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Abstract

Some environmental and management risk factors were investigated in the current case- control study for PPR outbreaks in Sudan in the period from 2008 to 2012. One hundred and fourteen Localities from 14 states out of 15 were divided into cases (n= 47) and controls (n= 67) according to the PPR outbreak history; cases are localities with PPR outbreaks through the five years of the study while controls are the localities which haven't reported any outbreak during the study period. Data about seven risk factors were collected and analysed using SPSS software, the factors are; ecological zone, annual rainfall, wildlife density, location at border with a foreign country, vaccination coverage against PPR, Sheep and goats population and State area. In the univariate analysis Odds Ratios (OR) were calculated using mantel Haenszel test and three factors were found to have a significant association with the occurrence of PPR outbreaks; being a locality in a state at the country borders (OR = 2.942, *p*-value= .019), or locality in Low rainfall ecological zone (OR = 2.134, *P*-value=.052) and the factor of having large size population of small ruminant (OR = 1.591, *p*- value=.251). These potential risk factors were entered into a multivariate analysis using logistic regression and only the factor of being at the border with a foreign country was found to be significantly associated with PPR occurrence (*P*-value = .027).

Keywords: PPR- risk factors- Sudan- case -control study

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Introduction

Outbreaks of Peste des Petits Ruminants (PPR) occurred annually in Sudan; although most cases are underreported (Saeed *et al.*, 2010). Among all reported outbreaks to the General Directorate of Animal Health and Epizootic Disease Control, PPR outbreaks were taking the first or the second class

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among the highest number of reported outbreaks during the last 5 years (Anonymous, AHEDC, 2008, 2012).

Infectious disease exhibits classic time-space clustering where case arise at similar time in similar places because of the contagious nature of the disease. This clustering may provide clues to the causes of the disease process and may assist in formulating disease prevention and control programs (Ward and Carpenter, 2000). There are considerable differences in the epidemiological pattern of the PPR disease in different ecological systems and geographical areas (Gopilo, 2005).

According to ecological zones the PPRV will survive longer in dry regions and might thereby engender genetic resistance to infection (Lefevre and Diallo, 1990). Also there are often a number of risk factors that contribute to the overall risk of PPR transmission in a particular community, these factors are quite attributes of the sub-population such as the amount of movement, exchange of animals, distance from services and inter-species contact or interaction with wildlife (Elsawalhy *et al.*, 2010).

Concerning seasonal effect on PPR in Africa; the more important epidemics of disease occur in the beginning and the end of the wet season among the settled farmers to the South of the Sahel and these outbreaks are perhaps explained by the variation in the susceptibility of different sheep and goat breeds and by the migration pattern of the Fulani pastoralists (Grenfell and Dobson, 1998). On the other side higher incidence of PPR were observed during the dry months of December and January in West Africa (Okoli, 2003).

The morbidity rate of PPR increases with environmental stress such as confinement of animals during winter and rainy seasons. However the effects of environment on PPR occurrence are solely based on the nature of animal husbandry conditions and socio-economic status of the owner (Munir, 2013).

The current case- control study is aiming to investigate some of the ecological, environmental and management potential risk factors that might be associated with the occurrence of PPR outbreaks in different localities in Sudan states.

Materials and Methods

Study Area:

Sudan is situated in Northeast Africa, it is the third largest country in Africa with a total area of 1,882,000 Sq Km. The country is bordering seven countries; Egypt from North, South Sudan from South, In the East Ethiopia and Eritrea and in the West Libya, Chad and central Africa, with the Red Sea coast in Northeast of the country (Anonymous, CBS, 2012).

Sudan has human population of 33,979,594. The livestock population estimate over 104,278,000Head of cattle, sheep, goats and camels. The small ruminants' population is 69,945,000 head (Anonymous, MoLFR, 2011).

The country is characterized mainly by desert and semi- desert ecological zones as well as low rainfall savanna. The defining geographical feature of Sudan is the Nile River (Fahey, 2007).

During the time of study Sudan was divided into 15 states, the study covered all the localities of Sudan states except the localities of Western Darfur state.

Study design:

One hundred and fourteen localities of the 14 Sudanese states were selected for case-control study (Which represent all the states in Sudan except Western Darfur because of the irregular report` flow from this state during the study period). Localities were divided to 47 cases and 67 controls. Controls are the localities which have no outbreaks

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records during the period from 2008 to 2012 while the cases are the localities which have PPR outbreaks even if have one outbreak during the study period. PPR outbreaks in different Sudan states during the study period. Showing the status of PPR outbreaks in States of Sudan during 2008 to 2012(Anonymous, AHEDC Annual reports 08-12).

