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Seroprevalence and Associated Risk Factors of Peste des Petits Ruminants among Sheep and Goats in Kassala State, Sudan

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Abstract

Peste des petits ruminant (PPR) is a contagious disease of small ruminants caused by a virus that belongs to the genus Morbillivirus of the family Paramyxoviridae. This study aimed to determine the seroprevalence of PPR disease in sheep and goats and its associated risk factors in Kassala State, Eastern Sudan. Across sectional study was conducted during the period from 30th August to 25th November 2015. The study was carried out using a structured questionnaire survey and a total of 918 blood samples were collected from apparently healthy unvaccinated sheep and goats in different localities in State of Kassala. A total of 546 sheep and 372 goats were tested for specific antibodies to nucleoprotein (NP) by competitive enzyme linked immunosorbent assay (cELISA). The apparent overall prevalence of PPR antibodies in Kassala was 58.2% while the true prevalence was calculated to be 61.3%. The apparent prevalence in sheep and goats was 68.1% and 43.5% respectively. Univariate analysis showed that the risk factors had significant associations with a cELISA positive status: locality, species, age, breed, husbandry system, housing mode, animals movement ($p = 0.000$) and animals sharing pasture and water ($p = 0.003$), while sex and newly introduced animals were not significant risk factors ($p = 0.771$) ($p = 0.050$) respectively. Factors found that significantly associated ($p < 0.05$) with increased odds of being cELISA positive in multivariate analysis were localities, species, age and newly introduced animals. The prevalence differed between localities and was the highest in the River Atbara (84.0%) locality, whereas it was lowest in Delta North (29.0%). No significant difference was observed among the sexes. However, the prevalence differed in different age groups and was 52.25% in animals of less than six months old; 49.3% were between seven months and two years old and

65.5% were above two years old. In different husbandry systems, the prevalence was 47.9%, 73.0% and 49.2% in intensive, open grazing and pastoral systems respectively. Housing type effects were also observed; the highest prevalence was in animals housed in metal fence (83.3%). The movement pattern showed significant effect, where the prevalence was the highest (81.3%) in animals that move inter-states/inter-localities. It is concluded that the disease is endemic in Kassala State, high prevalent in sheep and goats, posing a threat to animal exportation, and may have a serious economic influence. Owners and herders should compulsorily vaccinate their animals yearly and animals should be investigated periodically for implementation of crucial eradication program.

Keywords

Peste des Petits Ruminants, Sero-Prevalence, Risk Factors, Kassala State, Sudan

1. Introduction

The Sudan has a huge wealth of animal resources that has been estimated to be around 104 million head of animals. The livestock sector in the Sudan is an important contributor to the national economy, contributing 46% to the Gross Domestic Product (GDP) [1] [2] [3] [4].

Peste des petits ruminant (PPR) is severe highly contagious, notifiable, and transboundary viral disease affecting mainly small domestic ruminants [5]. There are several reports of PPR occurring in other wild species, particularly in captive wild ungulates [6]. Although both cattle and pigs are susceptible to infection, but no obvious clinical signs are observed [7]. The disease caused by a virus that belongs to the genus Morbillivirus, of the family Paramyxoviridae [8]. PPR virus have six structural proteins namely: the nucleo-capsid protein (Np) which encapsulates the virus genomic RNA, the phosphoprotein (P) which associates with the polymerase (L) protein, the matrix (M) protein, the fusion (F) protein and the haemagglutinin (H) protein [5], in addition to two nonstructural proteins C and V [7]. PPR usually characterized by onset of depression, fever, ocular and nasal discharges, and oral sores, disturbed breathing, cough, foul smelling diarrhoea and death [9]. The virus was firstly described in Ivory Coast in west Africa in early 1940s (Gargadennece and Lalanne, 1942 cited by OIE, 2012 [5] [10]) where it was used to be named as Kata, pseudo-rinderpest, pneumo-enteritis complex and stomatitis pneumo-enteritis complex [11]. However, the original strain of the virus was isolated in Nigeria in 1971 [5]. PPR caused numerous serious epidemics in small ruminant populations across sub-Saharan Africa, the Middle East, China, and major parts of the Indian subcontinent where PPRV is considered endemic [12]. In recent years, PPRV has extended its range southward in Africa as far as southern Tanzania (2008) and the Demo-

