ICAR

Vision 2050

National Research Centre on Equines

&

Veterinary Type Culture Collection

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Message

Foreword

In view of the contribution of equines in regional and national economy and also the futuristic roles the equines will play in Indian agriculture and transport in changing climate scenario, the research programmes needs a drastic re-orientation with a view to help the equine industry to grow further. The formulation of a perspective plan with a visionary approach for the next 37 years is indispensable. However, the realization of output maximally with limited resources available to us has to be kept in mind.

Despite the decreasing population of equines in India, the economic impact of these animals is appreciable. There is a tremendous potential for growth and development of equines in India. Donkey has been used historically as a working animal, as draught or pack animal, and will continue in this direction, along with mule, especially in hilly and difficult terrains. Donkey Milk is a nutritious food, since time immemorial, and has been reported to have medicinal, nutritious and cosmetic properties. The equine industry has got unlimited potential in terms of contribution to the country's GDP, through racing and other equine events as well as the breeding of best quality thoroughbred horses for this industry world over. The exploitation of these potentials and to create new opportunities would be the objective of NRCE.

National Research Centre on Equines (NRCE) has been playing an important role as a technical leader in the development of equine sector by initiating efficient R&D for equine health and production. NRCE is the only institute responsible for researches on equine production, health, management, and husbandry in the country. The activities include addressing researchable issues in disease surveillance and monitoring, diagnosis, prevention, production including reproduction, nutrition, feeds and fodder, developing value-added products and all aspects of management and husbandry as well as policy and planning, enhancing awareness among stakeholders about equine husbandry practices and biosecurity.

The utility of microbiology research is based on channelizing the immense potential of the microbes to secure mankind in terms of disease control, food safety, nutritional security, and ecosystem conservation. VTCC is committed to enhancing the livestock production and productivity; food safety and nutritional security; efficient utilization of resources and reducing methane production by livestock, and sustaining animal, human and ecosystem health by way of providing a valuable microbial resource developed over a period of time. Conservation, maintenance, surveillance and utilization of animal microbes coupled with their management for understanding the microbial evolution would thus help in identifying the traits of animal microbes that are useful for livestock development and human welfare. Development of the state-of-the-art laboratory infrastructure and research, of international standard, envisioned in the document would keep the VTCC in pace with other international agencies and would help in becoming the world leader.

The challenges in livestock sector are the basis of this visionary approach while developing the perspective plan for 2050. Considering the national and international requirements and extrapolating the current circumstances and issues, research and development programmes along with the linkages required are planned to cope up with the emerging situation in equine/microbiology sector in India as a means of preparedness to combat emerging and re-emerging diseases, development and strengthening of national equine biological resource bank, VTCC, and development of state-of-the-art research facilities for technologies innovations.

The strategy framework integrated in this document for achieving the objectives would help NRCE in expanding its scientific knowledge and would certainly strengthen the nation in competing globally. The efforts and valuable inputs provided by my colleagues at the ICAR headquarters and by the Director and his team at the institute for development of this Vision 2050 document deserve appreciation.

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Preface

India, at present, ranks first in milk production in the world. Economists are now realizing that economic growth is possible only by sustaining agricultural growth. In India, as a sub-sector of the agricultural economy, livestock play a significant role in the development process of our country by providing draught and traction-power for agriculture and rural transport; providing raw materials in the form of wool, hair, hides, skins etc., for the manufacturing sector; generating enormous employment as livestock rearing is a highly labour-intensive activity; and livestock also serve as a source of quality nutrient in the form of milk, milk products, meat and eggs. The share of livestock in the agricultural GDP improved consistently from 15 % in 1981-82 to 26 % in 2010-11, and this gave a cushion to overall agricultural growth. Growth in crop sub-sector reduces poverty but growth in livestock production does more by engaging labour round-the-year, ensuring gender equity, and providing income to farmers on day-to-day basis. The animal husbandry sector engages about 22.4 million people round-the-year, which is around 5.5 % of the total work force in the country. Further, the gender equity and economic empowerment of women is more pronounced in livestock sector, as women participation is 71 % of the labour force, while it is only 33 % in crop farming. Pluriactivity – the phenomenon of farmers to have another gainful activity that can be a diversification of the holding or an activity not related to the farm that can take place on or off the farm – combined with professionalism (*i.e.*, dealing animal husbandry in a scientific manner and utilizing full potential) has potential to change the economic scenario of rural India. Interventions that benefit livestock producers can help poor combating poverty and ensuring livelihood.

