Review Article

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

Planning, Implementation of *Peste des Petits Ruminants* Control Programme and Strategies Adopted for Disease Control in India

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Abstract | *Peste des petits ruminants* (PPR) is an acute, highly contagious, notifiable and economically important transboundary viral disease of sheep and goats. PPR is enzootic in India as more number of outbreaks have occurred in the past and now occurring regularly, round the year and most frequently during the lean period throughout the country. In some Indian states viz. Andhra Pradesh, Karnataka, and Chhattisgar h the PPR outbreaks in sheep and goats have declined after implementing the strategic mass vaccination programme. The decreased number of outbreaks in recent years as well as changes in the disease severity patterns and distribution might be due to the effectiveness of vaccine, timely vaccination, circulation of a single lineage virus and most importantly effective planning and implementation of the vaccination programme. Sharing the experiences on the PPR control strategies adopted by some of the states in India may motivate other Indian states or other countries of similar socio-economic and small ruminant rearing pattern to vaccinate and control PPR.

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Introduction

Peste des Petits ruminant (PPR), a viral disease of sheep and goats is caused by PPR virus (PPRV). It is also known as "*Goat Plaque*" and is a World Organisation for Animal Health (WOAH-OIE) notifiable terrestrial animal disease. It is highly contagious and economically important transboundary viral disease of domestic and wild small ruminants and is currently emerging to cause infection in camels (Albina et al., 2013). Clinically, the disease is manifested by high fever (pyrexia), oculo-nasal discharges, sore mouth (necrotising and erosive stomatitis), enteritis, diarrhoea and bronchopneumonia followed by either death of the animal or recovery from the disease (Munir et al., 2013; Balamurugan et al., 2014c).

PPR was first reported in the Ivory Coast, West Africa during 1942 (Gargadennec and Lalanne, 1942) and later from other parts of the Africa, the Middle East and the parts of Asia (Balamurugan et al., 2014c; Muthuchelvan et al., 2015; Parida et al., 2015). Spread of disease to a number of new countries in southern Africa, central Asia, Southeast Asia, China, Southern Europe and Western Turkey with involvement of various lineage of PPRV is a cause of global animal health concern, especially, recent introduction of Asian lineage in some African countries and presence of PPRV

in Europe through Western Turkey (Banyard et al., 2010; Kwiatek, et al., 2011; Albina et al., 2013; FAO, 2013; Libeau et al., 2014). Recently, many outbreaks of PPR is being reported frequently from number of new countries in Africa (Tanzania, Democratic Republic of Congo, Angola, Ismailia Province of Egypt, Morocco and Algeria) and Asia (China) (Parida et al., 2015). Because of the huge impact on production and PPRV emergences, the disease is considered as one of the main constraints in augmenting the productivity of small ruminants in enzootic countries such as Africa, the Middle East and parts of Asia including India; its control and eradication is a priority.

Globally, about 62.5 % population of total small ruminants are at risk due to PPR (Libeau et al., 2014). As of now, a total of 76 countries with approximately 1.7 billion (80 percent of the global population) of sheep and goats in Africa, the Middle East and the parts of Asia have confirmed PPR within their borders, and many countries are at risk of the disease being introduced (http://www.fao.org/ppr/en/). Considering the importance of small ruminants in food security and socio-economic growth in Africa, Asia and in many other parts of the world, the complete control and eradication of PPR becomes essential.

Rinderpest (RP) virus (RPV) caused catastrophic losses in large animals, which played a killing instinct for period of a century by causing a major impact on rural agricultural economy. In June 2011, OIE has officially declared a world free of RP, the first animal disease that has been eradicated in the world. PPR also has specific features with respect to RP in small ruminants. Thus, the successful global elimination of RPV has highlighted the feasibility of PPR eradication. Rigorous stamping out policy involving quarantine and mass slaughter can control the spread of the disease and eradication but difficult to follow in developing country like India due to various reasons. Similarly, generation of a vaccine that enables differentiation of infected from vaccinated animals (DIVA) would benefit PPR control and eradication programmes, particularly in the later stages of an eradication campaign and for countries where the disease is not endemic. This factor severely delayed progress during the RPV eradication campaign as for a country to gain international status as being free from RPV it had to demonstrate serological naivety in its population for several years following the cessation of vaccination.