cratic Republic of Congo and Angola (2012). The disease outbreaks have also been reported across North Africa, including Tunisia (2006), Morocco (2008), and Algeria (2011). In addition, some European countries as Turkey reported 20 laboratory-confirmed PPR outbreaks in sheep and goats during 2011 and 2012 [13]. In Sudan, the first outbreaks of PPR were originally diagnosed as rinderpest in 1971 in three areas in southern Gedarif State, Eastern Sudan and later confirmed to be PPR [14] [15], then in central Sudan (Sinnar area) during 1971-1972 and in Mielig (Gazera State) in 1972. Thereafter, PPR outbreaks continued to be reported in Darfur [16], central Sudan [17] and Khartoum State [18] [19]. More recently the virus was isolated from outbreak of PPR in camels in Kassala State during August to October 2004 in MDBK cell lines and the isolate was confirmed as PPR by AGPT, ELISA and RT-PCR [12].

The sero-prevalence and risk factors of the disease were determined in some States in the Sudan such as Sinnar, Gedarif, River Nile and North Kordofan, and some risk factors were found to be associated with disease of which states, localities, husbandry system, gender and age were the most prominent [20]. Enan *et al.* [21] indicated Seroprevalence of PPR in small ruminants in Marawi province Northern Sudan from which no previous outbreaks were recorded. Recent outbreak of PPR in small ruminants in Khartoum and River Nile States were described by Ali *et al.* [22].

Kassala State is located in the eastern Sudan. It has borders with Eritrea and Ethiopia in addition to other Sudanese States (Red Sea State, River Nile State, Khartoum State and Gedarif State). The animals have natural movement among Sudan, Eritrea and Ethiopia, although, there were check points to check animal's movement and to monitor trans-boundary animal diseases with availability of veterinary services. In the last years, new check points were also established on the borders with other States (Animal resources directorate, Kassala State).The disease investigation were continued during last years, in sheep and camels herds in different localities of the State by detection of viral antigen in blood samples using immunocapture ELISA [23].

Control of PPR depends mainly on vaccination, isolation of infected animals, restriction of animal's movement. A homologous vaccine produced locally in the Sudan is used to vaccinate small ruminants, but well organized vaccination campaigns are not well performed and culture of vaccination are not completely spread in the society, and some owners even think that the vaccine causes the disease rather than protect from it hence they reject vaccination.

The present work was performed to determine the prevalence and associated risk factors of the disease in Kassala State, Eastern Sudan.

2. Materials and Methods

2.1. Study Area

Kassala State covers an area of 42,282 km^2, which lies between latitudes 14˚N and 17˚N and longitudes 34˚E and 37˚E. Air temperature is between 33˚C to

47˚C and annual rain fall between 750 mm in north to 400 mm per annum in south. The state is divided into eleven localities namely: Kassala, Rural Kassala, Western Kassala, Refi Aroma, North of Delta (Wagar), New Halfa, River Atbara, Refi Algirba, Wad-elhilew, Hamshkoreib and Talkouk (Figure 1 and Figure 2). Sheep population in Kassala State is about 3,449,655 head, goats about 2,264,951 head and the total account of animals including sheep, goats, cattle, camels and

Figure 1. Location of Kassala State in the sudan map (red color).

