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Flock Level Economic Loss Due to Peste Des Petits Ruminants Outbreak in Transhumance Sheep and Goat Population in Himachal Pradesh (India)

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ABSTRACT

Background: Quantification of economic losses due animal diseases like peste-des-petits ruminants (PPR) helps in visualizing the impact of the disease in relational context as well as assist in prioritizing the disease control/eradication options. This study aimed to estimate the farm-level economic losses due to the disease in the state of Himachal Pradesh and carry out a cost-benefit analysis of control programme through vaccination.

Methods: An investigation was carried out on an outbreak of PPR in transhumance small ruminant population in Himachal Pradesh (HP). The incidence rates of PPR as obtained in the study were projected to the small ruminant population in the state.

Result: The overall morbidity and mortality rates were 36.85% and 27.69% and 25.32% and 1.44%, in goats and sheep, respectively. The estimated annual economic loss due to PPR in HP was INR 2495 million (under high incidence scenario). Under moderate and low incidence rate assumptions, the total losses were estimated at INR 1871 million and INR 1265 million, respectively. Benefit-cost analysis of vaccination against the disease in the state was carried out and the Benefit-Cost Ratios (BCR), ranging between 43:1 to 198:1 revealed the economic feasibility of investment made in PPR control.

Key words: Cost-benefit analysis, Economic losses, Goat, Peste des petits ruminants, PPRV, Sheep.

INTRODUCTION

Peste des petits ruminants (PPR) is the most important health constraint in goat and sheep rearing in India. Economic losses due to PPR remains significant (Bardhan *et al*., 2017a) and the disease is targeted for global eradication in 2030 by FAO and OIE (Parida *et al*., 2015). India is endemic for PPR and the outbreaks occur in all seasons (Muthuchelvan *et al*., 2015). The Government of India launched a national control program in 2010 leading to substantial reduction of PPR outbreaks in some states (Muthuchelvan *et al*., 2014).

In the present study, an investigation was carried out on a PPR outbreak in pastoralist sheep and goat populations in the state of Himachal Pradesh (HP). Sheep and goat rearing are the major source of livelihood for the pastoralists in the state. The circulation of PPR virus in this region and its economic consequences are largely unknown. Economic analysis of the disease, given its importance, is needed from the point of view of optimising resource allocation in disease control programmes. As such, this study aimed to estimate the farm-level economic losses due to the disease in the state and carry out a cost-benefit analysis of control programme through vaccination.

MATERIALS AND METHODS

A team of experts from the Animal Disease Investigating Laboratory, Shimla, HP attended an outbreak of PPR in transhumance sheep and goats at Kara Khanta alpine pastures in August, 2014. There were 3802 sheep and goats of different age groups in and around the pastures of the area. The team inspected six flocks and carried out clinical, post-mortem and epidemiological investigations. Samples including oral and nasal swabs and tissues from morbid animals were collected. Initial antigen screening was carried out at disease investigating laboratory, Shimla and further

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confirmed at Indian Veterinary Research Institute (IVRI), Mukteswar Campus. The sandwich ELISA, N-gene based RT-PCR, genetic and phylogenetic analysis were conducted (Muthuchelvan *et al.,* 2014).

Estimation of losses due to peste des petits ruminants in investigated flocks

The incidence rates as obtained during the above diagnostic study were used to compute the total economic loss at the investigated flock level. The total economic losses due to PPR - comprising mortality loss, direct loss in milk yield (in case of goats) and direct loss in wool yield (in case of sheep), losses due to reproductive failure, loss in body weight, the costs of treatment for affected animals and opportunity costs - were worked out as per the framework given by Singh *et al.* (2014) and Bardhan *et al.* (2017a).

The losses, as computed, were used to arrive at the per-animal economic loss due to PPR. The-per animal economic loss was calculated separately considering the incidence rates in the unvaccinated flocks and the same in combined (vaccinated + unvaccinated) flocks.

For estimation of economic losses due to PPR, the authors mostly relied on primary data collected through key informant interview. In addition, tiangulation exercise was carried out by holding focussed group discussion with the herders and cross validating the data obtained as such by discussing with local government veterinary officers and also by referring to secondary data published in various official government publications, like Basic Animal Husbandry Statistics (2017) and Livestock Census (2012). Table 1 summarizes the data on epidemiological and economic parameters - as used in this study - to compute the farm level losses due to PPR in HP.

