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Cross-Sectional, Longitudinal and Prospective Epidemiological Studies of Rift Valley Fever in Al-Hasa Oasis, Saudi Arabia

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Abstract: A cross-sectional and longitudinal serological study was conducted on domestic ruminants in Al-Hasa Oasis to clarify the presence, prevalence and distribution of Rift Valley Fever (RVF). A total of 598 serum samples were collected from sheep, goats, cattle and camel during the year 2007. Enzyme Linked Immuno-Sorbent Assay (ELISA) was used to detect the presence of anti-RVF IgG and IgM antibodies in sheep, goats and cattle sera. Camel sera were tested by isotype-nonspecific inhibition ELISA. Two out of 225 sheep sera were IgG, but not IgM, seropositive, other sera were IgG and IgM seronegative. In a single sentinel herd of 40 sheep, which was established in the oasis, no seroconversion was detected during the period from July 2005 to May 2008. The low intra-herd prevalence, the scattered distribution of the two seropositives, the absence anti-RVF IgM antibody and the absence of RVF-incidence in the sentinel herd, all suggest that the seropositive animals were introduced from outside of the oasis rather than infected inside the oasis. The prospective study shows that readiness of the region to RVF outbreak is possible.

Key words: Rift valley fever virus, Saudi Arabia, Al-Hasa, sentinel herd, sheep, goats, cattle, camels, epidemiological study, survey

INTRODUCTION

Rift Valley Fever (RVF) is an acute, mosquito-borne, viral disease affecting ruminants and man. The causative agent, RVF Virus (RVFV), belongs to the genus *Phlebovirus* of family *Bunyaviridae* (Flick and Bouloy, 2005). The virus was first isolated in 1930 in Kenya by Daubney *et al.* (1931). Since, then RVF have been reported in many African countries. In the year 2000, RVFV have been for the first time reported outside the African continent in the South-West region of Saudi Arabia and in the North-West region of Yemen. As a result, an outbreak with devastating effects on both human and animals have taken place (CDC, 2000a). Measures taken in affected region of Saudi Arabia to control the disease include: mass vaccination of young ruminants, effective measures to reduce mosquitoes population, establishing a surveillance system by both cross-sectional and longitudinal means and strict quarantine on animal movement inside the affected region as well as complete ban of animal export to prevent spread of the disease to other regions of Saudi Arabia (Al-Afaleq, personal communication; Elfadil *et al.*, 2006a). A retrospective study conducted by Al-Afaleq *et al.* (2003) indicated the absence of antibodies against the RVFV in the affected areas at least up to the year 1995. RVF was not reported and its status is unknown in the other regions of Saudi Arabia, emphasizing the need for a RVF-surveillance activity in those regions. One of these regions is Al-Hassa Oasis, which is an agricultural area with large animal population.

In this study, we aimed to describe the epidemiological status of RVF in Al-Hasa Oasis by performing a cross-sectional and longitudinal study on ruminants in the oasis and to evaluate the susceptibility of the oasis, from the available reports, to RVF outbreak.

MATERIALS AND METHODS

Study site: The study was conducted in Al-Hasa Oasis, located at 25°15'-25°40'N and 49°30'-40°45'E. It lies in the Eastern province of Saudi Arabia, about 60 km West of the cost of the Arabian Gulf. It is an agricultural area with date palm is the main crop; alfalfa, tomato, rice and other vegetables are also cultivated. Agriculture depends mainly on irrigation from drainage water, wells and numerous springs distributed throughout the oasis (Akkad, 1990). In 2006, according to the ministry of agriculture, the estimated amount of irrigation water was 113,000,000 m^3. Water is distributed through a huge

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unconcealed network of effluent. In the Irrigation and Drainage Project, which completed in 1971, the total length of the irrigation cannel was 1520 km, which is built of concrete and the total length of the drainage cannel was about 1320 km (Akkad, 1990). Climatic data were kindly provided by the presidency of meteorology and environment.