Given the similarities between RPV and PPRV, it is believed that any future plans for PPRV elimination may require the implementation of the same principles that led to RP eradication. There are however some requirements, which will have to be met before any coordinated action against PPR control is initiated (Singh et al., 2009). The possible existence of wildlife reservoirs and the role of wildlife in transmission of PPR remains to be elucidated although several wildlife ruminants species have been reported as susceptible. In addition to gaps in our complete understanding of PPRV epidemiology, the financial costs of a possible eradication campaign are also unknown and may be difficult to estimate. The shorter life-span of small ruminants compared to large ruminants (cattle and buffaloes) implies that their turnover rate is higher. This in turn implies in the need for more trained veterinary services to carry out vaccine administration. Another major gap for the success of PPR control is the lack of economic assessment of control strategies. Such information would be useful to help in convincing governments and international organizations to support and fund to control PPR. All of these factors need to be addressed before formulating a viable control and eradication programme.

The experience of RP eradication has shown that a strong coordination of all performers at the international level is necessary to achieve the results. It is now widely recognised that the Global Framework for the progressive control of transboundary animal diseases (GF-TADs), which is a joint Food and Agricultural Organisation (FAO) and OIE initiative combining the strengths of both organisations, would be the best channel for this international coordination (FAO, 2013). GF-TADs is an ideal forum where PPR control strategies can be elaborated and decided in collaboration with national veterinary services for involving in the coordination and implementation of control programme. The campaign will make PPR only the second animal disease ever to be eradicated, after rinderpest. Progressive control of PPR is the another initiative of the FAO and OIE organizations and the recent platforms on global PPR research alliance (GPRA), held at International Livestock Research Institute (ILRI), Nairobi, Kenya during 29th-30th April 2013. Further, FAO and OIE convened in Abidjan, Côte d'Ivoire during 31st March to 2nd April, 2015 for the International Conference for the control and eradication of PPR, the high-level authorities from affected countries agreed on a global plan to

get rid of sheep and goat plague by 2030 and agreed to launch Global PPR Control and Eradication Programme (GCEP) (http://www.fao.org/news/story/en/item/282397/icode/).

Planning of Control Programme

In India, PPR was first reported from Arasur village, Villupuram district in Tamil Nadu during 1987 (Shaila et al., 1989). Despite strict control measures including statutory regulations along with availability of vaccines and diagnostics, this disease still remain a constant threat to sheep and goats (Balamurugan et al., 2014c). The strong support of accurate diagnostics for mass screening and timely availability of vaccine and vaccination of the susceptible population are highly imperative for effective control of PPR. There is a need for a disease registry, both at state and national level, to ensure effective reporting and coordination of outbreak occurrence and monitoring (Balamurugan et al., 2014c). This would help to provide a rapid appraisal of the vaccination status, serological and epidemiological status, target population identification, movement of animals and tracking and locating prospective animal target foci (Singh et al., 2009). Therefore, baseline epidemiological data generation is a prerequisite for a successful vaccination programme. A better knowledge of sheep and goat population dynamics, herd management practices and animal movement pattern will be a critical condition for success of any control programme as stated by Singh et al. (2009). However, PPR is still a poorly recognised disease, particularly with regard to epidemiological features such as transmission dynamics under different production systems.

Another issue is the local management of the PPR control programme by farmers, community based animal health workers, veterinary professionals and services, and research organizations. Further, improvements to achieve in the governance of the surveillance systems and veterinary services for better coordination with the private and public sectors of animal health management is highly imperative. Though a good PPR vaccine is available, the implementation of a relevant vaccination and monitoring strategy might be tricky.

Appropriate design and practical implementation of PPR control strategies will have to find their own way, though more lessons learnt from RP eradication (Singh et al., 2009). The control and eradication programme of PPR may be taken up as the presence of conducive and enabling environments to control PPR like factors related to the virulence of virus, pathology and epidemiology of the disease, the limited geographical distribution of the disease, no latency or persistence of the virus in infected animals, the short infectious period of the disease and the requirement for direct or close indirect contact for transmission of the virus, etc., including capability of the country in the lines of RP eradication.