As per the Livestock Census in 2007, the total livestock population is 529.7 million while poultry birds are 648.8 million. In 2011-12, the production of milk was estimated at 127.9 million tonnes, eggs at 66.45 billion numbers, wool at 44.73 million kg, and meat at 5.51 million tonnes. Per capita availability of milk has also increased from 176g/day in 1990-91 to 290g/day in 2011-12. Per capita availability of eggs was around 55/year in 2011-12. Global demand for livestock products is increasing rapidly. This change is more pronounced in the developing world. Increasing global demand for livestock products is an opportunity for India to increase its exports.

The livestock sector has to gear itself so as to meet the animal protein requirement of our population and is able to face the challenges due to climate change; provide employment to rural youth; act as cushion in times of economic crunch; and improve exports. Trained veterinary graduates and para-vets are key to growth in livestock

sector, which also includes public health services, private health services, academic, research, dairy industry, pharmaceutical industry, feed industry, breeding farms, meet industry, and financial services. The Indian Council of Agricultural Research (ICAR) is ready to provide all out research support to farm diversification and new initiatives on animal husbandry. Knowledge of recent developments in the field of animal husbandry will empower the work force of livestock sector to take all the challenges being put forth by the changing times.

At present, animal husbandry matrix includes professional management of animal health, animal production, animal products, animal welfare which assure better life for entrepreneurs involved in animal husbandry. The Indian Council of Agricultural Research brought out the first edition of *Handbook of Animal Husbandry* in 1962 for students, teachers, scientists, educated farm people, and those interested in the livestock farming and poultry farming. It has been revised in 1977, 1990, and 2002. This is the Fourth revised and enlarged edition of *Handbook of Animal Husbandry* which covers 48 chapters under eight sections *viz.*, Animal Genetics and Breeding, Animal Nutrition and Feed Technologies, Animal Management, Animal Reproduction, Animal Health Management, Animal Biotechnology, Animal Products, Technology and Machineries, Economics and Trade of Livestock and Poultry Enterprise, and Social Sciences. The current edition has been enriched by incorporating 19 new chapters (like Impact of Biotechnology, Nanotechnology: applications in Animal Sciences; Carbon trading: Mechanisms and Opportunities in Livestock Sector; Intellectual Property Rights; Indigenous Technical Knowledge etc.) while retaining the old chapters which have been revised holistically. This latest revised edition of Handbook encompasses theory and practice of animal husbandry in lucid language with crisp sentences to disseminate information on aspects central to animal husbandry. The technical terms are authentic and correct.

I am confident that the fourth revised and enlarged edition of *Handbook of Animal Husbandry* will prove useful to the students, teachers, livestock/poultry farmers, and to those who are interested in animal husbandry enterprise.

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Vision 2050

Part-I

National Research Centre on Equines

1. CONTEXT

A. Rationale

Over the years, the Indian Agricultural Research System under the aegis of the Indian Council of Agricultural Research has served a very useful purpose. Nevertheless; managing the change on a time-scale by converting weaknesses into opportunities to become internationally competitive is considered important in the fast-changing global context. We need to be forward looking and visible with appropriate agricultural research policies in place supported by the cutting-edge technologies in order to attain and sustain global advantages. It is in this background that the formulation of a perspective plan with a visionary approach for the next 37 years is quite necessary. The clearly spelt out options and likely changes would enable the system to capitalize on our strength so that the threats, if any, are converted into opportunities.

The National Research Centre on Equines is basically charged with the responsibility for technology generation for equine development in the country. Since, its inception in 1986, the Centre has grown form strength to strength with notable achievements. Keeping livelihood of the poorest-of-the-poor (landless, small and marginal farmers) and interest of the richest-of-the-rich (Race Clubs, Breeders, Turf authorities of India) and powerful (Police, Paramilitary forces, and Army) equine keepers in view, the NRCE has been able to tackle some of the problems especially health coverage, health service delivery, and import/export health certification, benefits of which have reached to the end-users in several parts of the country. It is envisaged that technologies developed by NRCE in vaccinology, diagnostics and reproduction would go a long way to benefit equine development programmes.

B. Background Information

1. The current scenario of equine production in India

The horse have been a symbol of bravery and the national pride because it provided power of fast movement and transport since ancient time and this still holds good in Indian society, although the equine are gradually losing economic and social importance. Prior to the ingress of Aryans from Asian Minor through Khyber Pass in North Western Frontier Province - now in Pakistan - the horse was not known in India and all civil and military activities depended on bullock power. The Aryans had known the importance of equine and had developed five different type of horses used for sports, warfare, carrying heavy loads and agricultural operations. Because of their

fast-moving horses and sharp-edged metallic sword they could easily capture the local Indian inhabitance and starting with their dominance in Indus valley they spread to the whole of Indo-Gangetic plains. The horses were subsequently bred in the country and a large number of horses from Arabia, Iran and Afghanistan were imported from time-to-time for use in sports and cavalry.

