

INSECT ECOLOGY

Influence of climatic factors on the abundance of *Culex pipiens* and *Cx. quinquefasciatus* (Diptera: Culicidae) adults in the Western Coast of Saudi Arabia

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Abstract

This study aims to examine the effect of weather factors, temperature (T), relative humidity (RH) and wind velocity (WV) on the abundance of *Cx. (Cux.) pipiens* L. and *Cx. (Cux.) quinquefasciatus* Say, the two common and important mosquito species in the western coast of Saudi Arabia. The two species had the same ranges of T (15.00-30.00°C), RH (8.00-72.00%) and WV (0.10-8.06 Km/h). *Cx. quinquefasciatus* had insignificantly ($P>0.05$) lower means of the three factors than those of *Cx. pipiens*. Regression analysis indicated that abundance of *Cx. pipiens* and *Cx. quinquefasciatus* negatively related to T (regression coefficient, $b=-0.06$ and -0.01 for the two species, respectively) and WV ($b=-0.40$ and -0.16 for the two species, respectively) and positive-

ly related to RH ($b=0.05$ for both species). Such factors accounted for 81% and 76% of the variance in abundance of *Cx. pipiens* and *Cx. quinquefasciatus*, respectively while the remaining parts (19% and 24% for the two species, respectively) may be attributed to other factors mainly rainfall.

Introduction

Thirty two mosquito species belonging to 7 genera are indigenous in the western part of the Kingdom: 14 *Anopheles*, 12 *Culex*, 2 *Ochlerotatus*, and 1 species each of *Lutzia*, *Stegomyia*, *Culiseta* and *Uranotaenia* (Ai-Ali *et al.*, 2008; Al-Ghamdi *et al.*, 2008; Alahmed *et al.*, 2009; Kheir *et al.*, 2010; Al Ahmad *et al.*, 2011; Khater *et al.*, 2013; Alikhan *et al.*, 2014; Mahyoub *et al.*, 2015). In a recent survey in the western coast (Hassan *et al.*, 2016b), 19 species were identified of which *Cx. pipiens* (22.24% larvae, 27.42% adults) and *Cx. quinquefasciatus* (47.11% larvae, 57.52% adults) were the common species. The two species are the chief vectors of bancroftian filariasis, *Wuchereria bancrofti* in many parts of the world including the Middle East and Eastern Mediterranean countries (Ai-Ali *et al.*, 2008; Samy *et al.*, 2016). Omar (1996) reported that *Cx. pipiens* may act as a potential vector of introduced bancroftian filariasis to Saudi Arabia. In addition, *Cx. pipiens* and *Cx. quinquefasciatus* act as vectors of West Nile Virus (Al-Ali *et al.*, 2008; Samy *et al.*, 2016).

To control mosquitoes, a good knowledge and understanding of the relevant biology and ecology of the target species is of paramount importance (Seghal & Pillai, 1970; Gimnig *et al.*, 2001). Understanding climatic factors (temperature, relative humidity and rainfall) influencing adults and larvae is the first step to control over mosquito vector survival, production, development, abundance and distribution (Jemal & Al-Thukair, 2016). Temperature and rainfall were found to be closely associated with mosquito density (Tian *et al.*, 2015). The temperature affects the abundance and activity of mosquitoes; for example high temperature accelerates mosquito development from egg to adult and increases their abundance (Tun-Lin *et al.*, 2000; Hopp & Foley, 2001; Bayoh & Lindsay, 2003; Alahmed, 2012; Alshehri, 2013). However, it was reported that temperature greater than 30°C decreases mosquito survivorship and abundance (Westbrook *et al.*, 2010; Christiansen-Jucht *et al.*, 2014). The relative humidity is often increased by rainfall, particularly following drought and

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Key words: Mosquitoes; *Culex pipiens*; *Cx. quinquefasciatus*; Adult abundance; Climatic factors; Western coast; Saudi Arabia.

Contributions: the authors contributed equally.

Conflict of interest: the authors declare no potential conflict of interest.

Received for publication: 5 December 2016.

Revision received: 22 March 2017.