The incidence of PPR in inspected flocks, as obtained in this study, was used to project the total number of cases and deaths in HP by extrapolating on the sheep and goat population in the state. The loss estimated using the above models were based on incidence rate as obtained in the outbreak study carried out in the study area. As such, the incidence rate used is considered to be high. A sensitivity analysis was also carried out, considering lower assumptions regarding rates. Thus, 75% and 50% of the outbreak incidence were considered as moderate and low scenarios, respectively and accordingly the economic losses were worked out for these different scenarios.

Table 1: Estimates of parameters for PPR effects in goats.

Parameters	Notation	Units	Goat	Sheep	Source of information
Population at risk	P	Numbers	1119491	804871	DAHD, 2012
Proportion of animals infected	P_I	%	36.85	25.55	Computed based on diagnosed cases in inspected flocks
Proportion of animals died	P_D	%	27.69	1.44	Computed based on deaths in inspected flocks
Number of infected animals	I	Numbers	412532	205645	DAHD, 2012 and morbidity rates as obtained from inspected flocks
Number of animals died	D	Numbers	309987	11590	DAHD, 2012 and mortality rates as obtained from inspected flocks
Proportion of sheep in shearing age	P_H	%	-	69.51	DAHD, 2018
Proportion of animals in lactation	P_L	%	21.07	52.12	DAHD, 2018
Average annual milk yield in	Z_A	kg	61.00	-	Primary data
Average annual wool yield	Y_W	kg	-	1.73	Primary data
Average market value of animal	V	US$	78.57	71.43	Primary data
Increased abortion rate	A	%	28	33	Sahu, 2013
Proportion of lactation lost	L	%	15	-	Primary data
Proportion of wool yield lost	Y_L	%	-	0.20	Primary data
Price of wool per	M_W	US$/kg	-	0.86	Primary data
Kidding/lambing interval	K_I	Months	9	9	Primary data
Price of milk per kg	M	US$/kg	0.29	-	Primary data
Delay in conception	W	Months	2	2	Primary data
Price of live weight per kg	P_W	US$	4.29	4.29	Primary data
Price of meat per kg	P_M	US$	5.00	5.00	Primary data
Treatment cost of an infected animal	T_C	US$	4.93	4.93	Primary data
Number of live kids/lambs born	N_K	Numbers	1.50	1.00	Primary data
Birth weight	B_W	kg	2.50	2.50	Primary data
Average live weight	W_I	kg	35	40	Primary data
Average carcass weight (yield)	W_c	kg	19.58	19.19	Primary data
Proportion of body weight lost	W_L	%	20.00	20.00	Sahu, 2012
Price of new born kid	P_C	US$	10.71	8.57	Primary data

Cost-benefit analysis of vaccination against PPR

The study has assessed the impact of vaccination against PPR by carrying out a cost-benefit analysis and giving the benefit-cost ratio (BCR). The benefits from vaccination were arrived at by adjusting the economic losses - as obtained in this study-with vaccination coverage (%) and vaccine effectiveness (%) as per the formulae given by Govindaraj *et al.* (2017):

$$B = \sum_{t=1}^{n} L \times VC \times VE$$

Where

B = Benefits due to vaccination.
L = HS induced economic loss.
VC = Proportion of animals vaccinated.
VE = Vaccine effectiveness.
n = Different breeds/species, *viz.* indigenous and crossbred cattle and buffaloes.

The vaccine effectiveness of 75% as reported by de Alwis (1978) was considered in the study. The vaccination coverage was based on the number of flocks vaccinated against PPR as obtained during the inspection of infected flocks. The cost of vaccine was considered at Rs. 2 per dose (as per the prevailing market price) and the cost of vaccination was considered as Rs. 5 per dose which included the salaries of veterinary and para-veterinary staff, vehicle and transport cost, cost of surveillance including diagnostics, laboratory equipments, cost of campaign/ awareness creation like poster, travel, *etc.* The total cost of vaccination by summing all the cost components was divided by the targeted small ruminant population to arrive at the per dose vaccination cost.