Study population: The study was involved endogenous sheep, goats and camels and both endogenous and European cattle. The approximated size of animal welfare in Al-Hasa Oases in 2007 shown in Table 1 according to the Ministry of Agricultural-annual report 2007 and Al-Hasa branch. All the donor animals were >1 years old and had been present in their localities for at least 1 year.

Sampling: A total of 598 samples were collected from the study population. Sample size was calculated to obtain 95% certainty in detecting at least one positive case at a prevalence of 0.5%, the population being considered infinite (Thrusfield, 2005). To represent all species properly, proportional samples were taken according to the relative size of each species (Table 1).

Multistage sampling method was used for collection. In the primary stage a sample of 30 localities and spare replacement of 10 localities were chosen randomly from a population of 94 localities. In the secondary stage, samples were taken using the systematic random sampling method. Samples were collected during the year 2007. Each blood sample was obtained by separate needle and vacuum tube. Blood was collected by jugular vein puncture of donor animals and allowed to clot at the room temperature and then the serum was separated by centrifugation at 2000 rpm for 10 min. Serum samples were stored frozen at -30°C, until tested for the presence of anti-RVFV antibodies.

Data collection: Every serum sample in the screening survey was accompanied by questionnaire requesting epidemiological data. The questionnaire contains the name of the locality from which the sample was obtained; date of sampling; species, breed, sex and age of the sampled animal and type of husbandry (farm, home keeping, or pasture).

Sentinel herds: A group of forty Naámi sheep, brought from Al-Jawf governorate located in the North border of the kingdom and tested seronegative by RVF IgG ELISA, was used as a sentinel herd. All animals were male, aged 6 month and apparently healthy at arrival. The sentinel herd was established in the Agriculture and Veterinary Training and Research Station, King Faisal University, at Al-Ghwibah, Al-Hasa. The site is close to the Veterinary Teaching Hospital and located near date palm woodland. Sentinel herd was daily observed for any sings of illness. First bled for serum was obtained at July 2005 and continue at a monthly basis up to May 2008. Disease status was assessed by monitoring seroconversion at bimonthly basis. Sampling and storage was performed as described for the survey.

Table 1: The targeted animal population, drawn sample and results of sample testing

Species	Sheep	Goat	Cattle	Camels	Total
Population size (N)	52000	23000	61100	6400	142500
Sample size (n)	225	102	242	29	598
IgG positives	2	0	0	0	2
IgM positives	0	0	0	0	0
Apparent IgG seroprevalence	0.89%	0%	0%	0%	0.33%
True IgG seroprevalence	0.5%	0.5%	0.51%	0.5%	0.5%

Table 2: The threshold values, sensitivity and specificity of the used ELISA tests according to the manufacturer manual

Test and animal species	Threshold	Sensitivity (%)	Specificity (%)
Sheep IgG sELISA	11.1 PP*	99.1	99.1
Sheep IgM cELISA	8 PP	-	98.7
Goat IgG sELISA	18.1 PP	100.0	99.9
Goat IgM cELISA	9.5 PP	-	99.7
Cattle IgG sELISA	16.4 PP	96.3	99.7
Cattle IgM cELISA	14.3 PP	-	100.0
Camel non-specific iELISA	36.1 PI**	100.0	100.0

*Percentage positivity, **Percentage inhibition

Detection of anti-RVFV antibodies: Four ELISA format (from BDSL, South Africa) were used to detect anti-RVF antibody in serum samples. Sheep and goat IgG-sandwich ELISA was used to test serum samples from sentinel herd and from sheep and goat in the survey. Cattle IgG-sandwich ELISA was used to test serum samples form cattle in the survey. Sheep, goat and cattle IgM-capture ELISA was used to test sera of these species from the survey. Species non-specific and antibody isotope non-specific inhibition ELISA were used to test camel's sera from the survey. Each test was performed according to the manufacturer's instructions that previously described by Paweska *et al.* (2003a, b, 2005).

Interpretation of the tests results: Test results were interpreted using the cut off points mentioned in Table 2 according to the manufacturer instruction.

