Research Article

Special Issue: Molecular Virology and Control of *Peste des Petits Ruminants* Virus

# Estimation of Economic Loss of PPR in Sheep and Goats in India: An Annual Incidence Based Analysis

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**Abstract** | *Peste des petits ruminants* (PPR) is a highly contagious viral disease in small ruminants causing huge loss to farmers. In this study, an attempt has been made to estimate the economic losses based on the annual incidence, morbidity, mortality levels etc. derived from literature, discussion with experts, and based upon scientific facts. Different mathematical models were used to assess the losses due to mortality in young and adult sheep/goats, body weight loss in young and adult sheep/goats, milk loss, loss due to increased inter-lambing/kidding period, loss due to increased abortion, cost of high feeding and rearing inputs in young and adult sheep/goats etc. The results revealed that at the annual 10% incidence level, the estimated total loss due to PPR in sheep and goats was INR 5041.5 million (77% was mortality loss and 23% was morbidity loss) and INR 11074.6 million (73% mortality loss and 27% morbidity loss), respectively. Further, sensitivity analysis under *Ceteris paribus*, revealed a loss of INR 8058.8 million and INR 24174.1 million at the minimum (5%) and maximum (15%) incidence levels, respectively. Thus, the estimated loss due to PPR in sheep and goats is dependable till the large-scale primary survey estimates are available in India.

**Editor** | Dr. H. Tarik Atmaca, Faculty of Veterinary Medicine, Dept. of Pathology, Kirikkale University, Turkey.
**Received** | March 17, 2016; **Accepted** | April 01, 2016; **Published** | June 28, 2016
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**DOI** | http://dx.doi.org/10.17582/journal.bjv/2016.3.3s.77.85
**Citation** | Govindaraj, G., V., Balamurugan, H., Rahman. 2016. Estimation of economic loss of PPR in sheep and goats in India: An annual incidence based analysis. *British Journal of Virology*, 3(3s): 77-85.
**Keywords:** PPR, Mathematical models, Annual incidence, Sensitivity analysis, Economic loss, Sheep and goats

## Introduction

India has considerable sheep and goat population of around 200 million (BAHS, 2014). It is reared by millions of farmers from single animal to large flocks. Small ruminants provide social, financial and economic security especially for the landless, marginal and small farmers. In developing countries like India, majority of the sheep and goat is reared mostly under natural grazing conditions with some supplementation of fodder. Sheep and goats has inbuilt equity component as it is reared by the poor, landless and marginal with very low investment. The small ruminant production can be increased by rearing better breeds, feed supplementations etc., as well as through control of diseases. PPR is one such disease that limits the optimum production and hence, its control is highly imperative to increase small ruminant production.

*Peste des petits ruminants* (PPR) is an acute and highly contagious viral disease in sheep and goats and in wild small ruminants. It is an OIE notified transboundary disease causing severe morbidity and mortali-

ty (Venkataramanan et al., 2005; Diallo et al., 2007; Balamurugan et al., 2014). The clinical symptoms include pyrexia, stomatitis, discharge through ocular and nasal orifices, enteritis and pneumonia. PPR was first reported in the Ivory Coast of West Africa and later found in other parts of the world including India. In India, PPR was first recorded in the Tamil Nadu during 1987 and later reported in other regions. PPR is enzootic in India and outbreaks occur regularly among small ruminants population (Singh et al., 2004; Balamurugan et al., 2014; Muthuchelvan et al., 2015; Parida et al., 2015).

Despite the significance of the disease among small ruminant population in India, the reliable loss estimates are still lacking. Thombare and Sinha (2009) studied the economic implications of PPR in Pune district of Maharashtra state and the results do not represent true picture for the whole country, as the study was undertaken in the high outbreak district. Similarly, Singh and Prasad (2009) reported average annual loss of INR 9.14 million due to PPR in goats and the estimate was based on only reported time series data on outbreak, attack and death. Singh et al. (2009) reported that the tangible losses due to PPR based on various assumptions was USD 4610.3 million per year. Further, Singh et al. (2014) reported that based on the data reported by Department of Dairying Animal Husbandry and Fisheries (DAH&DF), Government of India the loss due to PPR estimated was INR 16.78 million and was too low as the reporting of the disease is not accurate due to many administrative and other hassles in reporting the disease. They also estimated the losses based on 2007 population census, morbidity and mortality rates, prevalence rates derived from few primary survey studies carried at different points of time (Thombare and Sinha, 2009; Balamurugan et al., 2012; Mahajan et al., 2013). The annual loss estimated by Singh et al. (2014) for PPR based on the above criteria was INR 88951 million (INR 54774.8 million in goat and INR 34176.4 million in sheep).