Data collection:

Data about PPR outbreaks, ecological zones, vaccination, sheep and goat population data and wildlife data were collected from the Reporting and Information Unit and Wildlife disease section in epidemiology unit in The General Directorate of Animal Health and Epizootics Control of The Ministry of Livestock and Rangelands.

Annual rainfall during the years from 2008 to 2012 and states areas were collected from the Central Bureau of Statistics (CBS), Ministry of Cabient of the Republic of Sudan.

Data analysis and presentation:

Data on PPR outbreaks and risk factors were entered into excel sheet for primary summations and coding and Choropleth Maps and maps with proportional point symbols were produced using GIS software ArcMap 9.3. All statistical analysis was conducted using Statistical Package for Social Sciences (SPSS) for Windows version 17.0.

Categorical variables

Seven dichotomous categorical variables were investigated in this study as explained in Table 1. The ecological zone divided the localities to ones located in desert and semi-desert and localities in low rainfall woodland savanna. The annual rainfall for the period from 2008 to 2012 divided the localities into localities with low rainfall and others with high rainfall. Wildlife density in states was divided into two categories; localities in states with low and medium density of wildlife, and localities within states with high density. Localities were also divided into two groups according to their state areas and state population. Vaccination coverage against PPR for every state was calculated by dividing the annual vaccination for the period from 2008 to 2012 over the total state population of sheep and goats. Figure (1) explains the numbers of vaccination against PPR comparing to sheep and goat population per state.

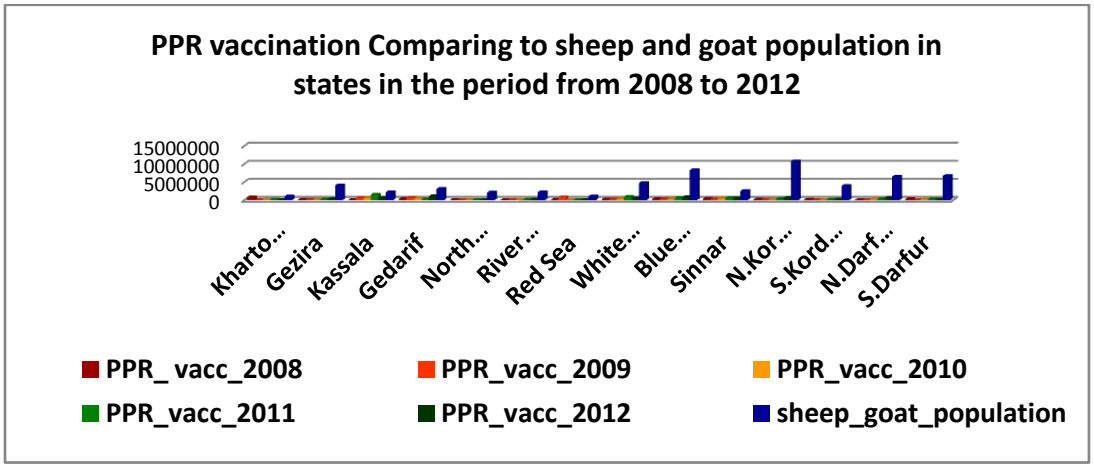

Figure 1: Chart showing vaccination against PPR disease comparing to sheep and goat population per states during the years 2008- 2009- 2010- 2011- 2012

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Source: Annual Reports of The General Directorate of Animal Health and Epizootic diseases control (AHEDC) for the years 08- 09- 10-11 and 2012

Univariate Analysis

All categorical variables were cross tabulated; and the association of the studied factors with the PPR outbreak occurrence was tested by calculating the Odds Ratio (OR) using Mantel Haenszel test. A risk factor with *p*-value ≤ 0.25 was considered to be significantly associated with the occurrence of PPR outbreaks, either positively (OR>1) or negatively (OR<1).

Multivariate Analysis

Potential risk factors in the univariate analysis (p- value ≤ .25) were entered and analysed multivariably using logistic regression to assess the association between PPR outbreaks occurrence and these potential risk factors. Risk factors with P-value ≤ .05 were considered to have a significant association with the occurrence of PPR outbreaks.

Results

Univariate analysis

The Odds ratios were calculated using Mantel- Haenszel test. Six risk factors were positively associated with PPR occurrence (Odds ratio >1). Three factors were found to have significant effect on PPR outbreaks occurrence (*p*- value ≤ .25); the ecological zone, being at country borders and the large sheep and goats population per states. Only vaccination was negatively associated with PPR occurrence, (Odds ratio<1), as shown in Table (1).