RESULTS

Cross-sectional survey: ELISA tests were used for detection of anti-RVFV antibody. As the sensitivity and specificity of the used tests differ from species to species (Table 2), the results are presented separately for each species in Table 1. No IgM seropositive were found,

Table 3: The epidemiological data of the seropositive animals

Locality	Species	Sex	Age (year)	Breed	+ve/n*(%)
Al-Ghuwaybah	Sheep	Female	3-4	Na'ami	1/19 (5.26)
Al-Uyun	Sheep	Female	3-4	Na'ami	1/12 (8.33)

*Number of sero-positive/number of sampled animals in each flock

hence the apparent IgM seroprevalence is 0% for all species. The sensitivity of the IgM ELISA varies according to the duration between infection and sampling; hence the true prevalence could not be calculated for the anti-RVFV IgM antibody. Epidemiological data of the seropositive donors are shown in Table 3. Two localities, representing 6.67% of the sampled localities and separated by about 45 km, had one RVFV IgG positive animal each. Seropositive animals were kept, each with their flock in a small farm. The overall apparent prevalence of anti-RVF IgG antibody in Al-Hasa Oasis is 0.33%, while those of anti-RVF IgM antibody appear to be 0%. The overall true prevalence of anti-RVF IgG antibody can be averaged to 0.5%.

Sentinel herd: The longitudinal study started in August 2005 with a single herd of 40 tagged male sheep and monitored till May 2008. Seven animals (17.5%) were died throughout the study period. Necropsy of died animals reveal nothing with exception of sings indicating ruminal impaction. Thirty five serum samples were collected from each animal, accounting for a total of 1295 sera, throughout the 3 years of the study period. Twenty sample, accounting for a total of 746 sera, were tested by the sheep anti-RVF IgG ELISA almost at a bimonthly basis. No sero-conversion was detected throughout the study period. Hence, it may be conceivable to say that the incidence density and the cumulative incidence of RVF in Al-Hasa Oasis is zero during the period from August 2005 to May 2008.

Analysis of climatic data: Reviewing the climatic data of the passed 23 years (1985-2007), reveals that the average annual rainfall is 88.87 mm^3, while the annual rainfall ranged from 27.4-266 mm^3. Figure 1 shows that the relative humidity takes a V shape throughout the year, reaching 57.8% during December and 21.6% in June. The hottest month is July in which the average air temperature is 37.73, while the minimum and maximum temperatures fluctuate between 27.6-31.4 and 42.8-47.8°C, respectively. The coldest month is January with average air temperature 14.67, while the minimum and maximum temperatures fluctuate between 4.5-12.6 and 17.4-24.6°C, respectively. These information were kindly provided by presidency of meteorology and environment, Saudi Arabia.

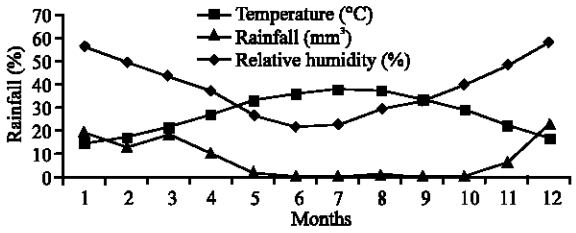

Fig. 1: Monthly average rainfall, air temperature and relative humidity in Al-Hasa as calculated throughout the period from year 1985-2007

DISCUSSION

The importance of such study goes beyond the eastern province of Saudi Arabia. After the outbreak of RVF in South-West tip of Asia in the year 2000, it is crucial to monitor the possible spread of the disease to further areas in Saudi Arabia and may be countries beyond in Asia and Europe. This is clearly happened with other arboviruses such as blue tongue were recently been found in Europe.

Sentinel herds were frequently used-method to confirm the presence or absence of a particular disease in a defined geographic area and to determine the disease incidence rates. These goals could be achieved by either detecting the presence of the virus, virus genome or the occurrence of sero-conversion. In the present study, duration of RVFV viraemia in infected domestic ruminants ranged between 3-9 days (Sellers *et al*., 1982) and hence the possibility of caching infected animals during this short period seems to be difficult. RVF virus is also a level three biohazard pathogen and requires a well-equipped laboratory to isolate the virus. On the other hand, sero-conversion is a long lasting and represents the easier way to detect RVFV activity when present.