The equine population is declining continuously which reflects its fast reducing economic and social importance due to continuous mechanization of agriculture and transport and little effort in genetic improvement through selection. Further, conservation of elite animals of each breed is one of the main issues that needs to be addressed on priority on the basis of the limitations in current equine improvement programmes.

Despite the decreasing population of equines in India, the economic impact of these animals is appreciable. In India, there is a unique paradoxical situation in equine husbandry; one group comprises elite and highly affluent owners keeping the elite horses and combinely forms the elite class of equines while another group includes the neglected non-descript equines (ponies, mules and donkeys) reared by poorest-of-the-poor for their livelihood. Both the classes have got tremendous potential for growth and development. Donkey (*Equus asinus)* has been used as a working animal, either as draught or pack animal, for at least 5000 years and will continue in this manner, along with mule, especially in hilly and difficult terrains. Donkey Milk is a nutritious food since time immemorial and most sought after in many parts of not only India but the world over and fed immediately to newborn babies, especially in South India as donkey milk is closest to human mother milk and also because of its medicinal, nutritious and cosmetic effects on human being.

The elite equine industry has got unlimited potential in terms of contribution to the country's GDP. This is foreseeable in two ways - first through races and other equestrian events and second, more important, is through the breeding of best quality thoroughbred horses for this industry which can later be exported world over. The later has a vast potential being the most economic and cost-effective production of best quality competitive (thoroughbred) horses in India owing to availability of inexpensive labour and inputs. In USA, the horse industry is important part of national, state and local economies. It is diverse, involving agriculture, business, sport, gaming, entertainment and recreation. Numerous people are involved in the industry as horse owners, breeders, service providers, sports persons, employees and volunteers and many more participate as spectators. The horse industry has a direct economic effect on the US of $39 billion annually while it has a $102 billion impact on the US economy

when the multiplier effect of spending by industry suppliers and employees is taken into account. Additional creation of millions of jobs through various activities has its implications separately. The horse business is, thus, a highly diverse industry that supports a wide variety of activities in all regions of the country. It combines primarily the rural activities of breeding, training, maintaining and riding horses with the more urban activities of operating racetracks, off-track betting parlors, horse shows and public sales. Similar trends have been reported in economy of UK and Australia. The surveys show considerable growth in the industry. The potential of growth of equine industry is far more in India and can be exploited with the support from technical institutions like NRCE and government. The apprehension of quality service in terms of disease diagnosis, health certification, health service delivery and nutrition in India has been tackled so far with special care and devising special policies for them.

Important Indian Breeds of Horses and their breeding tracts

There are six descript breeds of Indian horses *viz.*, Marwari, Kathiawari, Manipuri, Spiti, Bhutia and Zanskari. The breeding tract of Marwari horse is the Marwar region in Rajasthan while the Kathiawari horse is the original saddle horse of the former Kathiawar province in the state of Gujarat in India. The Marwari and Kathiawari horses are famous for their beauty and vigor. The Manipuri horses are bred in the north eastern Indian state of Manipur and are acclaimed as original polo pony. The Spiti horses are found in the Kaja subdivision of the Lahaul and Spiti district of Himachal Pradesh and the adjoining Yanthang area of the Kinnaur district of Himachal Pradesh. They are capable of thriving in cold -arid and semi-arid climates and can survive even in adverse climatic conditions. Zanskari horses are bred at the high altitude in Zanskar region of Ladakh in eastern Jammu and Kashmir State. Spiti and Zanskari ponies are able to undertake long journeys at high altitude. Bhutia animals have their home-tracts in foothills of Himalayas namely Sikkim, Darjeeling, Arunachal Pradesh in India and Bhutan.

Donkeys

In fact, there are no recognized breeds of donkey as there is no breeding society to register animals of any breed on the basis of their recognized physical conformation, use and work capacity and no steps are being taken to ensure the purity of the breeds and for their genetic improvement and conservation. It is now that the NBAGR of the ICAR in collaboration with NRCE and State Agriculture/ Veterinary Universities has undertaken extensive surveys for description and evaluation of the Indigenous breeds and for their sustainable improvement and conservation. The whole programme is in the initial stages and needs to be strengthened through a more concerted effort of DAHD&F of GoI, ICAR- NBAGR, NRCE and concerned SAUs/SVUs and State Animal

Husbandry Departments. Since sustainable improvement and conservation is a continuous process, the State Animal Husbandry Departments which have the responsibility for provision of animal husbandry services should be supported by the Central and State Governments.