RESULTS AND DISCUSSION

Incidence rate of PPR in inspected flocks

Table 2 presents the prevalence rates of the inspected flocks in the study area. The overall morbidity and mortality rates in goats and sheep were 36.85% and 27.69% and 25.32% and 1.44%, respectively. The case fatality rates were 75.13% in goats and 5.69% in sheep. Analyses of mortality and morbidity rates - based upon vaccination status - revealed that the morbidity rates were higher for un-vaccinated flocks (56% for goats and 38% for sheep) (Table 3). Mortality rates were also higher in case of un-vaccinated flocks (42% for goats and 2% for sheep). No vaccinated animals were observed to be affected by the disease. In a previous study, there was a PPR outbreak in 1994 in a migratory sheep and goats which passed through the Uttarakhand state to Shimla in HP. In that outbreak, the percent morbidity and case fatality rate for sheep were 9.4 and 0 respectively whereas in goats the rates were 33 and 9.4, respectively (Nanda *et al.*, 1996). Mahajan *et al.*, (2013) reported from Jammu region higher prevalence rate of PPR in goats (66.66%) than in sheep (35.71%).

Table 2: Epidemiological indices of PPR suspected flocks that were investigated at Kanta Kara region of Kinnaur district of Himachal Pradesh in August 2014.

Flock no.	Flock size (Heads)			Vaccination History	Animals affected (Heads)			Animals died (Heads)			Morbidity (%)		Mortality (%)		Case fatality rate (%)	
	Sheep	Goat	Total		Sheep	Goat	Total	Sheep	Goat	Total	Sheep	Goat	Sheep	Goat	Sheep	Goat
1	370	280	650	No	247	253	500	10	220	230	66.76	0.36	2.7	78.57	4.05	86.96
2	350	200	550	No	260	190	450	20	150	170	74.29	95	5.71	75	7.69	78.95
3	400	300	700	No	43	87	130	2	48	50	10.75	29	0.5	16	4.65	55.17
4	350	250	600	No	12	48	60	0	20	20	3.43	19.2	0	8	0	41.67
5	300	152	452	Yes	0	5	5*	0	0	0	0	3.29	0	0	0	0
6	450	400	850	Yes	0	0	0	0	0	0	0	0	0	0	0	0
Total	2220	1852	3802	-	562	583	1145	32	438	470	25.32	36.85	1.44	27.69	5.69	75.13

*5 kids of less than 6 months age and unvaccinated.

Out of 6 flocks investigated, only 2 (flock Nos. 5 and 6) were vaccinated against PPRV, however, in flock No. 5, five kids showed clinical signs. The affected animals were less than six months old and not vaccinated. Balamurugan *et al*. (2014) had reported that protective level antibody persisted up to 5 months only and suggested for vaccinating the lambs/ kids at the age of 4 and 5 months, respectively. Therefore, the possible reason for the infection in 5 kids in the current study could be due to the lack of protective immunity.

Flock level economic losses due to PPR in HP

Component-wise per animal losses due to PPR are given in Table 4 and 5, respectively for unvaccinated and combined flocks. The loss per animal was more when the same was calculated based on incidence rates in unvaccinated flocks. The per animal loss was INR 51.90 and INR 11.40 in case of goats and sheep, respectively. Per-animal loss based on incidence rates in combined flocks was INR 29.19 and INR 7.56, respectively in case of goats and sheep. The higher

Table 3: Overall mortality and morbidity rates in vaccinated and unvaccinated flocks.

Flock	No. of animals surveyed			Morbidity (%)			Mortality rate (%)		
	Sheep	Goat	Pooled	Sheep	Goat	Pooled	Sheep	Goat	Pooled
Un-vaccinated	1470	1030	2500	38.23	56.12	45.60	2.18	42.52	18.80
Vaccinated	750	552	1302	0.00	0.00	0.00*	0.00	0.00	0.00

* The 5 cases of PPR in this case was not considered for calculating morbidity rate as even though the flocks were vaccinated, the five goats (of les than 6 months age) belonging to this flock, were not vaccinated.

Table 4: Per animal (per head) loss (INR) due to PPR based on incidence rates in unvaccinated flocks.