In the sentinel herd, no sero-conversion was detected throughout the three years of the study period and it may conceivable to say that there was no incidence of the RVF in Al-Hasa oasis during this period.

Animals were kept in a small fence within the Agriculture and Veterinary Training and Research Station (AVTRS), King Faisal University. The AVTRS is located close to date-palm woodland which contains a considerable number of animals' farms. The AVTRS is also contains animals kept for other research purposes and Veterinary Teaching Hospital (VTH). The VTH receipt diseased animals from all over the oasis, surrounding regions and even from adjacent countries and contain stalls for monitoring and treating inpatient animals. Thus, the site selected for establishment of the sentinel herd is at risk site and vulnerable to receive many diseases, including RVF if present, from the adjacent VTH or from the animals' farms in the adjacent region.

The longevity of sentinel herd could be as short as 8 months (Abu-Elzein *et al*., 2006) 18 months (Zeller *et al*., 1997) or 24 months (Ward *et al*., 1995), however, sentinel herd in the present study was maintained for 35 month to increase the reliability of the obtained results. The samples obtained from sentinel herds could be tested at an annual basis (Broom *et al*., 2002) or half annual basis (Zeller *et al*., 1997); however, in this study samples were tested at a bimonthly basis in order of detecting any viral activity as soon as possible.

The screening cross-sectional survey was able to detect 2 animals with anti-RVF IgG antibody, but no IgM seropositive animal was detected. As shown in Table 3, both seropositive animals were sheep, Naámi breed, between 3-4 years old, located in a localities separated by about 45 km. Considering the age of these animals, the seropositivity could be revealed to previous exposure to either RVF virus or vaccine.

The presence of IgG along with absence of IgM seropositives could occur due to the rapid waning of the IgM antibody. It is known that IgG antibody is a life lasting antibody, while the duration of anti-RVF IgM antibody is not well-documented. IgM antibody was estimated to persist at a detectable level for up to 6 month after natural infection (Soumare *et al*., 2007) and for four week in vaccinated sheep and goats (Elfadil *et al*., 2006b). Paweska *et al*. (2003a, b) reported that the diagnostic sensitivity of the IgM ELISA is 100% in detecting sheep IgM antibody against RVFV between days 5-42 post infection and decreased to 12.5% 3 weeks later.

Previous exposure to the RVFV or its vaccine, as indicated by the presence of IgG sero-positives, does not indicate whether or not these exposures were occurred in Al-Hasa Oasis. Inside the Oasis, the vaccination program is supervised and afforded for free by the Ministry of Agricultural-Al-Hasa branch and no vaccine against RVF is permitted to be used in the Oasis; hence, it is unlikely that the sero-positivity was due to vaccination inside the oasis.

The other possibility is that the virulent RVFV was introduced into the oasis, despite the way of its introduction. Such possibility could not be completely excluded with arbovirus like RVFV. During a few decades RVFV invade many countries in North and West Africa and then invade Arabian Peninsula. Similarly, West Nile virus was reported for the first time in North America in New York City in 1999, in 2003 the virus was reported in 44 American states and six Canadian provinces (Chevalier *et al*., 2004). Two acute human infections with RVF were confirmed in a hospital in Al-Hasa during the 2000 epidemic. Fortunately, those patients were a travellers from South-West region (Madani *et al*., 2003), but entrance of a similarly viraemic human(s) or animal(s) or even vector(s) could not be excluded.

First introduction of RVFV into a previously unaffected virgin soil is expected to induce explosive outbreak with high sero-prevalence rates (Bird *et al*., 2008; Soumare *et al*., 2007). Such outbreak or even any viral activity was not reported in Al-Hasa Oasis. Thus it seems unlikely that the IgG sero-positives in this study is due to RVFV infection inside the oasis. Rather than that importation of previously infected or vaccinated animals from outside of the Oasis is strongly suggested.