Accepted for publication: 30 March 2017.

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Journal of Entomological and Acarological Research 2017; 49:6442
doi:10.4081/jeur.2017.6442

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strongly affects the number of females laying eggs, the number of eggs laid, feeding frequency, survival, flight and subsequent host seeking behavior of mosquitoes (Day & Curtis, 1989; Reiter, 2001; Ceccato *et al.*, 2005). Different studies have indicated that high RH increases mosquito lifespan, hatching, density, survival and abundance (Hopp & Foley, 2001; Reiter, 2001; Murty *et al.*, 2010; Alahmed, 2012; Alshehri, 2013; Tian *et al.*, 2015). Moreover, rainfall and RH were the most significant variables influencing anopheline density but the effects of temperature were not found as a significant variable on the abundance of anopheline mosquitoes in Bangladesh (Bashar & Tuno, 2014).

Very few studies were carried out in Saudi Arabia to examine the effect of climatic factors (temperature, relative humidity and rainfall) on mosquito abundance; these studies considered the dengue vector *Stegomyia aegypti* (Al-Ghamdi *et al.*, 2009; Alshehri, 2013) above all. Jemal & Al-Thukair (2016) examined the effect of these factors on mosquito abundance of three genera (*Culex*, *Aedes* and *Anopheles*) in the Eastern Province. However, no studies were carried out on *Cx. pipiens* and *Cx. quinquefasciatus* adults, this study was planned and aimed at examining the effect of the climatic factors (temperature, relative humidity and wind velocity) on abundance of these two common and important mosquito species in the western coast.

Materials and Methods

The study area

The Western part of the Kingdom of Saudi Arabia (16° and 33° N, 34° and 56° E) includes the west coast north of Asir. It contains a mountain chain (with peaks rising to 3000 meters) and the coastal plain bordering the Red Sea. It also includes the most cosmopolitan city of Jeddah which is the main port for thousands of pilgrims on their trip to Holy Cities of Mecca (to the east) and Al Madinah (to the north). In the mountains above Mecca and Jeddah is the town of Taif. Its elevation gives it a climate far cooler than either Jeddah or Mecca and without the uncomfortable humidity of these two cities. The coastal area of the Western part (1090 km long) is notorious for its humidity, with summer temperatures rising to above 40°C. Three regions representing this part: Mecca “21°25'N 39°49'E”, Al Madinah “25°0'N 39°30'30"E and Tabouk “28°0'N 37°0'E”.

The study was carried out in four sea ports (Jeddah: 21°32'36"N 39°10'22"E, Yanbu: 24°05'N 38°00'E, Duba: 27°20'57.3"N 35°41'46.2"E and Haql: 29°17'N 34°56'E) and two cities (Taif: 21°26'N 40°21'E and Mecca: 21°30'N 41°0'E) representing the three regions (Figure 1). In each locality, certain sites were selected and biweekly surveyed for mosquitoes during the period from January 2013 to December 2014.

Mosquito sampling

Adults were collected using three different types of traps: i) the CDC (Center for Disease Control) miniature light traps (Model 512, John W. Hock Co., Gainesville, FL, USA), ii) V-Mart Super photo-catalyst Black Hole (BH) traps (Venus Technology Co., Ltd. Wangthonglang, Bangkok, Thailand) and iii) UV traps (John W. Hock Company, Gainesville, FL, USA). The traps were set before sunset and collected after sunrise next morning. The collected mosquitoes were aspirated, placed in labeled paper cups that kept in a picnic ice box while being transported to the laboratory. In the laboratory, mosquitoes were preserved in 70% alcohol till identification to the species level according to keys of Mattingly & Knight (1956) and Harbach (1985; 1988).

The weather temperature and Relative Humidity (RH) were measured using 2-in-1 LCD Digital Thermometer Hygrometers Model: TA328 and wind velocity (Km/h) was measured using Digital Anemometer Model: AM-4203 (Lutron Electronic Inc., Coopersburg, PA, USA).