	Components	Goat	Sheep
A	Mortality loss	33.41	1.55
B	Direct loss in milk/wool yield		
	Milk yield loss	0.08	-
	Wool yield loss	-	0.001
C	Losses due to reproductive failure		
C1	Losses due to increased abortions		
C11	Milk loss due to increased abortions	0.10	-
C12	Live weight lost due to increased abortion	6.13	0.45
C2	Losses due to increased inter-calving period		
C21	Milk loss due to increased inter-calving period	0.09	-
C22	Live weight loss due to increased inter-calving period	5.57	0.32
D	Direct loss in body weight	3.22	5.91
E	Cost of treatment	2.77	1.88
F	Opportunity cost	0.53	1.29
	Total loss	51.9	11.40

Table 5: Per animal loss (INR) due to PPR based on incidence rates in combined (vaccinated + unvaccinated) flocks.

	Components	Goat	Sheep
A	Mortality loss	18.58	1.03
B	Direct loss in milk/wool yield		
	Milk yield loss	0.04	-
	Wool yield loss	-	0.001
C	Losses due to reproductive failure		
C1	Losses due to increased abortions		
C11	Milk loss due to increased abortions	0.06	-
C12	Live weight lost due to increased abortion	3.53	0.30
C2	Losses due to increased inter-calving period		
C21	Milk loss due to increased inter-calving period	0.05	-
C22	Live weight loss due to increased inter-calving period	3.21	0.21
D	Direct loss in body weight	1.86	3.92
E	Cost of treatment	1.55	1.25
F	Opportunity cost	0.31	0.85
	Total loss	29.19	7.56

per head mortality loss (INR 33) in goats than that of sheep (INR 1.5) implies the significantly higher fatality in the former species. Lower case fatality ratio in sheep results in higher opportunity costs, which are costs of extra resources that are employed in care of diseased animals (INR 1.29 per head) as compared to the same for goats (INR 0.5).

Table 6 presents the proportional contribution of different components of the total loss. There were hardly any differences in the shares of different loss components to total losses, whether computed on the basis of unvaccinated or combined flocks. In case of goats, the greatest share (around 65%) of the total economic losses due to PPR were made up of mortalities, followed by losses due to reproductive failure (23%), direct loss in body weight (6%) and treatment cost (5%). In case of sheep, mortality losses accounted for a smaller share (14%) of total losses. The major component of losses for sheep was direct body weight losses (52%).

The study projected losses due to PPR incidence in small ruminant population at the state level. The estimation of state-level losses was carried out pertaining to three scenarios, *viz*. outbreak incidence as observed in this study and 75% and 50% of outbreak incidence. Under high incidence scenario, the total loss due to PPR in HP was US$ 35.64 million with goats accounting for the overwhelming share of loss (US$ 29.54 million). Under moderate and low incidence rate assumptions, the total losses were estimated at US$ 26.73 million and US$ 18.07 million, respectively. The loss estimates as reported in published literature ranged between US$ 0.003 to 14.6 per head (Opasina and Putt 1985; Thombare and Sinha 2009; Abubakar and Munir, 2014).

Cost-benefit analysis of PPR control through vaccination

The BCR calculated was well over unity for both sheep and goats under all the scenarios, *viz*. high, moderate and low incidence rates (Table 7), thus indicating that the benefits of vaccination outweigh the associated costs. The BCR ranged between 43:1 to 198:1, depending upon level of incidence rate assumptions and species. The BCR for all levels of incidence rates assumptions were higher for goats than sheep. This is on account of greater prevalence of the disease in goats. The BCR as calculated in this study are in line with Bardhan *et al*., (2017b) who had reported a BCR of 123:1 for PPR control through vaccination using an economic surplus model.

There can be variations in many of the assumptions while calculating the returns to PPR control programme. In this context, sensitivity analysis was carried out to ascertain the effect of changes in two of the baseline assumptions. In the first scenario it was assumed that the vaccine has lower efficacy (50%) as compared to the baseline assumption. Given this pessimistic scenario, BCR decreased significantly (Fig 1). In the second scenario, accommodating for increase in vaccination cost by 50% the BCR also declined significantly (Fig 2).

Table 6: Share (%) of different components of losses to total losses due to PPR.

Components of losses	Losses based upon incidence rates of vaccinated flocks		Losses based upon incidence rates of vaccinated + unvaccinated flocks	
	Goat	Sheep	Goat	Sheep
Mortality loss	64.37	13.60	63.65	13.62
Milk yield loss	0.15	0	0.14	0
Wool yield loss	0	0.01	0	0.01
Losses due to reproductive failure	22.91	6.75	23.47	6.75
Direct loss in body weight	6.20	51.84	6.37	51.85
Cost of treatment	5.34	16.49	5.31	16.53
Opportunity cost	1.02	11.32	1.06	11.24

Table 7: Cost- benefit analysis of vaccination against PPR in the state of HP based upon extrapolation of data obtained from investigated flocks.