Strict quarantine measurements are applied on outside movement of animals from South-West region to prevent out spread of the disease (Elfadil *et al*., 2006a). On the other hand, Saudi Arabia is one of the major importers of sheep and goats all over the world (Bourn, 2003), with large official efforts to avoid importing animals from countries suffering RVFV activity. However, introducing or smuggling of sero-positive animals can not be excluded, especially during Eid Al-Adha. During Eid Al-Adha, there is a movement of large numbers of ruminants from all over Saudi Arabia, surrounding countries, some African countries and from Australia to Mecca (Davies, 2006). The presence of sero-positives is expected within any animals imported from infected areas and such animals may reach the oasis. Once, introduced into the non-quarantined regions of Saudi Arabia, animals can be transferred freely from region to another (Al-Afaleq A.I., personal communication). Though it is not sampled, apparently-pure and cross-breed Somalian breed of sheep were observed in the oasis and imported animals usually slaughtered in Al-Hasa slaughterhouse. The fact that all donor animals have been in the oasis for at least one year may explain the inability to detect IgM antibody in such animals. The scattered spatial distribution of the sero-positives, the low intra-herd sero-prevalence and the absence of any RVF incidence in the sentinel herds are also supporting this hypothesis. Similar situation where reported in Sinai peninsula-Egypt, where a seropositives human and animals reported but no viral activity was detected (Sellers, 1981).

On the other hand, the positive predictive value of the IgG sELISA decreased to 26.7% at a prevalence value of 0.33% and thus the presented prevalence became a matter of argument. Obtained result (0.33% prevalence) is also beyond the specificity of the used test (99.1%), thus the sero-positivity could be considered as false positive results. It may be conceivable to say that Al-Hasa oasis still a RVF-free zone.

Prospective analysis was based on two assumptions; the first is that Saudi Arabia is RVF-free with the exception of Jazan and its surrounding region, the second is that imported-African animals do not come directly into the oasis.

The most possible source of the viable RVFV for Al-Hasa oasis is Jazan which is a costal plain on the Red Sea, located about 1000 km from the oasis. By land transport, the journey time from Jazan to the oasis is about 16-20 h. Topographically, there is a wide desert stretched out between the two regions with a high mountain Al-Sarawat on the North-East border of Jazan. During the 2004, RVF infection rate in Jazan sheep and goats reported to be ranged between 0.12 and 1.04%, the herds immunity ranged between 22.2 and 39.3% (Elfadil *et al*., 2006b). The risk of transmitting RVFV will vary according to the strength of RVFV activity in Jazan at a given point of time.

The most probable routes of introducing the virus is infected host(s) (within the incubation or viraemic period), or infected vector(s). At least there are four scenarios for the virus to reach the oasis, within each scenario the virus could be transmitted directly into the oasis or indirectly by spreading through the in-between regions before reaching the oasis. These scenarios include: Windborne infected vector(s), Vehicle-borne infected vector(s), Smuggled infected-animal(s), Infected traveller(s) during the incubation or viraemic period.

Windborne insects were implicated in initiating at least two major RVF epidemics one in South Africa and the other in Egypt (Sellers, 1981; Sellers *et al*., 1982). Windborne insect and their role in transmitting diseases were reviewed by Sellers (1980). The wind direction in the Jazan-adjacent region Asir is South to South-West and may continue on the same direction till Bishah, but not to Wadi Al-Dawasir. Al-Sarwat Mountains could serve as a physical barrier for such scenario; however, it has been reported that wind could carry mosquitoes for up to 1500 m vertically and 175-300 km horizontally (Yuill, 1986). Suppose that infected vectors passed the mountain, they have to survive the desert and the counter winds; hence, the chance of infected mosquitoes to reach the oasis by this mean seems to be slight; however, it could transmit the infection out of the quarantined region, especially to Asir and its surrounding regions and thus supported indirect part of the other three scenarios.

It has been reported that aircraft could carry insects (Sellers *et al*., 1982) and it is thought that the aircrafts were responsible for introduction of Aedes mosquitoes to a previously free countries. The airport malaria, which occur due to carriage of malaria-infected mosquitoes on aircrafts is well documented (Mangili and Gendreau, 2005; Tatem *et al*., 2006). Beside the aircrafts, RVFV-infected mosquitoes could also arrive at the oasis carried on land vehicles either directly or indirectly.