Multivariate analysis

The risk factors showing significant association (*p*- value ≤ .25) in the Univariate analysis were entered into logistic regression model for multivariate analysis, only the risk factor of being at country borders with foreign country was found to be significantly associated with PPR outbreaks occurrence (*p*- value ≤ .05), as shown in Table (2).

Table 1: Univariate analysis for risk factors associated with PPR outbreaks occurrence by calculating the Odds ratios in cases and controls using Mantel Haenszel test

Variable	Variable categories	Case(n=47) No (%)	Control(n=67) No (%)	Odds ratio	95% CI		*P*-value
					Lower	Upper	
Ecological zone	Low rainfall woodland Savanna	23 (33.8)	45 (66.2)	2.134	.992	4.592	.052*
	Desert and semi-desert	24 (52.2)	22 (47.8)				
Annual Rainfall	High rainfall	27 (38.0)	44 (62.0)	1.417	.658	3.052	.373
	Low rainfall	20 (46.5)	23 (53.5)				
Wildlife	High density	18 (36.0)	32 (64.0)	1.473	.690	3.146	.317
	Low/ medium density	29 (45.3)	35 (54.7)				
Bordering foreign countries	At border	31 (35.2)	57 (64.8)	2.942	1.192	7.258	.019*
	Not at border	16 (61.5)	10 (38.5)				
Sheep and goat population/ state	Large population size	14 (34.1)	27 (65.9)	1.591	.720	3.517	.251*
	Small population size	33 (45.2)	40 (54.8)				
PPR Vaccination coverage	Weak coverage	36 (43.9)	46 (56.1)	.669	.286	1.560	.355
	Wide coverage	11 (34.4)	21 (65.6)				
State Area	Large/ medium area	25 (37.9)	41 (62.1)	1.388	.652	2.952	.392
	Small area	22 (45.8)	26 (54.2)				

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Table 2: Multivariate analysis for the association between PPR outbreaks occurrence and potential risk factors found significant in the univariate analysis using Logistic regression

Variable	Variable categories	B	Exp(B)	95% CI for Exp(B)		*P*-value
				Lower	Upper	
Ecological zone	Low rainfall woodland Savanna	-.689	.502	.224	1.122	.093
	Desert and semi-desert (Ref)					
Bordering Foreign country	At country border	-1.067	.344	.134	.886	.027*
	Not at border (Ref)					
Sheep and Goats population/ states	Large size population	-.694	.500	.213	1.173	.111
	Small size population (Ref)					

Discussion

This study is depending on the data of reported PPR outbreaks by states veterinary authorities to the Head quarter of the veterinary authorities, so the findings of this study is definitely affected by the accuracy of the reporting system and diagnosis method for PPR outbreaks.

In this study, an important potential risk factor for the occurrence rate of PPR outbreaks was found to be the geographical position at the country borders, with odds ratio of 2.942 and *p*-value of .019.

The highest numbers of PPR outbreaks d 89 the study period were found in the lo...es of Kassala state, its neighboring state River Nile and Sennar state. Kassala and Sennar states have shared borders with Ethiopia which has the same PPRV lineage III (Kwiatek *et al*., 2011). Hence pastoralists may play an important role in PPR spread (Salih *et al*., 2014). The shared borders with other country might increase the probability of spreading PPR to and from that country.

Also, PPR outbreaks were found to be associated with the ecological zone of the low rainfall woodland savanna which has rainfall rate higher than in the desert and semi- desert ecological zones, with odds ratio of 2.134 and *p*- value of .052. This finding agrees with the finding of Salih *et al*. (2014) who found the highest seroprevalence of PPR in states with higher rainfall, and also it is in agreement with Grenfell and Dobson (1998) who stated that widely spread epidemics of PPR occur in the beginning and end of the rainy season among the settled farmers. But many other studies mentioned the positive effect of dry areas and seasons on the PPR outbreaks as stated by Sarker and Islam (2011) and Okoli (2003).

The third potential risk factor which showed significant association in this study is large population of sheep and goats, which having a probability of 1.591times more for developing PPR outbreaks more than the small size populations. Pastoralists in states with large population of sheep and goats in Sudan such as North and South Kordofan, North and South Darfur, Blue Nile, White Nile and Gezira states are practicing either transhumance or open grazing. These two husbandry systems increase the probability of spreading PPR through the common pastures and water sources as found by Shuaib (2011) and Salih *et al*. (2014). Also, the association is in an agreement with Singh (2011) who stated that; the higher population density of animals' results in increased levels of contact between them and this helps to maintain the PPR virus within the environment.