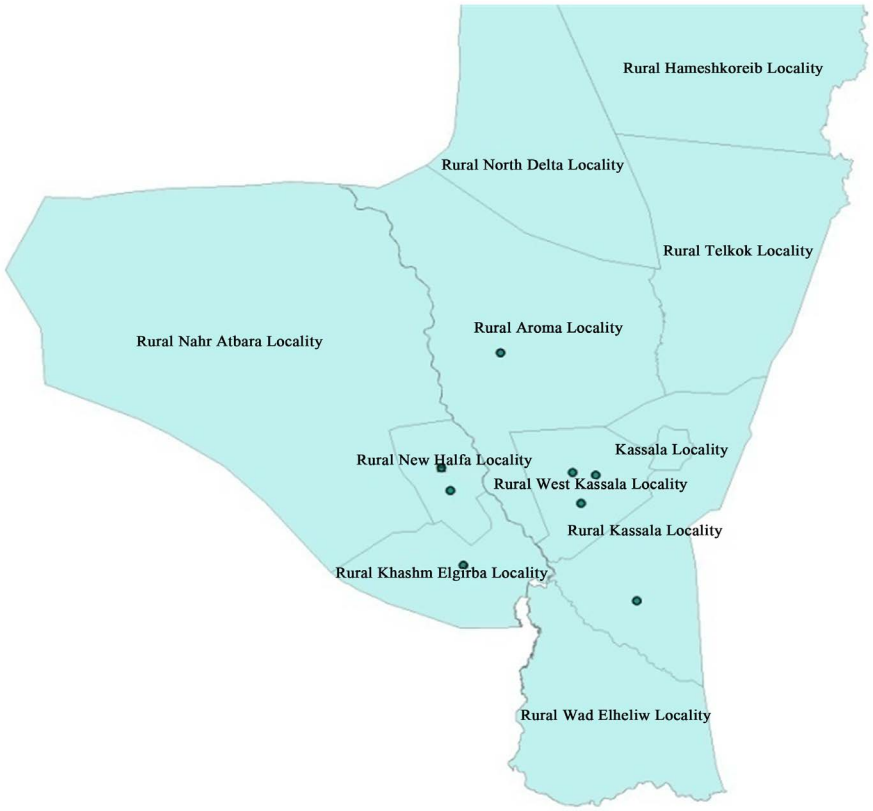

Figure 2. Localities of Kassala State.

equine about 8,215,238 head. There is distinct variation of density of sheep and goats flocks among different localities in Kassala State, The highest density found in Wad Elhilew locality which contribute by 17% of total account while Kassala locality contribute by 4%, talkouk and hamshkoreib 6%. The mixed crop-livestock system nomadic and semi nomadic system are predominant in the State. Sheep and goats in Kassala State are raise for meat and milk production for local consumption and for live animals exportation to different neighboring and Arabic countries.

2.2. Sampling

Sample size from sheep and goats were estimated using the underlined assumptions that the prevalence was 15% and confidence interval (CI) 95%. The following formula was used before collection to detect at least one seropositive animal [24]:

$$k = \left[1-\left(1-\alpha^{1/d}\right)\right]\left[\frac{N-1}{2(d-1)}\right]$$

k is the number of samples of each flock, α is probability of observing at least one seropositive animal, d is expected number of infected animals in herd and N is average of herd size. Accordingly the required sample size was found to be 532 sheep and 353 goats but 546 sheep and 372 goats were tested to complete final plate. Herds size in sheep was between 50 - 250 head and between 50 - 150 head in goats.

2.3. Sampling Design

A two-stage selection strategy was performed. The first stage was selection of villages from each of the 10 localities mentioned before, the strategy depends on the covering of 80% - 100% of villages from every locality, starting from center of every locality to the borders in circle shape. The second stage was selection of flocks, where 10 flocks were visited in every locality and samples tested covered all visited villages in different proportion. The number of selected villages for sampling from each locality (80% - 100%) was proportional to the numbers of sheep and goats in that locality. The vaccinated herds against PPR disease was excluded from sampling in this study.

2.4. Period of Samples Collection

Samples were collected during the period from 30th of August 2015to 25th of November 2015.

2.5. Collection of General Data

The data of PPR outbreaks, vaccination, animal census, and animal movement were collected from the General Administration of Animal Resources in Kassala State.

2.6. Questionnaire Survey Design

The questionnaire was designed to record the risk factors by direct contact with the flock's owners. The particulars gathered included locality, species, age, breed, sex, husbandry system, housing, animal movement, sharing pasture and water, and newly introduced animals. Also questionnaire included other particulars not analyzed such as name of villages, general status of flocks, mixing of sheep and goats, separation of different age groups in flock, any health problems observed by owners, and observed sings like lacrimation, nasal discharge, diarrhea, oral ulceration, dullness, fever, abortion, availability of veterinary services, impression about veterinary services, and other observations.

2.7. Collection of Samples

Blood samples for serum were randomly collected from sheep and goats flocks in all localities in Kassala State. About 5 ml of blood were collected from jugular vein using plain vacutainer tubes. The tubes were kept in slant position and protected from direct sunlight till blood clotted. Serum was separated and stored in cryovial tubes at −20˚C untill processed.