Any generalized annual loss estimation of PPR should consider the annual incidence of the disease in a year and not based on the point estimates of prevalence at different periods of time or exclusively based on outbreaks as earlier reported (Tiwari, 2004; Thombare and Sinha, 2009; Mahajan et al., 2013; Singh et al., 2014). The studies on prevalence was based on antibodies detection and it is not necessarily mean overt manifestation of the disease in animals and thus production losses and moreover, the antibodies level may depend on the virus load, breed, immunity levels, vaccination etc. Further, from the prevalence reports based on detection of antibodies, deducing the time of actual infection in the flock is difficult and hence, the prevalence percentages *per se* cannot be used for annual loss projections as reported earlier (Singh et al., 2014) for assessing the infected population due to PPR in a year. Hence, the annual incidence levels in a random population may be appropriate for loss projections. Though the cross-sectional field survey during a specific period provides appropriate results in loss estimation, it may not be applicable, if the survey is carried in outbreak regions only (Thombare and Sinha, 2009) or only in the high incidence district/region, since, it results in high incidence projection and thus over-estimation of losses.

Due to lack of appropriate data on actual field outbreaks occurring in different regions of India, the assessment of loss only based on reported outbreaks is less reliable for policy making. Hence, in this study an attempt was made to estimate the losses due to PPR using the annual incidence approach. The various incidence levels (%) considered for estimating the losses due to PPR was 5% (low), 10% (optimum) and 15% (high), based on the past reported studies (Awase et al., 2013). The results of such approach might be appropriate till a large-scale primary survey with the appropriate sampling frame results is available.

## Materials and Methods

The loss due to PPR in sheep and goat was estimated based on the data derived from secondary sources, expert opinion, field investigation results and past reviews. The details of the parameters and data sources for PPR loss estimation are presented in Table 1. Based on the past studies (Awase et al., 2013) an optimum 10% annual incidence level and sensitivity analysis for upper bound (15%) and lower bound levels (5%) the loss estimates were calculated. Thus, the loss due to PPR was estimated at 5%, 10 % and 15% annual incidence levels under *ceteris paribus*.