It has been suggested that RVFV was introduced into Arabian Peninsula via imported-infected ruminants (Davies and Martin, 2006). RVRV was also isolated from imported sheep in Nigeria (Yuill, 1986), thus infected ruminants could be enrolled as a possible route of transmitting RVFV between distant geographic areas. The role of animals in spreading infectious diseases has been reviewed by Fevre *et al*. (2006). As previously stated, the South-West region is quarantined; however, smuggling of ruminants, especially during Eid Al-Adha, cannot be excluded. Once leaved the quarantined region, animals can be transferred freely in the non-quarantined areas (Al-Afaleq A.I., personal communication). An important point in this regard is the duration of incubation plus viraemia periods and this appears to be ranging between 3-9 days in RVF infected ruminants (Sellers *et al*., 1982). Obviously, infected animals would arrive at the oasis before been dead or recovered.

During the 2000 epidemic, acute RVF infection was confirmed in two travellers in Al-Hasa. They were come from the South-West region (Madani *et al*., 2003). The risk of travellers introducing new infectious diseases into a previously free area has been reviewed by Wilson (1995). During the World War II, the movement of troops from Southeast Asia to the Pacific Islands was implicated as the cause of introducing dengue fever there (Gezairy, 2003). Most RVF infections in human are mild and even undetectable and this could increase the risk of such scenario. The thought that clinical illness will reduce the desire to travel does not affect the fact that the incubation period (4-6 days) is quite enough to have the journey before commencing of the clinical illness.

Given that viable RVFV has arrived in the oasis, its ability to survive and establish the disease will depend upon the route of its entrance (vector or host) and the availability of the next organism to be infected (hosts or vectors) at the site of entrance, the susceptibility of the hosts or competence of the vectors and the presence of suitable ecological conditions.

As previously stated, Al-Hasa oasis is an agricultural area growing relatively large numbers of domestic animals, especially ruminants. There are approximately 142,500 ruminants harboured in the oasis. The breeds of the grown ruminants are that grown in the South-West region, which were susceptible for RVF. Animals commonly kept in a fence within a croft which is usually contain the farmer house. Family members and/or herders usually have extensive contact with the animals they raised. They milked their animals, especially she-camels and drink it without heat treatment and as a part of their tradition and honourableness they invite their guests and neighbours to drinks with them. At nights, farmers usually burn fronds to repel mosquitoes.

Al-Ahmed *et al*. (2007, unpublished data) reported that the *Culex tritaeniorhynchus*, *Cx. pipiens*, *Aedes caspius*, *Cx. perexiguus* and *Anopheles multicolour*

represent 80% from the total adult mosquitoes that were captured in Al-Hasa. These five mosquitoes were reported as a RVF vectors and the first three of them, represent 65.5% of the total captured mosquitoes were implicated as a main vectors in a major RVF epidemics (Jupp *et al*., 2002; Turell *et al*., 1996; Gad *et al*., 1987). *Cx. tritaeniorhynchus*, the most abundant adult mosquito in Al-Hasa (36.7%) (Al-Ahmed *et al*., 2007, unpublished data) was one of the two most abundant mosquitoes during the 2000 epidemic in the South-West region of Saudi Arabia (Jupp *et al*., 2002). *Cx. pipiens*, represent 14.4% of Al-Hasa mosquitoes, was reported as the main vector during the 1977-78 Egyptian epidemic (Turell *et al*., 1996) and as important RVF vector in Kenya and Saudi Arabia (Logan *et al*., 1991; Miller *et al*., 2002). *Ae. caspius*, represent 14.4% of Al-Hasa mosquitoes, was the main vector during the 1993 Egyptian epidemic and was considered the most efficient RVF-vector in Egypt. *Cx. perexiguus*, represent 6.3% of Al-Hasa mosquitoes, was reported to have similar vectorial capacity to those of *Cx. pipiens* (Turell *et al*., 1996).