2.8. Competitive Enzyme-Linked Immunosorbent Assay (cELISA)

The collected sera were tested for PPR nucleoprotein (NP) antibodies using competitive ELISA kit, and the test was performed according to instructions of the manufacturer. (ID.vet rue. Louis Pasteur_Grabels-FRANCE), this diagnostic kit is designed to detect antibodies directed against the nucleoprotein of the peste des petits ruminants (PPR) virus. The test uses technology developed by FAO reference laboratories (CIRAD, Montpellier, France). This ELISA kit has 94.5% and 99.4% sensitivity and specificity respectively.

2.9. True Prevalence (TP)

True prevalence is the proportion of all those samples who are tested who are actually positive while the apparent prevalence is the proportion of all those samples who are tested who, writly or wrongly, tested positive. True prevalence was estimated using the equation [25]:

$$\mathrm{TP} = \frac{\mathrm{AP} + \mathrm{SP} - 1}{\mathrm{SE} + \mathrm{SP} - 1}$$

where TP the true prevalence, AP the apparent prevalence, SE the sensitivity of the diagnostic procedure (competitive ELISA), SP the specificity of the diagnostic procedure (competitive ELISA).

2.10. Statistical Analysis

The statistical package for social sciences SPSS version 22 was used for all appropriate statistical analysis. Descriptive statistic of the variables was obtained. Each variable (locality, spp., age, sex··· etc.) frequencies (number of observation within variable) and prevalence by cross tabbing (number of positive valid sam-

ples/number of individuals sampled in the variable) were obtained. Hypotheses of differences of locality, species, age groups, sex etc. between test-positive and test negative animals were first tested by univariate analysis by means of the 2 tailed Chi-square test. Furthermore, alogistic regression model was used to assess the association between the risk factors and PPR disease. Association in the logistic regression model were considered significant when $p < 0.05$. The true prevalence counted according to cELISA sensitivity and specificity supplied by kit manufacturer and confidence interval (CI) 95% as described by Rogan and Gladen [25].

3. Results

From 918 sheep and goats sera tested, 534 samples were positive for PPR antibodies. The overall apparent prevalence rate of PPRV antibodies in Kassala State eastern Sudan was estimated to be 58.2%, but according to diagnostic sensitivity and specificity of cELISA reported by manufacturer the overall true prevalence is 61.3%. The apparent prevalence in ovine was 68.1% and in caprine 43.5%, consequently the true prevalence is 67.7% and 40.5% respectively (**Table 1**). The prevalence at flock level was found to be 100% in sheep and goats. Regarding different localities, the highest and lowest rates of PPRV sero-positivite were recorded in River Atbara (84.0%) and Delta North (29.0%) respectively (**Table 2**). The prevalence in both sexes was 57.1% in males and 58.4% in females (**Table 3**). In different age groups the prevalence in animals less than six months old was 52.25%, from seven months to two years is 49.1% and that above two years old 65.5% (**Table 4**). The results showed that the prevalence is higher in younger and older animals than in middle ages animals. According to breeds of sheep, the prevalence was highest (83.8%) in Hamari breed (**Table 5(a)**). In goats, the highest prevalence (64.7%) in Jabali (mountainous) breed (**Table 5(b)**). The prevalence in open grazing system was the highest (73.0%), while it was 47.9% in intensive system and 49.2% in pastoral as shown in **Table 6**. Different movement patterns were identified for sheep and goats in Kassala State, the animal flocks move 1) inside localities, 2) between states and localities, 3) among localities, States and neighboring countries and 4) between countries.

Table 1. The prevalence of PPR in sheep and goats InKassala state.

	Species		Total	Pearson Chi-square		
	Ovine	Caprine		X^2	df	p-value
None-infected	88 52.1%	296 39.5%	384 41.8%	8.928	1	0.03
Infected	81	453	534			
AP	47.9%	60.5%	58.2%			
TP	50.4%	63.8%	61.3%			
Total animals tested	169 100%	749 100%	918 100.0%			

AP: apparent prevalence, TP: true prevalence.

Table 2. The prevalence of PPR in different localities in Kassala State.

	Delta North	Talkook	Kassala	Refi-Aroma	Rural Kassala	Wad El Hilewe	Halfa	River Atbara	Western Kassala	Al-GIRBA	Total
Non-infected	71 71.0%	54 64.3%	51 60.7%	32 32.2%	40 40%	27 27%	12 24%	16 16%	40 40%	41 40.6%	384 41.8%
infected	29	30	33	67	60	73	38	84	60	60	534
AP	29.0%	35.7%	39.3%	67.7%	60%	73%	76%	84%	60%	59.4%	58.2%
TP	30.24%	37.4%	41.2%	71.4%	63.3%	77.1%	80.3%	88.8%	63.3%	62.6%	61.3%
Total of tested	100 100%	84 100%	84 100%	99 100%	100 100%	100 100%	50 100%	100 100%	100 100%	101 100%	918 100%

Pearson Chi-square	X^2	60.647
	df	20
	p-value	0.000

Table 3. The prevalence of PPR in males (M) and females (F).