Even though wildlife density was found to have no significant association with PPR outbreaks occurrence in the current study, but the odds ratio; 1.473 was putative. Regarding the husbandry system in Sudan, the contact between pastoralists` herds and wild ruminants is more probable, and some wild small ruminants have been reported t 90 ract severe PPR infections such as (*Oryx gazelle*), (*Gazella dorcas*) and

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(*Capra ibex nubiana*) as stated by Housawi *et al*. (2004).

Annual rainfall level was found to be putative factor (OR=1.417) but without a statistical significant *p*-value, although the states with a high rainfall were found to have the highest PPR seropositivity (Salih *et al*., 2014) and also with high numbers of PPR outbreaks.

Only the factor of vaccination coverage against PPR was found to be associated negatively with PPR spread (protective factor, OR=.669), despite that it has no statistical significance (*p*-value=.35). That could be an indicator for the important role of vaccination in PPR control specially when considering that PPR vaccination coverage was very low comparing to the state population all over the country as in Figure 6.

The association between the occurrence of PPR outbreaks and the 3 potential risk factors found through univariate analysis was assessed with a multivariate analysis using logistic regression; only the risk factor of bordering foreign country was found to have a significant effect (*p*-value= .027). Localities within states that located at borders are with high numbers of PPR outbreaks in Sudan, and in particular are in the eastern borders of the country; where the tribes move freely between countries with their small ruminant herds in search for pastures and trade. Trade of live animals is one of the important risk factors which increase the spreading of PPR in Africa as mentioned by Kaukarbayevich (2009) and Singh (2011).

Conclusion

PPR is an endemic disease in Sudan and spreading all over the country, with a high rate of occurrence in the states within the low rainfall wood land savanna ecological zone, near the eastern borders of the country and their neighboring states.

More epidemiological studies are needed to explore the association between PPR occurrence and the environmental factors. The systems of diagnosis, vaccination and reporting of PPR outbreaks need thorough verification and assessment for more accurate studies and to facilitate appropriate control programs.

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دراسة حالات و شواهد لبعض عوامل الخطورة المؤثرة على حدوث مرض طاعون المجترات الصغيرة في السودان

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المستخلص

تم التقصي عن بعض عوامل الخطورة البيئية و الوقائية المتعلقة بمرض طاعون المجترات الصغيرة في السودان ضمن دارسة حالات (cases) و شواهد (controls) للفترة من 2008 الى 2012م. شملت الدراسة 114 محلية من 14 ولاية في السودان. قسمت المحليات الي حالات و عددها 47 محلية و شواهد عددها 67 محلية و ذلك حسب بلاغات المرض الواردة لادارة صحة الحيوان ومكافحة الاوبئة بالخرطوم ، حيث ان الخالات تمثل المحليات التي تم بها تسجيل بلاغات خلال سنوات الدراسة الخمس بينما الشواهد هي المحليات التي لم ترد منها بلاغات. جمعت بيانات لسبعة من العوامل الخاصة بالولايات التي تقع فيها المحليات موضع الدراسة. تم رصد و تحليل البيانات با ستخدام نظام الحزمة الاحصائية للعلوم الاجتماعية SPSS و العوامل هي؛ النطاق البيئي ، معدل هطول الامطار السنوي،كثافة توزيع المجترات البرية، موقع الولاية على الحدود الدولية، تعداد الضأن و الماعز بالولاية، مساحة الولاية و نسبة تغطية التطعيم ضد طاعون المجترات الصغيرة خلال سنوات الدراسة. عند اجراء التحليل احادي المتغير univariate تم حساب نسبة الارجحية Odds Ratios(OR) باستخدام اختبار Mantel Haenszel و نتج ان ثلاثة عوامل لديها ارتباط احصائي بالمرض و هي و جود المحلية في ولاية تقع على الحدود الدولية (OR = 2.942, *p*–value= .019)، و جود المحلية في ولاية ضمن نطاق السافنا منخفضة الامطار البيئي (OR = 2.134, *P*–value=.052)و التعداد الكبير للضان و الماعز بالولاية (OR = 1.591, *p*– value=.251). ادخلت هذه العوامل الثلاث في تحليل متعدد المتغير multivariate با ستخدام الانحدار اللوجستي logistic regression الذي نتج عنه عامل واحد مرتبط احصائيا بحدوث المرض و هو وجود المحلية ضمن ولاية تقع على الحدود الدولية (*P*– value = .027).