2. NRC on Equines

The NRC on Equines (NRCE) - an important research institute of the ICAR in Animal Sciences - is a component of National Agricultural Research System (NARS). It was established on 26th November 1985 at Hisar (Haryana) with a realization that equines play an important role in the economy of landless labourers and small and marginal farmers through supplementing their livelihood. NRCE has been striving hard since its establishment through performing research, training and extension activities that have resulted in improvement of equine health and production in India through control and eradication of a number of infectious diseases and genetic improvement of equine. The center grew stronger in 1989 when a sub-campus was established at Bikaner for undertaking breeding and production research because of the climatic conditions and ecology of Bikaner and this led to the working on the mandate of NRCE especially on equine production.

The research activities continue to bridge the gap between basic biology and clinical applications thereby providing cutting-edge technologies and products for improving the health and wellness of the Indian equines. The ongoing research covers the areas of equine virology, bacteriology, parasitology, immunology, pathology, medicine, biochemistry, biotechnology, genetics, breeding, physiology, reproduction, nutrition, and extension. The institution is disseminating information at national and international level to equine keepers through publications and direct contact.

The Centre has contributed significantly for upliftment of the landless lobourers and small and marginal farmers through improvement of their horses and donkeys through providing superior germplasm for natural service and AI and has also taken up programmes for conservation and sustainable improvement of the indigenous equines *viz.*, Marwari horses, Zanskari ponies, Poitu donkeys as well as small-grey and large-white donkeys.

A Veterinary Type Culture Centre (VTCC) has been established in the year 2005 at NRCE for collection and storage of microbes of animal origin. NRCE looks forward to the future with great enthusiasm to extend benefits to equine keepers in the country while VTCC has geared up to strengthen the national repository of microbes of animal origin for education, teaching and training, research and development, and microbial

diversity conservation which will serve as a biological resource not only for the present generation but also for the posterity.

Vision

Generation of relevant technologies in equine health and production and capacity building for competitive draught animal power (DAP) utilization in agriculture and rural transport and utilize other equine products and provide services particularly to the underprivileged members of the society under fast-changing environmental and socio-economic scenario.

Mission

- Achieving freedom from dreaded equine diseases through development of modern diagnostics, vaccines and therapeutic agents and undertaking proper disease surveillance, monitoring and forecasting and providing strategic control and eradication measures.
- Transfer of germplasm of superior donkey and indigenous horse breeds for improvement of horses and in their home tracts using A.I. and embryo transfer technology with an aim to establish embryo bank of Marwari and Kathiawari horses to enhance export of superior germplasm.
- Enhancing performance of working equids especially in arid, semi-arid and mountainous regions.
- Income generation through market intelligence activities especially through other products and services which equine can provide.

Mandate

- To undertake research on health and production in equines;
- To develop diagnostics/ biologicals for major equine diseases;
- To act as a National Referral Facility for diagnosis, surveillance and monitoring of equine diseases;
- To provide diagnostic, advisory and consultancy services.

Objectives

- Generation of demand-driven technologies for equine health & production.
- Capacity building for competitive equine power utilization in agricultural operations to serve the under privileged under changing environment & socio-economic scenario and also develop technologies for utilization of other equine

products and services.

C. Major R&D Achievements

I. Equine Health

1. Immunoassays and PCR-based diagnostics for equine diseases

The Centre has been recognized as national referral centre for diagnosis of 10 important equine infectious diseases by Department of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture (Government of India). The Centre has developed and refined diagnostics (including immunodiagnostics and molecular diagnostics) against various equine diseases. The immunoassays which are routinely being used in the laboratory for day-to-day work include Equiherpes B-ELISA for diagnosis of EHV-1 (released by Hon'ble DG, ICAR on August 20, 2008; under the process of commercialization by NRDC); EHV-1/4 recombinant glycoprotein G antigens-based type-specific ELISA for differentiation of EHV-1 and EHV-4 infections (routinely used in the laboratory); anti-ERV VP6 monoclonal antibody-based sELISA for detection of equine rotavirus (ERV) from stool samples (also detects rotaviruses from cattle, buffalo, sheep, human) (routinely used in the laboratory); Haemagglutination inhibition (HI) assays for diagnosis of equine influenza, Japanese encephalitis, and West Nile (routinely used in the laboratory); Serum neutralization test for diagnosis of Japanese Encephalitis (routinely used in the laboratory); Indirect Haemagglutination (IHA) test and Dot ELISA for the diagnosis of glanders; EMA-2 recombinant protein antigen based-ELISA for serodiagnosis of *T. equi* (DSp: 97%; DSn: 96% in comparison to OIE-approved CI ELISA) (routinely used in the laboratory);Indirect ELISA for serodiagnosis of *Trypanosoma evansi* (routinely used in the laboratory); EIAVgP26 synthetic recombinant protein antigen-based Coggins test and indirect ELISA for sero-diagnosis of EIA (DSn: 100%; DSp: 100%) (routinely used in the laboratory);Field-oriented Immunostick ELISA for EHV-1/4 detection (DSp: 93.24%, DSp: 100%); Virus neutralization (VN) test for serodiagnosis of equine viral arteritis (EVA) (routinely used in the laboratory); RoTat 1.2 and EMA-1/2 gene-specific PCR for sensitive detection of *Trypanosoma evansi* and *Theileria equi* infection, respectively; M-gene-based RT-PCR for diagnosis of equine influenza (routinely used in the laboratory); HA-3 and N8 gene-based RT-PCRs for typing and diagnosis of equine influenza (routinely used in the laboratory); M-gene-based Real-time RT-PCR for diagnosis of equine influenza and quantification of equine influenza virus (routinely used in the laboratory); Multiplex PCR targeting glycoprotein G for differentiation of EHV-1 and EHV-4 (routinely used in the laboratory); *Cho*E gene and species specific genes-based PCRs for detection of *R. Equi*; and Indirect