In India, currently three live attenuated PPR vaccines (Sungri 96, Arasur 87 and Coimbatore 97 stains) are available, of which, PPR vaccine (Sungri 96 strain), developed by Indian Veterinary Research Institute (IVRI), Mukteswar has undergone extensive field trial (Singh et al., 2009; Singh, 2011). All Indian PPR vaccine virus strains belong to Asian lineage IV and use of any PPR vaccine may be sufficient to protect against the circulating field isolates / strains of PPRV in India. These vaccines can be used for the control and eradication of the disease not only from India but also from other countries following the example of the global RP eradication programme (GREP), as one single vaccine of any lineage may provide protective immune response against any four lineage viruses so far identified in various geographical areas in the world. Experimental vaccination against PPR after field testing has been practiced in 15 states of India since 2002 to combat the disease as "focus vaccination" targeting the outbreaks area (Singh et al., 2009). Seroconversion and protection has been observed in vaccinates by PPR vaccine (Sungri 96 strain) with a field dose of 10^3 $TCID_{50}$ (Singh et al., 2009; Singh, 2011), which ensured protective immunity for 3 to 6 years without booster (Saravanan et al., 2010) and the vaccine is well suited for mass immunisation programme. The vaccine production and quality control technology generated in IVRI, Mukteswar has been transferred to three multinational companies (MNCs) viz. M/s Intervet India Pvt Ltd. (*MSD* Animal Health), Pune India, M/s Indian Immunologicals Limited (IIL), Hyderabad, India and M/s Hester Bioscience, Ahmadabad, India, apart from few Veterinary Biological Production Units (VBPUs) or Animal health institutes of states.

In addition, base line epidemiological information data on disease situation is available in India over a period of time in sheep and goats (Singh et al.,

2004a; Balamurugan et al., 2012a; Balamurugan et al., 2014a). Further, efficient, specific and sensitive diagnostic assay/tests viz. monoclonal antibody based competitive-ELISA (Singh et al., 2004c) and sandwich ELISA (Singh et al., 2004b) for PPR antibody detection and antigen detection, respectively are available and are currently being used for serosurveillance /monitoring and clinical prevalence throughout the country. These are of great help in providing quick evidence for the presence of PPRV antigen/antibodies in susceptible population.

Further, the availability of an effective vaccine, accurate mass screening diagnostic assays, an experienced or improved infrastructure, expertise, success with eradication of RP under the NPRE programme, have provided the confidence and prompted India to propose a national level PPR control programme initially on the lines of NPRE. Besides availability of aforesaid elements (Singh et al., 2009; Singh, 2011) in India, the Department of Animal Husbandry, Dairying and Fisheries (DADF) the Central Government of India, has better co-ordination and cooperation with the state animal husbandry departments in the federal setup. Therefore, the launching of control and eradication programme appears technically feasible, economically viable and a practically attainable proposition.

Some of the countries have already initiated PPR control measures either through their own resources or with the help of other agencies in order to augment the small ruminant production (Singh and Bandyopadhyay, 2015). India too, initiated PPR control measures using its own resources (availability of base line epidemiological information about the disease situation, competence and indigenously developed technologies for the diagnosis and control of PPR) in order to control PPR to augment the small ruminant production. In the initial period (since 2002), focused and/ or strategic vaccinations were carried out in some states of India (Singh et al., 2009; Singh and Bandyopadhyay, 2015), but neither a systematic sero-monitoring programme was initiated during the last decade to assess the efficacy of the vaccination campaign nor any sero-surveillance plan was taken up during these period (Singh and Bandyopadhyay, 2015). However, it was decided by DADF, Government of India to undertake a national control programme on PPR (NCP-PPR) or PPR control programme (PPR_CP) in the 11th five-year plan (2007-2012) similar to FMD Control Programme (FMD-CP) (DADF, 2007), with an aim to control and eradicate this disease from India in a time bound manner on the lines of RP eradication (http://dahd.nic.in/). Accordingly, this proposed programme has been initiated by following eradication pathway of OIE during the year 2010-2011 with a sum of INR 432.5 million in first phase for undertaking various activities of the programme (http://dahd.nic.in/).