Scenarios	Species	Total loss (US$ in million)	Vaccine coverage (%)	Vaccine effectiveness (%)	Benefits of vaccination (US$ in million)	Vaccination cost (US$ in million)	BCR
High incidence rate	Sheep	6.10	33.79	75	1.55	0.03	56.92
	Goat	29.54	34.89	75	7.73	0.04	198.22
Moderate incidence rate	Sheep	4.57	33.79	75	1.16	0.03	42.69
	Goat	22.14	34.89	75	5.80	0.04	148.66
Low incidence rate	Sheep	3.31	33.79	75	0.84	0.03	30.86
	Goat	14.77	34.89	75	3.87	0.04	99.11

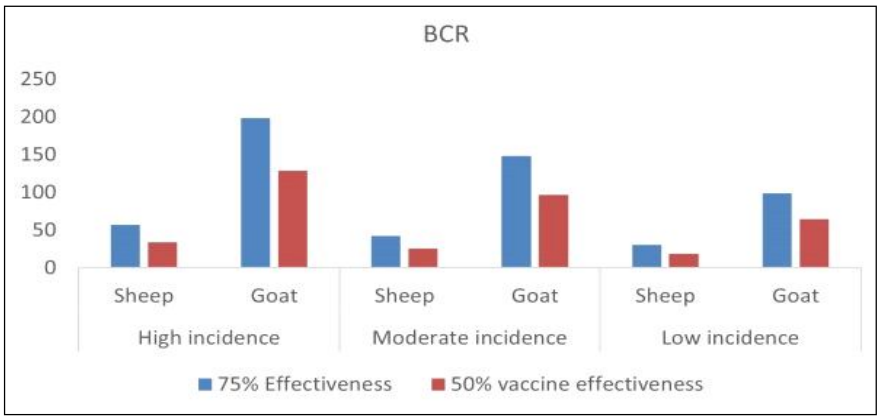

Fig 1: Sensitivity of estimated vaccine impact to assumptions (50% vaccine efficacy).

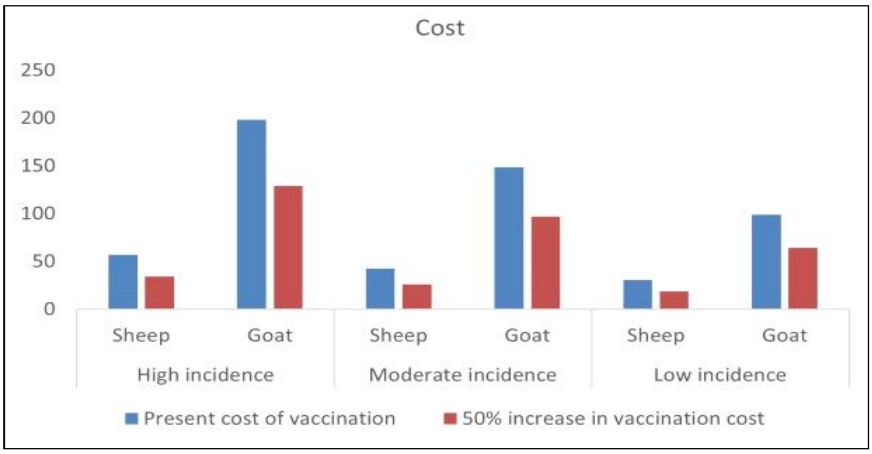

Fig 2: Sensitivity of estimated vaccine impact to assumptions (50% increase in vaccination cost).

CONCLUSION

The outbreak of PPRV in transhumance population is a significant threat to the small ruminant animal husbandry as these are migratory in nature. The endemic nature of PPR in India poses significant threat to both the livestock sector and the agriculture sector as a whole. The economic feasibility criteria of vaccination against the disease, as estimated in this study suggest sustaining and intensifying mass prophylactic vaccination to curtail mortality associated with PPR.

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Conflict of interest

None of the authors have any competing interest.

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