immunoperoxidase technique (IPT) for diagnosis of EHV-1, EI, *Rhodococcus equi,* Buffalo pox, and Camel pox; etc.

2. **Vaccines and Immuno-biologicals developed by NRCE**

Vaccines and Immuno-biologicals developed by NRCE include: Updated inactivated Equine influenza vaccine (A/equi-2/Katra/2008) for equine influenza; Inactivated EHV-1 vaccine (field-tested, this vaccine now in demand by Equine Breeders, Army); *Salmonella Abortusequi* (improved bacterin and outer membrane protein-based) vaccines for Salmonella *Abortusequi*; Inactivated equine influenza vaccine; Monoclonal antibodies and recombinant antigen(s)-based diagnostics for EHV-1, equine rotavirus, equine influenza virus, and Japanese encephalitis virus, EIA, glanders and *Theileria equi*.

3. **Services on Surveillance and monitoring, Disease Investigation and Contractual testing for equine diseases in India**
    - S&M activity: NRCE regularly carries nation-wide monitoring and serosurveillance for important equine infectious diseases with a view to manage, control, and eradicate diseases. A total of 11265 samples for more than 8 diseases have been tested during 2002-2012 under S&M alone.

4. **New initiatives undertaken**

***In vitro* culture system** has been developed for *Theileria equi* and *Trypanosoma evansi* which will help in understanding of pathogenesis of these pathogens as well as also serve as an *in vitro* model for drug screening. **Low-dose anti-trypanosoamal drug delivery**: Low-dose anti-trypanosoamal drug delivery by Nanonized drug (dose substantially reduced – a proof-of-the-concept study). **New chemotherapy trials against *Theileria equi*:** Limited study indicated that arteether+buparvaquone combination could be a better choice than imidocarb dipropionate for treating *T. equi* infection in donkeys. Individually arteether and buparvaquone showed no efficacy against clearing *T. equi* from blood in experimental donkeys. Haemato-biochemical parameters on these animals had shown that imidocarb had deleterious effect on the liver function while on the other hand arteether+buparvaquone combination was found to be safe.

II. Equine Production

The NRCE has been able to consolidate its activities by various developments like (i) establishment of Nucleus Herd of equines (Exotic donkeys, indigenous large white and

small grey donkeys, Marwari horses, and Zannskari ponies. Other animals like spiti and Manipuri will be added shortly; (ii) generating baseline data on different biochemical, physiological and hematological Indices in equines; (iii) work on equine work efficiency, (iv) phenotypic and genetic characterization of all the 6 recognized breeds of horses/ponies and on-going studies on characterization of donkeys; (v) cryopreservation of stallion and jack semen and use for breeding by artificial insemination (AI), (vi) collection and cryopreservation of semen of elite horses at farmers' door, (vii) early pregnancy diagnosis, and developing technology for utilization of animal energy and biowaste.

Why Vision 2050

The importance of equine in India is well known. India possesses 1.17 million equines. Major population of equidae - especially the indigenous equines - is with rural societies living in arid, semi-arid and hilly regions, and uses it as pack animal for transport of men & materials, carting etc.; while the Thoroughbred horses breeding and racing is another important component. With the acceptance and implementation of WTO, it has become imperative to improve and update the diagnostics/immunoprophylacsis for the betterment and augmentation of the equine production programmes in the country to meet out the international standards. The Centre has the responsibility of conducting research and providing effective health coverage and better technologies for reproduction and work performance for the welfare of the equines. In this endeavor, the NRCE has contributed remarkably.