Implementation of Control Programme

Available expertise in the country, especially, scientific and technical manpower, trained veterinarians, technical and para-veterinary staff, is being used for handling vaccines at various stages from production to delivery in the field. Professional commitment on the part of veterinarians and ancillary personnel involved in mass immunisation programme is crucial to succeed vaccination programme (Singh et al., 2009). These prophylactic services being gradually expanded by involving public-private partnership (PPP) especially, participation of non-governmental organisations (NGOs), cooperatives and private veterinary practitioners in implementing and execution of disease control programme as stated by Singh et al. (2009). Further, setting up of a network cum database would be of help in developing a coordinated approach towards effective implementation of the control programme.

At present, the disease occurrence, severity of the clinical disease and number of outbreaks in India have progressively and substantially declined in areas under regular mass vaccination mostly under PPR_CP and partly under Assistance to States for Control of Animal Diseases (ASCAD) of the Government of India. The disease incidence has been in decline over the past five years as per outbreak data analysis (Balamurugan et al., 2014b). In India, the decreased numbers of outbreaks as well as changes in the severity of disease patterns recently observed might be due to the effectiveness of live attenuated vaccines, timely vaccination of sheep and goats, and circulation of a single Asian lineage virus, since the disease was first reported in India (Balamurugan et al., 2010). Current vaccination programme implemented in some states of India like Andhra Pradesh Chhattisgarh and Karnataka may alter PPR epidemiology, particularly distribution and pattern of disease (Balamurugan et al., 2014a, b, c; Singh, 2011). The other states which shortly follow the vaccination under PPR_CP in the ongoing XII

five year plan are Kerala, Tamil Nadu, Maharashtra, Goa, Union Territories (UTs) of Lakshadweep, Daman & Diu, Dadra & Nagar Haveli, Andaman & Nicobar Island and Puducherry (www.dadf.nic.in). Finally, it is hoped that PPR in the direction of RP will be eradicated in India within a decade.

Control Strategies

Control strategies may vary from country to country as per the prevalence of disease but in developing or under-developed countries the choices are limited. Social acceptance, public and regulatory support is essential for success of any disease control and eradication programme. In India stamping out policy is not feasible because of economic and socio-cultural reasons. However, the society will readily accept the vaccination programme without much hindrance. Hence, vaccination is a recommended tool to support control and eradication efforts and thus to limit the economic losses due to PPR (Singh et al., 2009; Balamurugan et al., 2014c).

Vaccination strategies for the control of PPR would be slightly different from vaccination programmes for RP, which was discussed earlier in detail (Balamurugan et al., 2014c). A mass vaccination campaign to cover 80% herd or flock immunity would be needed to account for the population dynamics of sheep and goats, differences in sheep and goats husbandry practices and the agro-climatic conditions affecting the pattern of disease (Singh, 2011). The slaughtering of male goats at an early age combined with the high fecundity of the caprine species results in replacement of population (~30-40% naïve population appears) every year and thus a different approach is needed to control the PPR. Initially, 'intensive vaccination' of the entire population within a specified area, subsequently 'vaccinations on younger animals' at approximately >6 months of age is necessary (Singh, 2011) to avoid window of susceptibility in kids to PPRV infection (Balamurugan et al., 2012c). The 4 to 6 months old young ones in and around the vaccinated flocks will be 20 to 30% of the population at that point of time but the vaccinated flocks available will be 70 to 80% and provide the flock immunity. Vaccinated animals, infected and recovered animals are protected from re-infection for the remainder of their lives. Hence, in this direction, the strategies were proposed in the PPR_CP involving intensive vaccination of all susceptible sheep and goats and their three subsequent generations (approx. 30%) with 100% fund from central assistance. The basis for selection of some states in the first phase for control programme may be due to high prevalence of disease in the region or dense population of small ruminants, availability of facilities and personnel to cover the vaccination in a stipulated time periods, etc. or to make disease free zone in case of UTs where less population of sheep and goats. In the past five years, the vaccination and sero-monitoring was carried out extensively in the PPR_CP in some states of India especially Andhra Pradesh and Karnataka. Government of India also providing funding / grand in-aid under this PPR_CP, to research institutions for assisting and undertaking surveillance and monitoring of PPR during the surveillance stage with states / UTs animal husbandry department. The second alternative strategy may be focussing vaccinations initially on high-risk group animals, namely young animals (6 months to 1 year aged) and goat population rather than sheep and migratory flocks (Singh, 2011) in suitable period preferably during lean periods. The third strategy might be intensive vaccinations based on populations to make disease free areas (zone) by identifying the hotspots and implementing vaccinations followed by screening, testing and over all revaccination, if required, in those areas as reported earlier (Singh, 2011; Balamurugan et al., 2014c).

