLE I
DESCRIPTIVE STATISTICS OF THE VARIABLES

Variables	Minimum	Maximum	Mean	SD	r
S	0	584	124,89	152,35	
T	3,50	30,40	16,82	8,11	0.891**
$MinT$	-3	22,30	10,20	7,27	0.887**
$MaxT$	7,90	38,70	23,43	9.02	0.888**
P	0	157,30	19.23	22.15	-0.153
RH	23	82	50.36	15,63	-0.799**
$MinRH$	4	63	26.53	13,85	-0.740**
$MaxRH$	40	96	74.61	14,71	-0.854**
I	134,90	361,90	251,34	51,18	0.609**
W	1,40	5,10	3,12	0,86	0.182
$MaxW$	6,30	16,70	12,30	2,55	0.530**

** The correlation is significant at the 0.01 level (bilateral).

E. Time Series Analysis

Scorpion stings are recorded throughout the year and the epidemiological year starts from March to April (lowest scorpion stings cases) with peaks in July-August, to resume its lowest rate toward November-December (Fig. 6 (A)). The monthly peaks are observed in July (27.9% of cases) and in August (27.9% of cases), accounting alone for more than half of cases (55.8% of cases). The maximum recorded scorpion sting cases during the study period occurred in July and August 2008, with 584 and 570 cases respectively; for these dates highest temperature recorded was $37.9^{o}C$ in July 2008 and $37^{o}C$ in August 2008. Most of the cases (70.4%) were notified during the summer period followed by Autumn period (16.7%), then Spring period (12.3%) (Fig. 6 (B)).

The monthly recorded scorpion sting cases with monthly mean maximum temperature and mean minimum temperature and with monthly accumulated precipitation are plotted in Fig. 7. Temperature follows the same trends with scorpion sting cases. The highest accumulated precipitations were recorded in October 2008 and in September 2005 with an amount of $157.3\ mm$ and $93.2\ mm$ respectively and the corresponding recorded scorpion sting cases were 76 (average number is 79 and minimum is 40) and 134 (average number is 169 and minimum is 130) recorded cases respectively; this is against the stated conclusion in [2].

F. Regression Analysis

Temperature, relative humidity, and sunshine time are highly pairwise correlated; the Pearson product-moment correla-