The mechanization of agriculture and transport has led to reduction in number of equines. However, the increasing concerns on pollution, dwindling fossil fuel resources, ever-growing human population and therefore demand for energy are some points, increasing population opting fort tourism more frequently, and realization about importance of pet as companion animals in human welfare and wellness arousing passion in human population about companion animals, etc are some examples which indicate that we need to conserve horse power for future as we have already started moving towards conservation agriculture. The analysis of the previous experiences, problems and constraints revealed that sustainable development of equines can be achieved by envisioining the status of equines in country vis-à-vis international trends and formulating strategies for serving this sector with efficiency. This entails that NRCE should have a statement which should steer it through the changing times. As such, it is incumbent upon NRCE that it updates its infrastructure (physical and intellectual) so as to prepare it to meet the new challenges as time moves. The way ahead would be guided by integrated multi-disciplinary approach, targeted by sound research

programmes involving various stakeholders especially the farmers (poorest-of-the-poor and richest-of-the-rich), the Remount Veterinary Corps of the Ministry of Defense, Border Security Force and equestrian sport and tourism. There is a need to develop a strong national and international cooperation for sustainable development of equine production and health in the country. There already have been attempts in this direction immediately after the establishment of the centre which gave impetus to disease diagnosis and vaccine production and undertaking breed improvement programme. This vision document will pave our way and vision in this regard and will be bacon light for the NRCE as such.

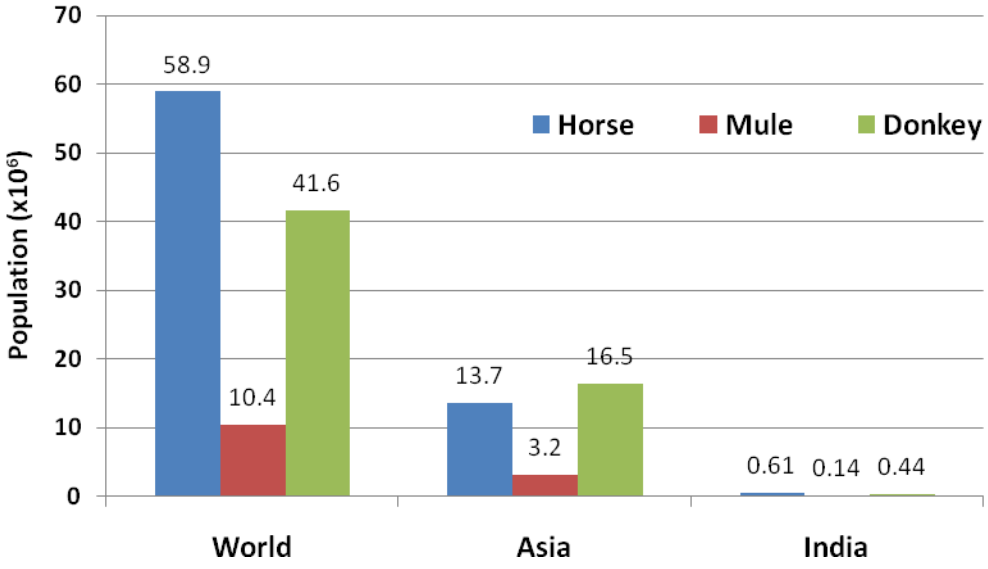
2. CHALLENGES

The total world horse population (~60 million) has been static, whereas donkey population has increased from 38.9 to 41.65 million and mule's population has decreased from 12.93 to 10.64 million, for the past thirty years. However, the most population of domestic ruminants (cattle, buffaloes, sheep, goats, camels) has increased at higher percentage over the same period of time, but this increase is small compared to rise in human population.

Equine Population – Global Scenario

(x1000,000)

	World	**Asia**	**India**
Horse	58.9	13.7	0.61
Mule	10.4	3.2	0.14
Donkey	41.6	16.5	0.44
Total	**110.9**	**33.4**	**1.19**