Data analysis

The data collected during 2013 and 2014 from all localities were compiled and considered for data analysis. Means±SD were calculated for T, RH and WV of the two mosquito species and tested for significance by the one-way ANOVA. Multiple Regression analysis was used to examine the relation of adult abundance (No collected/trap of all types) with T, RH and WV. The regression equations were in the form of:

$$\text{adult abundance} = a + b_1 T + b_2 \text{RH} + b_3 \text{WV},$$

where a=constant (intercept), b_1 - b_3 are the slopes (regression coefficients). The slopes were tested for deviation from 0 by t-test. The PAST (Paleontological Statistics Version 2.08; Hammer *et al.*, 2001) computerized software was used for statistical analysis.

Results

Ranges of the weather temperature, relative humidity and wind velocity

The ranges of the weather T, RH and WV were determined for *Cx. pipiens* and *Cx. quinquefasciatus* and results (Table 1) revealed that the two species had the same ranges of T (15.00-30.00°C), RH (8.00-72.00%) and WV (0.10-8.06 Km/h). *Cx. quinquefasciatus* had insignificantly ($P > 0.05$) lower means of T (25.20°C), RH (36.63%) and WV (2.24 Km/h) than those of *Cx. pipiens* (25.53°C, 38.36% and 2.33 Km/h for the 3 factors, respectively)

Relation of mosquito abundance with the temperature, relative humidity and wind velocity

The results of multiple regression analysis (Table 2) indicate that: i) abundance of *Cx. pipiens* ($b = -0.06$, $t = 1.09$, $P > 0.05$) and *Cx. quinquefasciatus* ($b = -0.01$, $t = 0.13$, $P > 0.05$) is inversely related to



Figure 1. Surveyed localities in the western part of Saudi Arabia.

T, *i.e.* decreases as T increases, ii) abundance of *Cx. pipiens* ($b=0.05$, $t=1.92$, $P>0.05$) and *Cx. quinquefasciatus* ($b=0.05$, $t=1.12$, $P>0.05$) is directly related to RH, *i.e.* increases as RH increases, iii) abundance of *Cx. pipiens* ($b=-0.40$, $t=1.54$, $P>0.05$) and *Cx. quinquefasciatus* ($b=-0.16$, $t=0.32$, $P>0.05$) is inversely related to WV, *i.e.* decreases as WV increases.

Discussion and Conclusions

In the present study, *Cx. pipiens* and *Cx. quinquefasciatus* had the same ranges of T (15.00-30.00°C), RH (8.00-72.00%) and WV (0.10-8.06 Km/h). No comparable results for these two mosquito species in the study area or in any other area of the Kingdom were available. In the Eastern Province, Jemal & Al-Thukair (2016) determined the effect of T, RH and rainfall on mosquito abundance of 3 genera (*Culex*, *Aedes* and *Anopheles*) and showed that T of 15-27°C and RH between 4% and 69% favors the high abundance and spread of the adult mosquitoes and that T greater than 35°C in summer season is unsuitable for adult mosquito growth. Similarly, in Jeddah city, T range from 20°C to 29°C favors the increase in *Aedes aegypti* density and during summer months the average T is more than 40°C which is not suitable for rapid mosquito growth (Alshehri, 2013). Christiansen-Jucht *et al.* (2014) indicated that higher environmental temperatures (than 30°C) significantly lower adult survival and increase adult mortality ($P<0.001$), however it was reported that high T speeds up mosquito growth and increases mosquito abundance (Tun-Line *et al.*, 2000; Hopp & Foley, 2001; Alahmed, 2012). Other authors (Bayoh & Lindsay, 2003; Tan *et al.*, 2015) indicated that temperatures of 20-29°C are favorable for mosquito growth and development. Abdel-Hamid *et al.* (2011b) in El Ismailia Governorate, Egypt, found that both *Cx. pipiens* and *Cx. antennatus* had T range of 16-22.7°C and RH range of 43.8-73.9%.