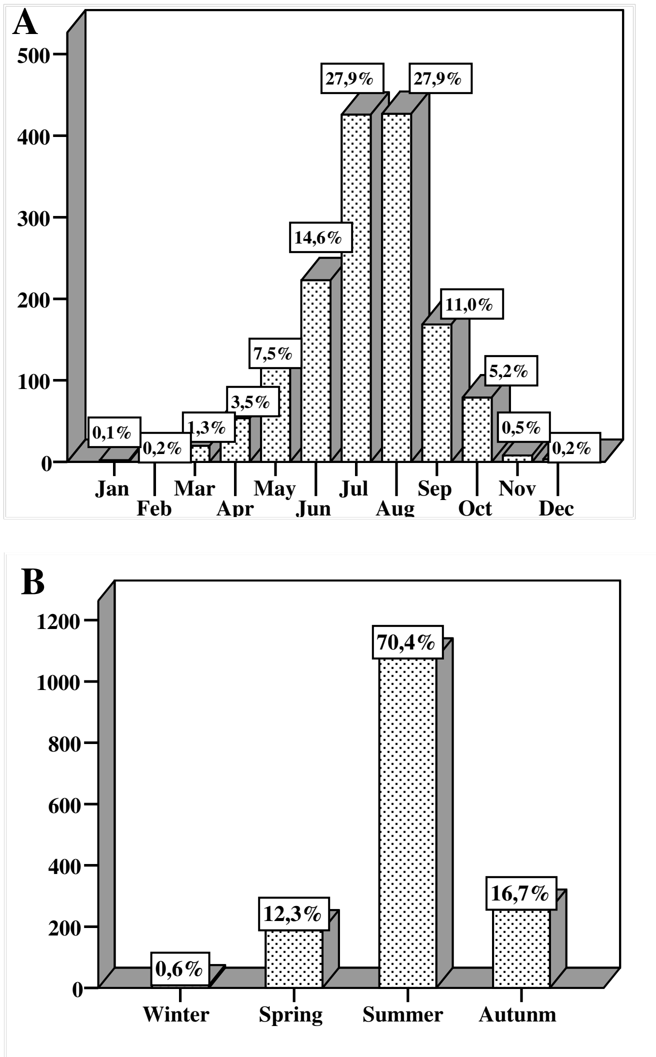

Fig. 6. **A** Monthly average distribution of recorded scorpion sting cases. **B** Seasonal average distribution of recorded scorpion sting cases in Naama province for the period $2003 - 2010$.

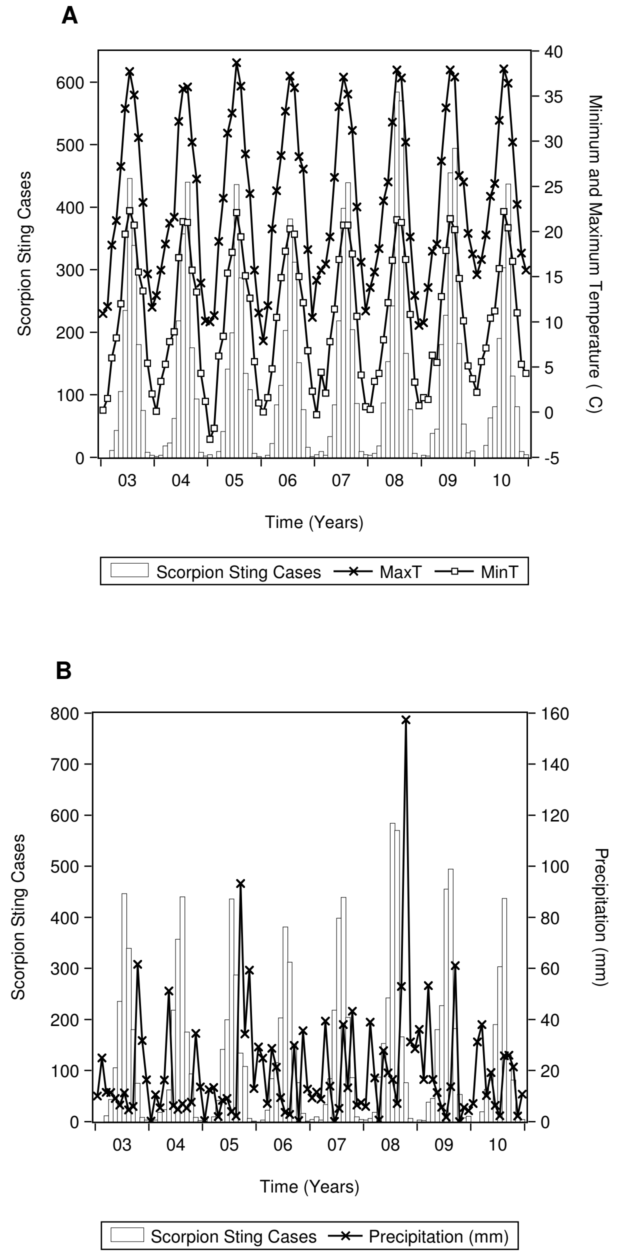

Fig. 7. Time series of the monthly recorded scorpion sting cases (bars); **A** with monthly average of the maximum and minimum temperature and **B** with monthly accumulated precipitation in Naama province for the period $2003 - 2010$.

tion coefficient between temperature and relative humidity is $r = -0.901$, between temperature and sunshine time is $r = 0.734$ and between relative humidity and sunshine is $r = -0.823$. Therefore these variables will impart nearly exactly the same information to a regression model. To avoid the multicollinearity and the unreliability of the regression model's regression coefficients related to these highly pairwise correlated variables, we included into the model only the temperature. The choice of the temperature is justified by the fact that the activity of scorpions increases with increasing temperature [12].