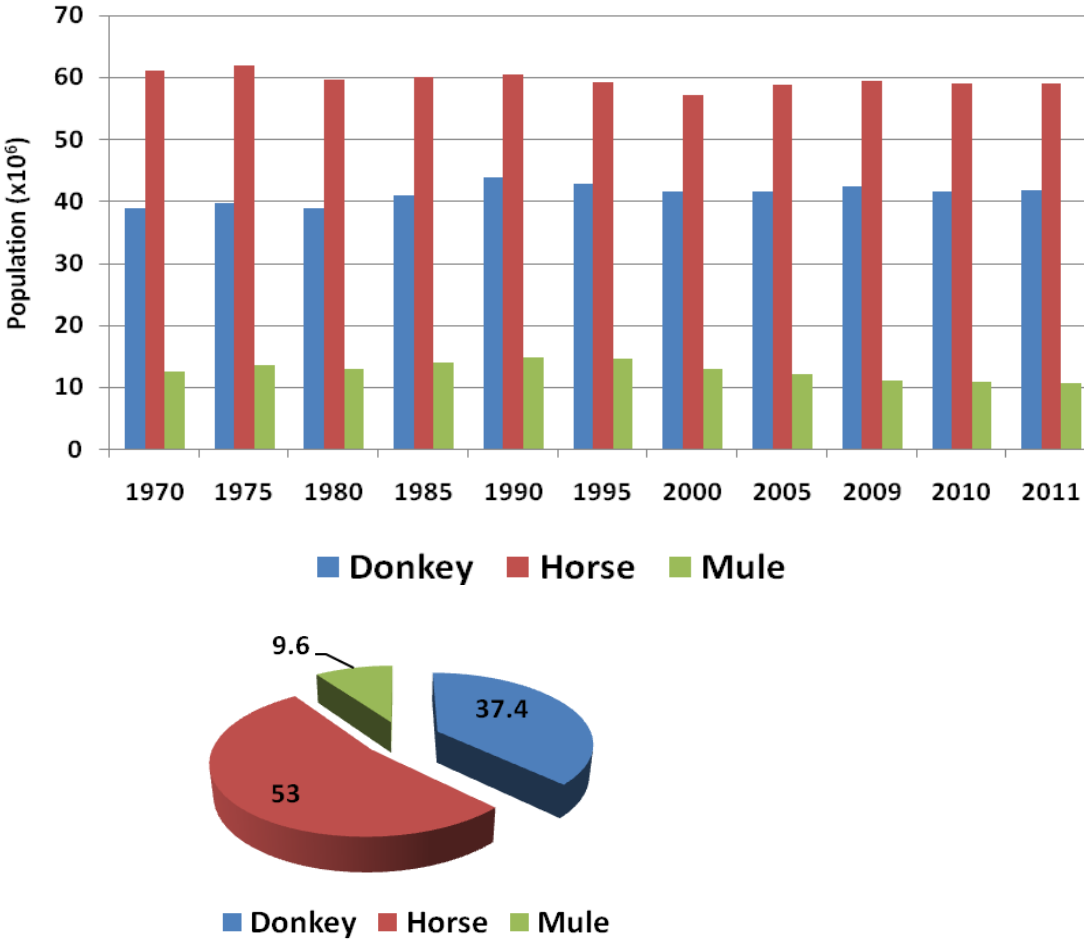


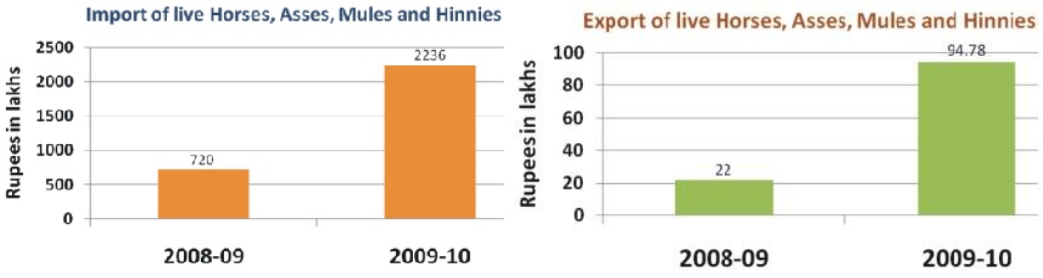
Indian Scenario

In India, there has been a continuous decline in the equine population starting with 1966 up to the last census conducted in 2007, the export/import of live horses has

increased remarkably. The present scenario with respect to equines in the economic and social milieu varies in different parts of the world and so is in India. In contrast to the affluent Western societies which prefer horses for sports and recreation, in India it is for the livelihood of the landless, small and marginal farmers the equine serve. The total population of equids in India is 1.18 million which comprises 52% horses, 37% donkeys and 11% mules.

Equine Population Trend in India





Live horse, ass, mule and hinny export import trends

Approximately, 98% equine in India contributes to the employment and income of the poor farmers and landless labourers who primarily depend on livestock. The remaining about 2% of the equine population is owned by elite sections of society and is used for sports such as racing, polo and for national security purpose by military and paramilitary forces.

Donkey Population Trend

The great majority of donkeys in the world (probably over 95%) are kept specifically for work. Their most common role is for transport, whether riding, pack transport or pulling carts. In most countries, donkeys can be owned and used by either men or women. Children are frequently given responsibility for working with donkeys. Some farmers keep donkeys for guarding sheep. Since donkeys are seldom owned and maintained unless they are worked, estimates of national and regional donkey populations provide useful indicators of donkey work worldwide. Overall population figures cannot provide information on the frequency of donkey use.

Donkey's population has declined dramatically in the most industrialized countries of Europe and North America. Although donkey populations are low in the developed countries, but it is the relatively stable in many rapidly industrializing countries such as Brazil, China, Dominican Republic, Ecuador, Egypt, Mexico, Morocco and Pakistan. These countries may be rapidly urbanizing, but they also have large rural populations with low incomes. These rural people continue to benefit from donkeys for local transport. The countries that have shown major declines in donkey numbers in recent years, have often have been those where the rural populations have had access to private motor vehicles (e.g., Italy, Ireland). The implication is that urbanization and industrialization only starts to have a significant effect on donkey populations when rural people are wealthy enough to replace donkey power with motor power. This is still a long way off in many parts of Africa, Asia and Latin America.