**A)** Formulae to assess the loss due to PPR in sheep is given below :

$$M_{AS} = A * A1 * B * C * G * I$$
$$M_{YS} = A * A2 * B * E * H * I$$
$$BW_{AS} = A * A1 * B * D * G * L * I$$

**Table 1:** *Parameters and data sources considered for assessing the loss due to PPR in sheep and goats in India*

| Label | Parameters | Sheep | Goats | Data source |
|---|---|---|---|---|
| A | Population (Million) | 65.06 | 135.17 | 2012 Livestock census; BAHS, 2014 |
| A1 | Adults (%) | 66 | 65 | 2012 Livestock census; BAHS, 2014 |
| A2 | Young (%) | 34 | 35 | 2012 Livestock census; BAHS, 2014 |
| B | Annual PPR incidence (percent/year) | 10 | 10 | Awase et al., (2013) and Expert opinion |
| C | Adult Mortality (%) | 10 | 10 | Expert opinion, Obtained during PPR outbreak investigation by the authors |
| D | Adult Morbidity (%) | 5 | 5 | Expert opinion, Obtained during PPR outbreak investigation by the authors |
| E | Young-Lamb/kid Mortality (%) | 20 | 20 | Expert opinion, Obtained during PPR outbreak investigation by the authors |
| F | Young-Lamb/kid Morbidity (%) | 20 | 20 | Expert opinion, Obtained during PPR outbreak investigation by the authors |
| G | Average weight of Adult (kg) | 20 | 20 | Probable values |
| H | Average weight of Young (kg) | 10 | 10 | Probable values |
| I | Price of live weight animal (INR/kg) | 300 | 300 | Prevailing market price |
| J | Price of one young animal (INR) | 3000 | 3000 | |
| K | Price of one adult animal (INR/Kg) | 6000 | 6000 | |
| L | Reduction in body weight due to morbidity (%) | 10 | 10 | Obtained during PPR outbreak investigation by the authors |
| M | Average number of Lamb/lambing or kid/kidding per animal | 1 | 2 | Expert opinion |
| N | Average birth weight of lamb/kit (Kg) | 2.5 | 2 | Expert opinion |
| O | Proportion of female animals in abortion (%) | 2 | 2 | Expert opinion |
| P | Inter-kidding or Lambing period (months) | 10 | 10 | Expert opinion |
| Q | Delay in next conception (months) | 3 | 3 | Expert opinion |
| R | Cost of feed incurred (INR per animal/month) | 120 | 120 | Obtained during PPR outbreak investigation by the authors |
| S | Additional period of feeding the animals (months) | 3 | 3 | Expert opinion |
| T | Average treatment cost of the animals (INR) | 125 | 125 | Obtained during PPR outbreak investigation by the authors |
| U | Increased cost of Management including labour (INR) | 60 | 60 | Obtained during PPR outbreak investigation by the authors |
| V | Other miscellaneous indirect cost (INR) (cost incurred in transporting medicines; POL cost, etc) | 60 | 60 | Obtained during PPR outbreak investigation by the authors |
| W1 | Milk yield (litre/day/animal) | - | 0.25 | Obtained during PPR outbreak investigation by the authors |
| W2 | Goat milk (INR/litre) | - | 60 | Probable values |
| W3 | Number of days milk loss in the morbid animals | | 20 | Obtained during PPR outbreak investigation by the authors |

$$BW_{YS} = A^{*}A1^{*}B^{*}F^{*}H^{*}L^{*}I$$
$$BW_{ILPS} = A^{*}A1^{*}B^{*}0.5^{*}\{[12/P]-[12/P+Q]^{*}M^{*}N^{*}I$$
$$BW_{LAS} = A^{*}A1^{*}B^{*}0.5^{*}O^{*}N^{*}I$$
$$FRI_{AS} = A^{*}A1^{*}B^{*}D^{*}R^{*}S$$
$$FRI_{YS} = A^{*}A2^{*}B^{*}F^{*}R^{*}S$$
$$MIS_{AS} = A^{*}A1^{*}B^{*}D^{*}(T+U+V)$$
$$MIS_{YS} = A^{*}A1^{*}B^{*}D^{*}(T+U+V)$$

**Where:**

$M_{AS}$ = Mortality loss in adult sheep (INR)
$M_{YS}$ = Mortality loss in young sheep (INR)
$BW_{AS}$ = Body weight loss in adult sheep (INR)
$BW_{YS}$ = Body weight loss in young sheep (INR)
$BW_{ILPS}$ = Live body weight loss due to increased inter-lambing period (INR)


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$BW_{IAS}$ = Live weight loss due to increased abortion (INR)
$FRI_{AS}$ = Cost of high feeding and rearing inputs in adult sheep (INR)
$FRI_{YS}$ = Cost of high feeding and rearing inputs in young sheep (INR)
$MIS_{AS}$ = Miscellaneous cost in adult sheep (INR)
$MIS_{YS}$ = Miscellaneous cost in young sheep (INR)

Further details about the notations are provided in Table 1.

**B)** Formulae to assess the loss due to PPR in goats is given below:

$M_{AG} = A * A1 * B * C * G * I$
$M_{YG} = A * A2 * B * E * H * I$
$BW_{AG} = A * A1 * B * D * G * L * I$
$BW_{YG} = A * A1 * B * F * H * L * I$
$BW_{ILPG} = A * A1 * B * 0.5 * \{[12/P]-[12/P+Q] * M * N * I$
$BW_{IAG} = A * A1 * B * 0.5 * O * N * I$
$FRI_{AG} = A * A1 * B * D * R * S$
$FRI_{YG} = A * A2 * B * F * R * S$
$MIS_{AG} = A * A1 * B * D * (T+U+V)$
$MIS_{YG} = A * A2 * B * F (T+U+V)$
$M_{K} = A * A1 * B * D * 0.5 * W1 * W2 * W3$