	Sex Numeric		Total	Pearson Chi-square		
	M	F		X^2	df	p-value
Non-infected	69 42.9%	315 41.6%	384 41.8%	0.085	1	0.771
Infected	92	442	534			
AP	57.1%	58.4%	58.2%			
TP	60.2%	61.5%	61.3%			
Total tested	**161** **100%**	**757** **100%**	**918** **100%**			

Table 4. The prevalence of PPR in different age groups.

	Age Numeric			Total	Pearson Chi-square		
	0 - 6 months	7 months - 2 years	Above two years		X^2	df	p-value
Non-infected	73 47.7%	146 50.9%	165 34.5%	384 41.8%	60.647	20	0.000
Infected	80	141	313	534			
AP	52.3%	49.1%	65.5%	58.2%			
TP	55.05%	51.7%	69.1%	61.3%			
Total number tested	**153** **100%**	**287** **100%**	**478** **100%**	**918** **100%**			

The prevalence in flocks, which move between states and localities (inter-states/inter-localities) showed the highest prevalence (81.3%), while the flocks that move inside localities showed the lowest prevalence (46.9%) (Table 7). The prevalence in flocks sharing pasture and water was 60.5% and 47.9% in flocks that not sharing pasture and water (Table 8). In flocks which introduced new animals the prevalence was 45.3%, while it was 59.0% in flocks that did not introduce new animals (Table 9 and Table 10).

Table 5. (a) The prevalence in different sheep breeds; (b) The prevalence in different goats breeds.

(a)

	Darash	Garaj	Gash	Hamari	Watish	Ashgar	Dubasi	Total
Non-infected	32 24.6%	17 22.4%	93 45.6%	6 16.2%	3 25.0%	12 24.5%	11 28.9%	174 31.9%
Infected	98	59	111	31	9	37	27	372
AP	75.4%	77.6%	54.4%	83.8%	75.0%	75.5%	71.1%	68.1%
TP	79.6%	82.04%	57.3%	88.6%	79.2%	79.8%	75.03%	71.9%
Total tested	**130** **100%**	**76** **100%**	**204** **100%**	**37** **100%**	**12** **100%**	**49** **100%**	**38** **100%**	**546** **100%**

(b)

	Hasani	Jabali	Nubian	Kinani	Saanen	Total	Pearson Chi-square		
Non-infected	40 63.5%	12 35.3%	129 56.3%	8 47.1%	21 72.4%	210 56.5%	X^2	df	p-value
Infected	23	22	100	9	8	162	97.316	11	0.000
AP	36.5%	64.7%	43.7%	52.9%	27.6%	43.5%			
TP	38.2%	68.3%	45.9%	55.7%	28.7%	45.7%			
Total tested	**63** **100%**	**34** **100%**	**229** **100%**	**17** **100%**	**29** **100%**	**372** **100%**			

Table 6. The prevalence of PPR according to husbandry system.

	Husbandry Numeric			Total	Pearson Chi-square		
	Intensive	Open grazing	Pastoral		X^2	df	p-value
Non-infected	88 52.1%	96 27.0%	200 50.8%	384 41.8%	52.105	2	0.000
Infected	81	259	194	534			
AP	47.9%	73.0%	49.2%	58.2%			
TP	50.4%	77.06%	51.8%	61.3%			
Total tested	**169** **100%**	**355** **100%**	**394** **100%**	**918** **100%**			

Table 7. The prevalence of PPR in different housing mode.

	Housing Numeric				Total	Pearson Chi-square		
	Metal	Mud	No	Tree branches		X^2	df	p-value
Non-infected	4 16.7%	24 49.0%	96 27.0%	260 53.1%	384 41.8%	64.581	3	0.000
Infected	20	25	259	230	534			
AP	83.3%	51.0%	73.0%	46.9%	58.2%			
TP	88.1%	53.7%	77.06%	49.3%	61.3%			
Total tested	**24** **100%**	**49** **100%**	**355** **100%**	**490** **100%**	**918** **100%**			

Table 8. The prevalence of PPR in different movement patterns of sheep and goats flocks.