A brief description of the strategic vaccination followed in some states of India viz. Karnataka, Chhattisgarh, Andhra Pradesh are presented here.

In Karnataka, 9.58 million sheep and 4.79 million goats are reared (BAHS, 2012). The disease was reported in the state for the first time in 1992 (Srinivas and Gopal, 1996) and started spreading across varied agro-climatic conditions with varying intensities. The disease occurrence intensified in the later years and reached a peak during 2004-2006. Outbreaks were more frequent during winter seasons and all the districts in the state except coastal districts, where density of the small ruminants population is less. Considering the threat to the smallholder's economy due to PPR, the state has started 'focused vaccination' using experimental batch of the vaccine till 2003. Since 2004, live attenuated homologous vaccine on a large scale was produced in the state government facility at Institute of Animal Health and Veterinary Biologicals (IAH&VB), Bengaluru and utilized in the state 'vaccination programme' (Hegde et al., 2009). Thus, the number of outbreaks started declining and reached

as low as six outbreaks during 2011-2012 and nine outbreaks 2012-2013 from 184 and 175 outbreaks during 2004-2005 and 2005-2006 with a reduction mortality percentage of 73.4% (Anonymous, 2013).

In consonance with NCP_CP, Karnataka state continued its initial success and furthered the vaccination programme in the 'pulse polio vaccination model' covering approximately 14 million sheep and goats in all the villages of the state using 250 vaccination teams targeting 13 million vaccination doses during 2011-2012. Each vaccination team comprises of one veterinary officer, five vaccinators and one assistant. The entire programme is planned for 24 working days in a month to cover various routes. Proper care has been taken for cold chain maintenance, timely supply of vaccine doses, needles, syringes and other materials. Compulsory disease reporting and sero-monitoring work (pre and post vaccination serum samples) to evaluate the efficacy of PPR vaccination was also taken up. Severity of outbreaks after the first phase of pulse vaccination was very low (only three outbreaks were reported with 42 diseased and eight deaths cases) due to intensive vaccination (coverage was >90%). Further, state level monitoring committee decided to take up 100% of vaccination in the 2nd phase in the pulse polio model and vaccination was carried out during May to June, 2013. Subsequently. 30% of the naïve sheep and goat population of the state was taken as target for the 3rd phase of vaccination and programme was taken up after 6 months of 2nd phase in the month of November to December, 2013 and thereafter every six month intervals vaccination of the naïve population of aged between four to 10 months along with left over animals in previous vaccination were undertaken regularly. In conclusion, Karnataka, which was reporting outbreaks between 60-142 in the years 2005-2006 to 2007-2008, came down to a level of one to three reported outbreaks in the year 2011-2012 by adopting mass vaccination campaign in the target population (Singh and Bandyopadhyay, 2015).

In Andhra Pradesh around 26.3 million sheep and 9.07 million goats are reared (BAHS, 2012) and state stands number one in sheep population in India. During the year 1998, around 183 PPR outbreaks were reported and later the outbreaks become unabated and reached a peak of 532 during 2004 - 2005. During 2005, a loss of INR 1265 million was estimated due to 533 PPR outbreaks (Sireesha et al., 2014). Andhra Pradesh was continuously reporting 300 to 500 PPR outbreaks during the year 2002 -2003 to 2005 -2006 (Singh and Bandyopadhyay, 2015) and during 2000 to 2007, on an average, 400 outbreaks were recorded every year (Sireesha et al., 2014). Action plan was prepared for control of PPR by considering the disease outbreaks data, population density, migration profiles, and seasonality of the disease and availability of the vaccine (Sireesha et al., 2014).