**Where:**

$M_{AG}$ = Mortality loss in adult goats (INR)
$M_{YG}$ = Mortality loss in young goats (INR)
$BW_{AG}$ = Body weight loss in adult goats (INR)
$BW_{YG}$ = Body weight loss in young goats (INR)
$BW_{ILPG}$ = Live body weight loss due to increased inter-kidding period (INR)
$BW_{IAG}$ = Live weight loss due to increased abortion (INR)
$FRI_{AG}$ = Cost of high feeding and rearing inputs in adult goats (INR)
$FRI_{YG}$ = Cost of high feeding and rearing inputs in young goats (INR)
$MIS_{AG}$ = Miscellaneous cost in adult goats (INR)
$MIS_{YG}$ = Miscellaneous cost in young goats (INR)
$M_{K}$ = Milk loss in goats (INR)

Further details about the notations are provided in Table 1.

## Results

### Estimated mortality and morbidity loss in sheep

At the optimum incidence level (10%), the estimated total loss due to PPR in sheep was INR 5041.5 million (mortality loss amounts to INR 3904.2 million and morbidity loss was INR 1137.4 million) (Table 2). At the minimum (5%) and maximum (15%) incidence levels, the total loss estimated was INR 2520.8 and INR 7562.3 million, respectively (Table 2). The age-group wise loss estimation revealed that at the optimal incidence (10%), among the mortality loss, the major loss was in adult animals (INR 2576.7 million) than in young animals (INR 1327.4 million). Among the morbidity loss, the loss due to reduction in body weight was INR 261.6 million (INR 128.8 million in adult animals and INR 132.7 million in young animals). The live weight loss due to increased inter-lambing period and live weight loss due to abortion was INR 446 and INR 32.2 million, respectively. Among the other associated losses, the loss due to high feeding and rearing was INR 236.6 million and

**Table 2:** *Mortality and morbidity losses in sheep for various levels of annual incidence of PPR in India (INR Millions)*

| Type of loss | Annual Incidence levels | | |
|---|---|---|---|
| | 5% | 10% | 15% |
| **1. Mortality loss** | 1952.1(77.5) | 3904.2(77.5) | 5856.2(77.5) |
| **2. Morbidity loss** | | | |
| **I.** Weight loss | | | |
| **a.** Direct losses due to reduction in body weight | 130.8(5.2) | 261.6(5.2) | 392.4(5.2) |
| **b.** Live weight loss due to increased inter-lambing period | 223.0(8.8) | 446.0(8.8) | 669.0(8.8) |
| **c.** Live weight loss due to increased abortion | 16.1(0.6) | 32.2(0.6) | 48.3(0.6) |
| **II.** Other associated loss | | | |
| **a.** Cost of high feeding and rearing inputs | 118.3(4.7) | 236.6(4.7) | 354.9(4.7) |
| **b.** Miscellaneous loss* | 80.5(3.1) | 161.0(3.1) | 241.5(3.1) |
| **3. Total Loss** | **2520.8 (100)** | **5041.5 (100)** | **7562.3 (100)** |

** Includes treatment cost, increased cost of management including labour and other minor costs; Figures in parentheses indicate per cent to total*

**Table 3:** *Mortality and morbidity losses in young and adult sheep for various levels of annual incidence of PPR in India (INR Million)*