	Movement Numeric				**Total**	**Pearson square**		
	Inter countries	Inter countries/inter states/inter localities	Inter states/inter localities	Inside		X^2	df	p-value
Non-infected	40 41.7%	67 33.5%	29 18.7%	248 53.1%	384 41.8%	64.154	3	0.000
Infected	56	133	126	219	534			
AP	58.3%	66.5%	81.3%	46.9%	58.2%			
TP	61.5%	70.2%	58.9%	49.3%	61.3%			
Total tested	**96** **100%**	**200** **100%**	**155** **100.0%**	**467** **100.0%**	**918** **100.0%**			

Table 9. The prevalence according to animals sharing pasture and water sources.

	Sharing Numeric		Total	Pearson square		
	No	Yes		X^2	df	p-value
Non-infected	355 41.0%	29 54.7%	384 41.8%	8.928	1	0.003
Infected	510	24	534			
AP	59.0%	45.3%	58.2%			
TP	62.1%	47.6%	61.3%			
Total tested	865 100%	53 100%	918 100%			

Table 10. The prevalence due to introduction of new animals.

	New animals Numeric		Total	Pearson Chi-square		
	No	Yes		X^2	df	p-value
Non-infected	355 41.0%	29 54.7%	384 41.8%	3.839	1	0.050
Infected	510	24	534			
AP	59.0%	45.3%	58.2%			
TP	62.8%	47.6%	61.3%			
Total tested	865 100%	53 100%	918 100%			

Univariate analyses using Chi-square test revealed that the risk factors that had a significant association with cELISA sero-positivity were locality (p = 0.000), species (p = 0.000), different age groups (p = 0.000), breeds (p = 0.000), husbandry system (p = 0.000), housing mode (p = 0.000), animals movement (p = 0.000), sharing pasture and water (p = 0.003), while sex (p = 0.771) and newly introduced animals (p = 0.050) had not significant association.

Results of logistic regression analysis that assess the combined relationship between analyzed risk factors with the cELISA positivity status for PPR are presented in Table 11. The factors that were significantly associated with increased

Table 11. Multi-variable logistic regression analysis of the risk factors associated with PPR in sheep and goats in Kassala State.

C ELISA results Numeric	B	Std. Error	Wald	df	Sig	Exp(B)	95% Confidence interval for Exp(B)	
							Lower bound	**Upper bound**
Negative intercept	1.353	0.737	3.369	1	0.066	0.863		
Locality	−0.147	0.046	10.161	1	0.001	0.364	0.788	0.945
Species	−0.10.010	0.168	36.232	1	0.000	1.116	0.262	0.506
Sex	0.110	0.214	0.263	1	0.608	0.566	0.733	1.699
AGE	−0.570	0.110	26.851	1	0.000	0.993	0.456	0.702
Breed	−0.007	0.027	0.067	1	0.796	1.233	0.941	1.048
Husbandry	0.210	0.262	0.639	1	0.424	1.229	0.737	2.062
Housing	0.206	0.182	1.278	1	0.258	1.051	0.860	1.755
Movement	0.050	0.086	0.332	1	0.565	0.434	0.888	1.244
Sharing pasture and water	−0.834	0.473	3.102	1	0.078	0.434	0.172	1.099
New animals	0.833	0.411	4.094	1	0.043	2.299	1.026	5.150

odds (Exp(B)) of being cELISA positive included: locality, species, age groups and newly introduced animals.

4. Discussion

In the last few years, PPR disease has become endemic in Kassala State [26]. In the past, there was the view that PPR disease was introduced from neighboring countries. In contrast, this study revealed that animals from inner localities like River Atbara and New Halfa have the highest prevalence. Although Wad Elhilew locality is a border area which has a high prevalence, but animals from this locality spend a long time yearly in River Atbara locality (Al-Butana plains) where they may become infected by mixing with animal flocks from others localities like River Atbara, Halfa and Refi Algirba. Animals from bordering localities like Rural Kassala and Talkouk which do not go to Butana area reported medium rates of sero-positivity, but animals that have the least contact with animals from other localities showed the lowest sero-positivity (e.g. Delta North). Studies of seroprevalence of PPR in River Nile and white Nile States revealed that the prevalence was 56.5% and 49.4% respectively; this shows that the prevalence of the disease is high in other states in Sudan [27] confirming the endemicity of PPR in Sudan. This study also revealed that sheep are more susceptible to PPR infection than goats, which is supported by the fact that most of PPR outbreaks in Kassala State registered in sheep (Ministry of animal resource Anon). These findings agree with Ozkul *et al.* [28] who found that the prevalence of PPR found in sheep (29.2%) is higher than in goats (20%) in Turkey. Another study in Punjab province, Pakistan revealed that the prevalence in sheep is higher than goats be-