The scatterplot (Fig. 8. A) between the monthly scorpion sting cases and the monthly mean temperature shows a quadratic relationship. We therefore performed a regression analysis to regard (S) as dependent variable and T and T^2 as independent variables. Even though the model is good, it cannot be used for forecasting; the residuals were heteroscedastic and the residuals were not normally distributed.

The scatterplot (Fig. 8. B) between the monthly squared root of scorpion sting cases and the monthly square of mean temperature shows a linear relationship; $(S^{1/2})$ is strongly correlated with T^2 with Pearson product-moment correlation coefficient $r = 0.978$. We therefore performed a regression analysis to regard $(S^{1/2})$ as dependent variable and T^2 and all the other climate variables as well as a trend variable to account for non-climatic factors such human behavior, degradation of the environment and other factors that could influence the number of sting cases, as independent variables. The choice of the model was based on the coefficient of

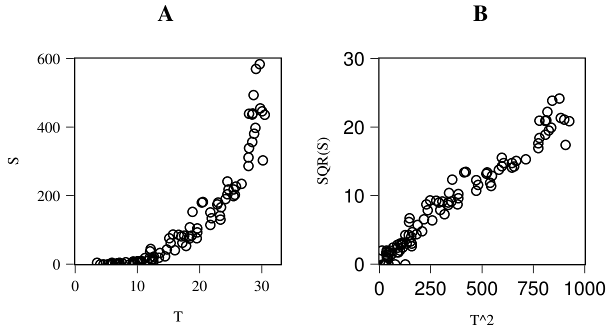

Fig. 8. The scatterplot : (**A**) of recorded scorpion sting cases and temperature, (**B**) of squared root of scorpion sting cases and square of temperature.

TABLE II
MODEL OUTCOMES

Dependent Variable: SQR(S)
Method: Least Squares
Sample: 2003Month1 2010Month12
Included observations: 96

Variable	Coefficient	Std. Error	t-Statistic	Prob.
T^2	0.023998	0.000351	68.39514	0.0000
P	0.021780	0.005399	4.034130	0.0001

R-squared	0.959746	Akaike info criterion	3.528154
Adjusted R-squared	0.959317	Durbin-Watson stat	1.510372
S.E. of regression	1.397706	Log likelihood	-167.3514

determination R^2, the Akaike information criterion (AIC), and Standard Error (SE). A model with higher R^2, smallest AIC, and lower standard error and fulfilling the features of the best regression model for forecasting corresponds to the model incorporating only T^2 and P as independent variables, and the squared root of S as dependent variable. The model outcomes are displayed in Table II. The estimation equation is given by :

$$S^{1/2} = 0.0239\,T^2 + 0.0218\,P \tag{2}$$

- The value of R^2 is more than 60% hence the model is acceptably fitted. It indicates also that 95.93% variance in the dependent variable can be explained jointly by the temperature and precipitation; the remaining 4.07 percent variation in the dependent variable can be explained by residuals or other variables other than the selected independent variables.
- The independent variables T^2 and P are individually significant to influence the dependent variable; their corresponding $p-value$ are less than 5%.
- Temperature and precipitation are jointly significant to influence the dependent variable; the $p - value$ of F-statistic is less than to 5%.
- The residuals are normally distributed; Jarque-Bera value 4.644 is less than 5.99 and the corresponding $p-value = 0.098$ is more than 5%.
- Moreover the residuals are not serially correlated; the Bruesch-Godfrey serial correlation LM test shows that corresponding $p-value = 0.0532$ is more than 5%.
- Finally, according to Bruesch-Pegan-Godfrey Test, the residuals are not heteroscedastic; the corresponding $p-value = 0.061$ is more than 5%.