| Type of loss | Age group** | Annual Incidence levels | | |
|---|---|---|---|---|
| | | 5% | 10% | 15% |
| 1. Mortality loss | Adult | 1288.4(66) | 2576.7(66) | 3865.1(66) |
| | Young | 663.7(34) | 1327.4(34) | 1991.1(34) |
| | Total | 1952.1(100) | 3904.2(100) | 5856.2(100) |
| 2. Morbidity losses | | | | |
| I. Direct losses due to reduction in body weight | Adult | 64.4(49.3) | 128.8(49.3) | 193.3(49.3) |
| | Young | 66.4(50.7) | 132.7(50.7) | 199.1(50.7) |
| | Total | 130.8(100) | 261.6(100) | 392.4(100) |
| II. Live weight loss due to increased inter-lambing period | Adult | 223.0(100) | 446.0(100) | 669.0(100) |
| | Total | 223.0(100) | 446.0(100) | 669.0(100) |
| III. Live weight loss due to increased abortion | Adult | 16.1(100) | 32.2(100) | 48.3(100) |
| | Total | 16.1(100) | 32.2(100) | 48.3(100) |
| 3. Other associated losses | | | | |
| I. Cost of high feeding and rearing inputs | Adult | 38.7(32.7) | 77.3(32.7) | 116.0(32.7) |
| | Young | 79.6(67.3) | 159.3(67.3) | 238.9(67.3) |
| | Total | 118.3(100) | 236.6(100) | 354.9(100) |
| II. Miscellaneous loss* | Adult | 26.3(32.7) | 52.6(32.7) | 78.9(32.7) |
| | Young | 54.2(67.3) | 108.4(67.3) | 162.6(67.3) |
| | Total | 80.5(100) | 161.0(100) | 241.5(100) |

** Includes treatment cost, increased cost of management including labour and other minor costs; **Age group refers to young (animals less than one year age); Adult (animals more than one year age); Figures in parentheses indicate per cent to total*

**Table 4:** *Mortality and morbidity losses in goat for various levels of annual incidence of PPR in India (INR Million)*

| Type of loss | Annual Incidence levels | | |
|---|---|---|---|
| | 5% | 10% | 15% |
| 1. Mortality loss | 4055.2(73.2) | 8110.4(73.2) | 12165.6(73.2) |
| 2. Morbidity loss | | | |
| I. Weight loss | | | |
| a. Direct losses due to reduction in body weight | 273.7(4.9) | 547.5(4.9) | 821.2(4.9) |
| b. Live weight loss due to increased inter-lambing period | 729.9(13.2) | 1459.9(13.2) | 2189.8(13.2) |
| c. Live weight loss due to increased abortion | 26.4(0.5) | 52.7(0.5) | 79.1(0.5) |
| II. Milk loss | 32.9(0.6) | 65.9(0.6) | 98.8(0.6) |
| III. Other associated loss | | | |
| a. Cost of high feeding and rearing inputs | 249.4(4.5) | 498.8(4.5) | 748.2(4.5) |
| b. Miscellaneous loss | 169.7(3.1) | 339.5(3.1) | 509.2(3.1) |
| 3. Total Loss | 5537.3(100) | 11074.6(100) | 16611.8(100) |

** Includes treatment cost, increased cost of management including labour and other minor costs; Figures in parentheses indicate per cent to total*

miscellaneous costs was INR 161 million. Around 67% of the loss incurred for higher feeding and recovering was in young animals and 33% in adult animals (Table 3).

## Estimated mortality and morbidity loss in goats

At the optimum incidence level (10%), the estimated total loss due to PPR in goat was INR 11074.6 million (mortality loss amounts to INR 8110.4 million and morbidity loss was INR 2964.2 million) (Table 4). At the minimum (5%) annual incidence levels, the loss due to PPR in goats amounts to INR 5537.3 million whereas, at the maximum annual incidence levels (15%), the total loss estimated was INR 16611.8 million (Table 4). The age-group wise loss estimation in

**Table 5:** *Mortality and morbidity losses in young and adult goats for various levels of annual incidence of PPR in India (INR millions)*