The state government received PPR vaccine technology from IVRI and the Veterinary Biological and Research Institute (VBRI), Hyderabad and started producing on a large scale since 2006. A 'mass vaccination programme' against PPR was carried out from January 2007 to March 2008 covering 82% sheep and goat population (25.50 million sheep and 9.60 million goats) followed by 'annual vaccination campaigns' until 2010 to cover the new-born young stock above five months age and unvaccinated animals, which resulted in marked decline in PPR outbreaks (Sireesha et al., 2014). In consonance with the Government of India's initiative to control PPR in the national control programme mode, Andhra Pradesh government furthered its initial success in the pulse vaccination mode during 2011. Implementation of pulse vaccination and continuation of vaccination on a half yearly basis based on the lambing/kidding pattern during predesignated specified period from 2012 to 2014 (with pre and post vaccination sero-monitoring @ 0.01% of the total vaccinates) resulted in outbreaks limited to three numbers during 2013-2014 (Sireesha et al., 2014). The flock immunity in vaccinated animals ranged from 81 to 95.6 % (Singh and Bandyopadhyay, 2015).

Andhra Pradesh with a population of about 35 million sheep and goats was able to reduce the burden of PPR outbreaks by about 99 % (one reported outbreak in 2011–2012 and 2012–2013 as against about 300 outbreaks in the year 2005–2006) (Singh and Bandyopadhyay, 2015). Further, focused vaccination to contain the outbreak followed by two cycles of intermittent mass vaccination and selective vaccinations of unvaccinated lambs/kids above five months age reduced the epidemic level to more than 95 % (Singh and Bandyopadhyay, 2015). However, identification of unvaccinated animals, which also include 35-40% newly introduced animals, movement of animals in and out of the districts and farmers' insistence on repeat vaccination for vaccinated animals and cold chain maintenance for storage of vaccines and wast-

age of vaccines in the field due to large number of doses in a vial were the problems related to the field vaccination (Sireesha et al., 2014). With a strategic vaccination campaign, the disease has been kept under control, it may eventually lead to complete control and eradication of the disease from the state and subsequently from the country. The major success of PPR_CP initiated in this state was due to availability of the vaccine technology; capacity to produce the required doses in its own facility; financial, administrative and policy support from the state government and furthering the initial success of PPR control by inclusion of state actions in first phase of PPR_CP as per central government policy. Above all, active participation of sheep and goats rearing farmers in the vaccination programme strengthened the programme in controlling PPR in small ruminants.

In Chhattisgarh, 0.16 million sheep and 3.22 million goats are reared (BAHS, 2012). It is one of the small states in India and carved out of Madhya Pradesh during 2000. In this state, the goat is overwhelmingly reared in the rural setup than sheep, under very low input conditions. During the last decade, PPR inflicted profound damage to the goat population resulting in huge mortality and morbidity and thus affected the livelihood of goat rearing farmers. The annual loss estimated due to PPR in the state was > INR 590 million (Roy et al., 2014). Lack of efficient diagnostic facilities available in the state hampered timely testing & reporting of the disease thus in exercising control options to control PPR. Considering the increasing PPR outbreaks trend and erosion of livelihood of goats rearing farmers, the vaccination against PPR was initiated by the state government on the lines of 'pulse polio campaign' targeting sheep and goats during 2009-2010 through funds from ASCAD and Rashtriya Krishi Vikas Yojana (RKVY). Since 2010-2011, regular 'annual mass vaccination' campaign is being conducted.