Cx. tritaeniorhynchus and *Cx. pipiens* prefer to breed in permanent water (Jupp *et al*., 2002; Nasci *et al*., 2001) in contrast to *Ae. caspius*, which prefer floodwater breeding site (CDC, 2000b). However, Al-Ahmed *et al*. (2007) reported the presence of the *Ae. caspius* all over the year in Al-Hasa.

Cx. tritaeniorhynchus, *Ae. caspius* and *An. multicolour* feed on animals and human and could act as animal-to-animal, animal-to-human and human-to-human transmitters. *Cx. perexiguus* prefer to feeds on domestic animals and could serve as animal-to-animal transmitter. *Cx. pipiens* feeds mainly on human and could act as a human-to-human transmitter (Jupp *et al*., 2002; Turell *et al*., 1996; Becker *et al*., 2003). *Cx. pipiens* could play an important role in transmitting RVF in Al-Hasa oasis as the moderate to hot weather (26-33°C) increases its vectorial capacity for transmitting RVFV (Turell *et al*., 1985b; Brubaker and Turell, 1998). It was also suggested that the poor feeding efficiency in RVF-infected *Cx. pipiens* could associated with increased transmission rates due to repeated probing (Turell *et al*., 1985a). *An. stephensi*, represent 7.3% of Al-Hasa adult mosquitoes, could be the sixth RVF-vector in the oasis providing a concurrent infection with RVFV and *Plasmodium berghei* or other malaria parasites that could disrupt mosquito's salivary gland barrier (Vaughan and Turell, 1996).

RVF emergence involves many environmental factors including water availability, moisture, vegetation, temperature and other factors (Anyamba *et al*., 2001). The oasis has a dense greenish cover mainly, but not only, due to date palms. Cultivation in the oasis depends on irrigation and 113 million m^3 of the irrigation water was used during the year 2006. A branched network of irrigation and drainage canals extends throughout the oasis is unconcealed and the water it contains, represents a habitat for mosquitoes' larvae, *Gambusia affinis*, water bug, Odonata nymphs and water beetle. Drainage canals discharge their contents into the man-made Al-Asfar Lake locating in the Northeast verge of the oasis. These may explain the reported presence of adult mosquitoes throughout the year in Al-Hasa with two peaks, which were suggested to associate with the rainfall and suitability of air temperature, the first peak is in April and May, while the second is in September and October (Al-ahmed *et al*., 2007). Figure 1 shows the essential climatic parameters in Al-Hasa oasis, which were reported to affect mosquitoes and or RVF emergence.

The situation appears to be suitable for mosquito-borne diseases to spreads in Al-Hasa oasis. In 2006, the Ministry of Health reported the presence of 26 infections with malaria out of 51920 tested samples and 846 case of cutaneous leishmaniasis in Al-Hasa. Bovine Ephemeral fever also appears from time to time in the oasis.

In Egypt and West Africa, RVF occurrence was not linked to rainfall, instead it was linked to agricultural activities and dam constructions (Chevalier *et al*., 2004). Al-Hasa oasis is also an irrigated agricultural land and shares most of their anticipated RVFV vectors with Egypt. In such a situation the emergence of the mosquito and probably the disease, does not depend on rainfall flooding.

CONCLUSION

The probability of introducing the virus into the oasis appears to be negligible during the interepizootic period and moderate to high during epizootic period in Jazan, especially through the indirect way.

Al-Hasa oasis harbours all necessities for RVFV outbreak to occur. If introduce, the RVFV would induce a large outbreak as the majority of the host populations are susceptible (based on breeds and immune status). The outbreak would continue for few months then starts to go down in corresponding with converted immune status. It has been reported that the herd immunity would reach 80% following an outbreak. The disease would then subsides for few years, during which the herd immunity remains sufficient to prevent disease emergence (Chevalier *et al*., 2004). During this period the virus would maintain itself through low incidence of inapparent

infections in small foci (Davies, 1975; Zeller *et al*., 1997). As the herd immunity wane off the region will be again susceptible for another outbreak.

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