| Loss type | Age group** | Annual Incidence levels | | |
|---|---|---|---|---|
| | | 5% | 10% | 15% |
| 1. Mortality loss | Adult | 2635.9(65) | 5271.8(65) | 7907.6(65) |
| | Young | 1419.3(35) | 2838.6(35) | 4258.0(35) |
| | Total | 4055.2(100) | 8110.4(100) | 12165.6(100) |
| 2. Morbidity losses | | | | |
| I. Direct losses due to reduction in body weight | Adult | 131.8(48.1) | 263.6(48.1) | 395.4(48.1) |
| | Young | 141.9(51.9) | 283.9(51.9) | 425.8(51.9) |
| | Total | 273.7(100) | 547.5(100) | 821.2(100) |
| II. Live weight loss due to increased inter-kidding period | Adult | 729.9(100) | 1459.9(100) | 2189.8(100) |
| | Total | 729.9(100) | 1459.9(100) | 2189.8(100) |
| III. Live weight loss due to increased abortion | Adult | 26.4(100) | 52.7(100) | 79.1(100) |
| | Total | 26.4(100) | 52.7(100) | 79.1(100) |
| 3. Milk loss | Adult | 32.9(100) | 65.9(100) | 98.8(100) |
| 4. Other associated losses | | | | |
| I. Cost of high feeding and rearing inputs | Adult | 79.1(31.7) | 158.2(31.7) | 237.2(31.7) |
| | Young | 170.3(68.3) | 340.6(68.3) | 511.0(68.3) |
| | Total | 249.4(100) | 498.8(100) | 748.2(100) |
| II. Miscellaneous loss* | Adult | 53.8(31.7) | 107.6(31.7) | 161.4(31.7) |
| | Young | 115.9(68.3) | 231.8(68.3) | 347.7(68.3) |
| | Total | 169.7(100) | 339.5(100) | 509.2(100) |

** Includes treatment cost, increased cost of management including labour and other minor costs like transportation cost of medicines etc.; **Age group refers to young (animals less than one year age); Adult (animals more than one year age); Figures in parentheses indicate per cent to total*

goats revealed that at the optimal annual incidence levels (10%), among the mortality loss, the major loss was in adult animals (INR 5271.8 million) than in young animals (INR 2838.6 million). Among the morbidity loss, the loss due to reduction in body weight was INR 547.5 million (INR 263.6 million in adult animals and INR 283.9 million in young animals). The live weight loss due to increased inter-kidding period and due to abortion was INR 1459.9 million and INR 52.7 million, respectively. The annual milk loss estimated was INR 65.9 million due to PPR in sheep and goats at the optimum incidence level. Among the other associated losses, the loss due to high feeding and rearing was INR 498.8 million and miscellaneous costs was INR 339.5 million. Around 68% of the loss incurred for higher feeding was in young animals and 32% in adult animals (Table 5).Among the miscellaneous costs, major loss was in young animals (INR 231.8 million) than the adult animals (INR 107.6 million).

### Estimated total loss due to PPR in sheep and goats

The results revealed that at the optimum incidence level (10%), the estimated total loss due to PPR in sheep and goats was 16116.1 million (mortality loss amounts to 12014.5 million and morbidity loss was 4101.6 million) (Table 6). The sensitivity analysis results revealed that at the minimum (5%) annual incidence level, the loss amounts to 8058.8 million whereas, at the maximum (15%) annual incidence, the total loss was around 24174.1 million (Table 6).

## Discussion

In the present study, the annual incidence approach (10%) was used compared to the earlier estimate by Singh et al. (2014), which was based on combination of Government of India data and sample survey results from Chhattisgarh and Madhya Pradesh (Awase et al., 2013; Sahu, 2013). The number of infected animals derived by Singh et al. (2014) for estimating the national level loss due to PPR was based on the prevalence of PPR in the clinical samples (Balamurugan et al, 2012) submitted to the Laboratory, Division of Virology, IVRI, Mukteswar, India. As the samples submitted were collected from outbreaks, the preva

**Table 6:** *Mortality and morbidity losses in goat and sheep for various levels annual incidence of PPR in India (INR millions)*

| Type of loss | Annual Incidence levels | | |
|---|---|---|---|
| | 5% | 10% | 15% |
| **1. Mortality loss** | 6007.3(74.6) | 12014.5(74.6) | 18021.8(74.6) |
| **2. Morbidity loss** | | | |
| **I.** Weight loss | | | |
| **a.** Direct losses due to reduction in body weight | 404.5(5.0) | 809.0(5.0) | 1213.5(5.0) |
| **b.** Live weight loss due to increased inter-lambing period | 952.9(11.8) | 1905.8(11.8) | 2858.8(11.8) |
| **c.** Live weight loss due to increased abortion | 42.5(0.5) | 84.9(0.5) | 127.4(0.5) |
| **II.** Milk loss | 32.9(0.4) | 65.9(0.4) | 98.8(0.4) |
| **III.** Other associated loss | | | |
| **a.** Cost of high feeding and rearing inputs | 367.7(4.6) | 735.4(4.6) | 1103.1(4.6) |
| **b.** Miscellaneous loss | 250.2(3.1) | 500.5(3.1) | 750.7(3.1) |
| **3. Total Loss** | 8058.0(100) | 16116.1(100) | 24174.1(100) |