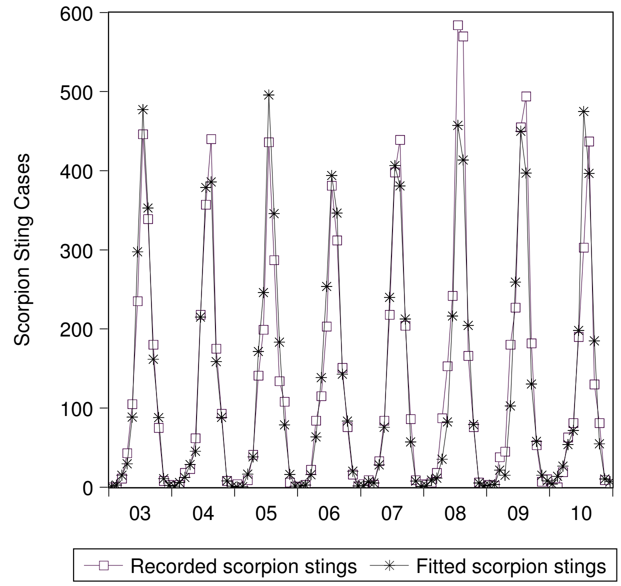

Fig. 9. Recorded scorpion sting cases versus simulated scorpion sting cases during the period $2003 - 2010$.

All features of a best regression model are fulfilled, thus the model can be used for forecasting.

The simulated scorpion sting cases for the period 2003 – 2010 are closely approximated to the recorded data (see Fig. 9.) with correlation $r = 0.968$.

The predicted number of scorpion stings for the year 2011 was computed using the model equation (2) and temperature and precipitation for 2011 [8] and was compared with recorded scorpion stings for the same year and plotted in Fig. 10. The correlation between simulated and recorded scorpion sting cases for this year is very strong ($r = 0.996$).

IV. DISCUSSION

Using the monthly recorded scorpion sting data for the period $2003 - 2010$ for Naama province, the linkage between scorpion stings and weather conditions was demonstrated using a regression analysis. The temperature and precipitation are the retained climate factors for this province. This raises optimism for forecasting scorpion stings provided that appropriate climate information are at our disposal. If we know beforehand the change in the climate variables, we can use the built regression model to estimate how much the change in the value of those variables influence the number of cases of scorpion stings. This could be used to help health authorities determine the appropriate number of antivenom vials necessary for the province in advance. This study represents also an important step to find a way to help in the designing of a control strategy.

In conclusion, our study shows optimism for weather-based forecasting of scorpion stings. It represents an important

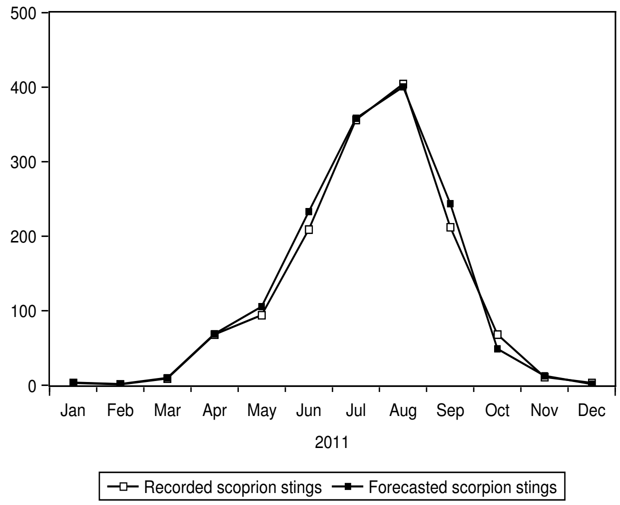

Fig. 10. Forecasted versus recorded scorpion sting cases in 2011.

support for designing of intervention strategies. However, further studies are needed to explore whether other independent variables, such as land cover index, can improve the prediction. As the epidemiology of scorpion envenomation is determined, besides scorpions, by man and environment, the modeling incorporating environmental conditions and human behavior is to be undertaken.

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