Regression analysis indicated that abundance of the two species insignificantly ($P>0.05$) decreases as both T and WV increase and abundance increases as RH increases. Such result reflects the seasonality trends of these two species. In a concurrent study (Hassan *et al.*, 2016a), adults of the two species were active all year round with peaks of abundance during spring, *i.e.* during the mild temperature (mean \approx 26°C) and RH (mean=48%). High activity was also observed during autumn (\approx 28°C, 50% RH) for

Cx. pipiens and during winter (\approx 21°C, 58% RH) for the two species, while lower activity was observed during summer with high mean temperature (\approx 33°C) and lower RH (42%).

There was no study examining the effect of weather factors (T, RH and WN) on abundance of these two species in the western part of Saudi Arabia. However, similar findings were reported by Jemal & Al-Thukair (2016) in the Eastern Province (6 studied localities) who found i) strong negative correlation between mosquito abundance and T ($R=-0.867$), ii) a strong positive correlation with RH ($R=0.654$). Other available studies in Saudi Arabia are dealing with the dengue vector, *St. aegypti*. Al-Ghamdi *et al.* (2009) found that the role of RH on the seasonal abundance of *Aedes* mosquitoes in Jeddah is well established compared to other climatic variables. Alshehri (2013) in Jeddah city, showed a strong correlation between *Aedes aegypti* density and climatic factors (T and RH), but no significant influence of rainfall was visible on mosquito density. Several studies were carried out on Egyptian *Cx. pipiens*, *Cx. antennatus* and *Cx. perexiguus* mosquitoes and indicated that abundance: i) increases as T and RH increase in El Sharqiya Governorate (Abdel-Hamid *et al.*, 2009), ii) insignificantly ($P>0.05$) decreases as T and RH increase in El Menoufia Governorate (Abdel-Hamid *et al.*, 2011a) and iii) insignificantly ($P>0.05$) increases as T increases, while decreases as RH increases in El Ismailia and El Dakahlia Governorates (Abdel-Hamid *et al.*, 2011b; 2013).

The regression model with abundance as criterion variable and the three weather factors (T, RH and WV) as predictor variables showed that 81% ($R=0.81$) for *Cx. pipiens* and 76% ($R=0.76$) for *Cx. quinquefasciatus* of the total variance were accounted, in agreement with observation of Jemal & Al-Thukair (2016) for T, RH and rainfall (84.5%, $R=0.845$), while Alshehri (2013) showed that the three climatic parameters (T, RH and rainfall) accounted for 24% of variance in density of *Aedes aegypti* mosquito. The remaining 19% (*Cx. pipiens*) and 24% (*Cx. quinquefasciatus*) of the variance may be attributed to other factors mainly rainfall that have moderate positive correlation with mosquito abundance ($R=0.147$) (Jemal & Al-Thukair, 2016) and is considered the most significant variable influencing anopheline density (Bashar & Tuno, 2014).

In conclusion, the results of this study demonstrate that the two mosquito species respond to similar weather conditions and that their abundance had an indirect relation with weather T and WV

Table 1. Ranges and means of the weather temperature (T), relative humidity (RH) and wind velocity (WV) for the two common mosquito species.

Attribute	<i>Cx. pipiens</i>		<i>Cx. quinquefasciatus</i>		F _(1,18)
	Range	Mean \pm SD	Range	Mean \pm SD	
T (°C)	15.00-30.00	25.53 \pm 4.16	15.00-30.00	25.20 \pm 4.40	0.03
RH (%)	8.00-72.00	38.36 \pm 7.11	8.00-72.00	36.63 \pm 6.92	0.29
WV (Km/h)	0.10-8.06	2.33 \pm 0.71	0.10-8.06	2.24 \pm 0.55	0.01

Table 2. Multiple regression analysis for the effect of temperature (T), relative humidity (RH) and wind velocity (WV) on the abundance of the two common mosquito adults.

Species	b (regression coefficient)			R (correlation coefficient)
	T	RH	WV	
<i>Cx. pipiens</i>	-0.06	0.05	-0.40	0.81
<i>Cx. quinquefasciatus</i>	-0.01	0.05	-0.16	0.76

and a direct relation with RH. Such factors accounted for 81% and 76% of the variance in abundance of *Cx. pipiens* and *Cx. quinquefasciatus*, respectively, while the residual variance may be attributed to other factors mainly rainfall.

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