*Figures in parentheses indicate per cent to total*

lence level (%) tend to be high and thus the number of animals infected calculated by Singh et al. (2014) were also high resulting in over estimation of losses. Moreover, as the prevalence of antibodies could not delineate the year of infection, any estimate based on this level will be a cumulative loss and could not be attributed for one year. The proportion of animals died due to PPR among the infected animals considered by Singh et al. (2014) was 24% in goats and 21.8% in sheep (Balamurugan et al., 2012), irrespective of the ages, whereas, different researchers reported that mortality in adult animals is less compared to young ones indicating differential mortality consideration among age groups would have provided better estimates. Hence, in the present study 20 % and 5% mortality in young and adults animals, respectively were considered based on expert opinion as well as based on the results of outbreaks investigations in the field by the authors. Further, the overall scenario of reported number of outbreaks in India has declined in the recent years (Singh and Bandyopadhyay, 2015) in general with drastic reduction in the reported outbreaks particularly in state of Karnataka, Andhra Pradesh, and Chhattisgarh with implementation of PPR Control Programme. In Karnataka, the reported outbreaks were between 60–142 in the years 2005-06 to 2007-08, declined to a level of one to three in the year 2011–2012 by adopting mass vaccination campaign (Singh and Bandyopadhyay, 2015). Similarly, in Andhra Pradesh implementation of pulse vaccination and continuation of vaccination on a half yearly basis resulted in outbreaks limited to three numbers during 2013-14 (Sireesha et al., 2014). In Chhattisgarh, with the well planned "vaccination programme" with yearly vaccination, no incidence of PPR was reported since 2013-14 (Roy et al., 2014). The diseases dynamics pattern or epidemiology of disease in terms of severity, mortality and morbidity has changed in the recent years due to ongoing vaccination in many states of India (Balamurugan et al., 2014). Hence, the present study, based on the optimum annual incidence level of PPR (10%) is close to reality than the prevalence (24.5% in sheep and 38.2% in goats) based or mortality levels based estimation without delineating young and adults as reported earlier by Singh et al. (2014).

The optimum annual PPR incidence level (10%) considered in the present study for assessing the losses was based on the field survey study (Awase et al., 2013) and further discussion with the experts on possible annual incidence level of PPR in the country in the random survey in the light of National Control Programme implementation in the country. Of the total loss estimated, the mortality loss was 77% in sheep and 73% in goats; implying mortality loss was high than the morbidity loss irrespective of the species. The results from the earlier study (Singh et al., 2014) reported that morbidity loss was higher than mortality loss, and the variation in both the studies might be due to differences in assumptions on mortality and morbidity proportions across the young and adult population, change in the total population, the components considered in morbidity loss estimation, etc.

## Conclusions

The study revealed that based on the optimum annual incidence levels, the estimated loss due to PPR in sheep and goat was 5041.5 million (77% was mortality loss and 23% was morbidity loss) and 11074.6 million (73% mortality loss and 27% morbidity loss), respectively. The results of this study besides quantifying the loss due to PPR in sheep and goats, highlighted the importance of assumptions to be considered while assessing the losses, especially, the use of latest livestock census population, optimum incidence levels, optimum mortality and morbidity levels in young and adult population, and also the disease changes occurring in the field in the wake of implementation of PPR Control Programme in some states of India.

## Acknowledgements

Authors thank Indian Council of Agricultural Research (ICAR), New Delhi, India for support and encouragement. The authors also thank the Staff of ICAR-National Institute of Veterinary Epidemiology and Disease Informatics (NIVEDI) for their constant support and guidance. Mrs. K.R. Nethrayini and Ms. R. Salini, for their timely help and assistance.

## Conflict of Interest

No conflict of interest exists

## Authors' Contribution

Govindaraj G designed and carried out the study, interpreted the data and wrote the draft of manuscript. Balamurugan V interpreted the data, provided support and edited the manuscript and Rahman H provided guidance and support to carry out the study.

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