The "mass vaccination strategy" was followed in the pulse polio programme mode in the designated dates every year with intense mass media campaign to reach out to farmers. During the campaign, continuous vaccination work is being carried out for 11-12 days with daily monitoring of events through control rooms at district and state level. For each campaign, vaccination teams are identified which consists of two to three members assigned to cover six to 12 villages (depending upon the topography, animal distribution, transport availability etc.) in designated campaign period. Besides farm reared small ruminants, goat markets, nomadic units and selling units, check post in the city and state borders were also vaccinated to maximize the vaccination coverage. Further, emergency vaccination in the face of disease incidence, outbreaks and / or epizootics (if any) and vaccination in villages that missed out during the campaign were also carried out subsequently as follow up vaccination to cover un-vaccinated animals in the regular programme. The vaccination was undertaken in three phases. In the pre-vaccination phase, besides administrative activities, training of the personal, procurement of vaccines and collection of random pre-vaccination serum (@ 0.01% of the goat population) were carried out. In the vaccination phase, vaccinating the animals, report generation on daily basis and monitoring were undertaken. In the post vaccination phase collection of serum samples for monitoring the progress of sero-conversion were undertaken. As a result of co-ordinated efforts of various departments with the well planned "vaccination programme" no incidence of PPR was reported since 2013-2014 (Roy et al., 2014).

On comparison, trend of PPR outbreaks at the national level was similar to the trend as observed in Karnataka, Chhattisgarh and Andhra Pradesh states indicating a decline of about 75-80 % outbreaks. Around 165 to 247 outbreaks were reported between 2009-2010 to 2012-2013 as compared to 1071 outbreaks during 2005-2006 (Singh and Bandyopadhyay, 2015). However, there was no further definite declining trend during the last four years (2009-2013) at the national level. This observation indicates that the mass vaccinations at national level is necessary as carried out in the aforementioned states to control PPR in sheep and goats (Singh and Bandyopadhyay, 2015). In India, the animal husbandry practices is a state subject and initiation of the programme has to be from the state level. Generally, success of the vaccination programme and control of disease depends on various factors, like animal husbandry practices, availability of sheep and goats population in particular area, seasonal lambing and kidding periods, etc., Any other states in India or any endemic countries of similar geographical size and socio-economic and /or socio-cultural rearing of small ruminants rearing pattern can take up the strategies which would be better for their region, conducive and highly suitable based on their available resources, fund availability, infra structure facilities, trained manpower, etc.

In overall, fixed strategies may not work for all the states or region or the countries. However, in the mass vaccination in pulse polio model covering entire population initially, followed by bi-annual vaccination in a predesignated stipulated period, covering the naïve young population of sheep and goats at least four to five years will have a tremendous impact on the control of PPR outbreaks in sheep and goats. Thus, after three to four round of vaccination, the population in the state may be immune to the disease, but the threat persists from ingress of disease from other bordering states, hence vaccination on the migratory population at the check post or border regions of the states or inter-state border or in the place of entry or place of trade market of animal through transport from other states are to be targeted for mass vaccination as and when required.

Conclusion and Perspectives

At present, the disease has been brought under control in sheep and goats by available effective and safe live attenuated cell culture PPR vaccine. Andhra Pradesh, Karnataka, and Chhattisgarh states have shown a decline trend with >90% reduction in number of reported PPR outbreaks during the preceding five years due to implementation of strategic mass vaccination programme. Sharing experiences on the planning and implementation of vaccination and control strategies adopted against PPR in sheep and goats by some of states in India may motivate other Indian states or countries for similar initiatives leading to progressive mass vaccination and control of PPR. The epidemiology of PPR is likely to change due to vaccination, as the disease occurs more severely in the naïve population, which warrants the study to be undertaken to know the changing pattern of the disease and its severity in vaccinated and unvaccinated regions. Understanding the determinants affecting virus or vaccine response, immune-biology of vaccine response in different host or bread will enable us to find low and high responder animals or factors that affect the vaccine efficiency and will also direct us regarding how to modulate these factors to obtain better protection to combat the disease, which in turn will improve the ongoing vaccination programme. Analytical study with statistical validity about incidence of disease and socioeconomic impact would be extremely useful and elicit widespread interest by providing sufficient additional information, which are important to support control policy decisions.

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Conflict of Interest

No conflict of interest exists.

Authors' Contribution

V. Balamurugan planned and wrote the draft of manuscript, G.Govindaraj provided inputs, support, and edited manuscript and H. Rahman provided guidance and support.

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