ing 65.80 and 48.24 respectively [29]. The antibody-based prevalence against PPRV in female of sheep and goats were 65.20% and 54.70%, respectively, compared to 39.64% and 41.75% for corresponding males. The females were more prone to infection of PPRV and showed significantly higher number of positive cases in Punjab [29], but this study revealed that there was no significant association between the prevalence of PPR disease and sex, similar to that found by Muse *et al.* [30] who recorded no statistical significance in prevalence between males and females in Tanzania. In contrast, other previous studies in Sudan in North Kordofan State and Kassala State found that the prevalence in males (58.6%) was less than in females (80.2%), but in River Nile and White Nile States the prevalence in females (60.4%) was higher than in males (27.4%) [27]. In Bangladesh, the prevalence of PPR in goats males (28.52%) was higher than in females (13.04%) [31]. In the present study, the prevalence differed between age groups, animals of less than six month were less susceptible compared to that of more than two years, while animals of ages between seven months and less two years showed the lowest prevalence, this of some agreement with Sarker and Islam [31], whose found that the prevalence in 1 - 12 months old is higher than in adults above one year, but another study of PPR in different areas in Algeria found that the prevalence in adults 14.4% was higher than in young (9.78%) [32]. The variation of prevalence between age groups may due to development of immune system, immune response in animals of seven months and less than two years may stronger than other age groups that confirmable by a fact that animals in middle ages have a general fitness. Present disease investigation in different local breeds and cross local breeds of sheep and goats in Kassala State, indicated that sheep of Hamari breed showed the highest prevalence, while Gash type showed the lowest prevalence and the remainder breed don't express significant difference in prevalence of the disease. In goats the highest prevalence was seen in Mountainous breed and the lowest prevalence was record in Saanen breed. In different husbandry systems higher prevalence was observed in open grazing system compared to pastoral and intensive systems, this may be due to movement stress, mixing with other flocks and sharing pasture and water resources, however in another study the prevalence was highest in pastoralist system (68.1%) than other systems [20]. In different types of housing, animals housed in metal houses showed the highest prevalence and the animals housed in tree branches fences showed the lowest prevalence, this was in disagree with Salih *et al.* [20], who found that the highest prevalence in animals with no houses while there was no prevalence in animals housed in metal housings, foundings in present study is may due that owners leave animals crowded in limited spaces with close contact together that make animals more exposure to infected aerosols. In the present investigations, animal flocks that move between different localities and cross the border between states (inter states/inter localities) demonstrated higher prevalence than those that cross the borders between the countries, while the flocks grazing inside localities showed the lowest prevalence rate. This is may be attributed to less exposure of these animals to the virus. In this

study the prevalence in flocks sharing common pasture and water sources is investigated, animals sharing pasture and water showed higher prevalence than animals grazing in one pasture and not sharing water resources; Shuaib *et al.* [26], found that animals sharing pasture and water sources together have higher prevalence (74.0%) than that just sharing water sources (70.7%). In flocks that introduced new animals the prevalence was lower than in flocks did not introduce new animals, this is in agreement with shuaib *et al.* [26] who found that the prevalence is lower (70.3%) in flocks that brought animals from outside than that did not bring (74.1%). Analysis of the risk factors by using Chi-square test and multivariable logistic regression revealed strong correlation to all risk factors ($p < 0.05$) except in sex and introduction of new animals.

Finally it is concluded that PPR disease is endemic in Kassala State, high prevalence in sheep and goats, all breeds, different sexes and all ages expostured to infection and pose a threat to export and economic situation of the State. It is recommended that owners and herders must yearly vaccinate their animals and periodic investigation should be carried out including all livestock species to establish disease eradication plan in Kassala State which is considered as a major production and live animals export area.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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