Certainly, declines have been recorded from Turkey, Israel and South Africa. In these countries (as in others) the use of donkeys is perceived as 'backward' and there are sometimes psychological pressures to remove the donkeys and become modernize. In Indian context also somehow more industrialization/mechanization may be responsible for decreased trend for donkey population.

In industrializing countries, expectations of declining donkey populations could become self-fulfilling prophesies, if accompanied by social pressures or legislation that marginalize donkey owners.

Challenges

(a) Short-term challenges

The short-term challenges include (i) development of user-friendly technologies which can provide disease-specific results more rapidly so that suitable control measures could be taken at the right time. Development of precise and economic diagnostics, effective vaccines, and other biologicals in mission-mode is important, (ii) enhance the utilization of equine (equestrian events, therapeutic horse riding, equine-assisted therapy or hippotherapy, agricultural operations especially in hilly terrain, tourism, human consumption of equine milk for therapeutic purposes, vermin-compost, electricity generation, etc) as such so that this species could become popular and become sustainable, (iii) provide a model plan towards cheap housing and nutritional management based on local resources so that health condition of working equids could be improved, (iv) impart training to local veterinarian in the field of modern tools of diagnosis and treatment so that they can deliver the necessary services at farmer's door-step, (v) to educate equine owners about package-of-practices of equine husbandry so that they can initiate this as an entrepreneur, (vi) the large gap between the available and usable technologies and their transfer to the equine keepers needs critical analysis and modification in identifying priorities, developing technologies and identifying procedures for their transfer. This must involve a participatory approach with the beneficiaries, (vii) to develop proper perception of the needs of location-specific technologies for problems associated with equine husbandry in different regions of the country, specific R&D inputs and feedback is required, (viii) there is a need to achieve freedom from economically important equine diseases through development of proper disease surveillance and monitoring and strategic control through developing modern diagnostics, vaccines, and therapeutics, (viii) studies on utilization of various services, products and by-products of equine origin, *viz*., draft power, milk, meat, skins, dung, urine and hair should be enhanced so as to improve income of the equine keepers, and (ix) ensuring market intelligence on various products and services and their transmission to the equine keepers for maximizing their economic returns.

(b) Long-term challenges

The long-term challenges include (i) to make efforts so as to popularize the use of equid-power in routine use for transport, human welfare, agricultural operations so as to plateau the equine population trend in coming years, and (ii) to foresee the introduction of exotic disease in Indian context and initiate research work accordingly so that we can combat these calamities efficiently by being in the state of "Emergency preparedness".

Issues related with Indian Equine Husbandry and future prospects

The equine population is declining continuously, which reflects its fast reducing economic and social importance due to continuous mechanization of agriculture and transport and little effort in genetic improvement through selection. Further, conservation of elite animals of each breed is one of the main issues that need to be addressed on priority on the basis of the limitations in current equine improvement programmes.

National Equine Breeding Policy: There is an urgent need to have a clearly defined "National Equine Breeding Policy" to ensure sustainable improvement and conservation through selection and avoidance of indiscriminate breeding which has already led to erosion of genetic resources in almost all recognized breeds of horses, viz., Marwari, Kathiawari, Manipuri, Spiti, Zanskari and Bhutia as well as donkeys. The large white donkeys are almost extinct. Registration of indigenous equines by a National Equine Society registered under the Department of Animal Husbandry, Dairying and Fisheries, GOI along with establishment of stud books and taking steps for conservation and sustainable improvement is urgently required.

Sustainable improvement and conservation strategies for equine genetic resources: At National level, there is a need to decide the effective (minimum) breeding population size of each of the recognized equine breeds so as to ensure their sustainable management and conservation. The effective population size is a function of number of breeding males and breeding females. Since the breeding males are generally used are few it results in inbreeding and random genetic drift and thus leads to deterioration in the performance of the breeds. This can be avoided by maintaining an adequate effective population size, especially the number of breeding males. The equine strength of descript/true-to-breed animals in each breed is declining and is endangering the genetic effectiveness of the breed. According to the current effective population size, most of Indian pony breeds (Manipuri, Zanskari, Spiti and Bhutia) are endangered. Almost similar is the situation for Marwari and Kathiawari breeds. Donkeys are also no exception, especially large white donkeys are almost extinct.

Since future requirement of indigenous equine products and services in the country has not been worked up, efforts are needed to determine such requirements and ensure the availability of requisite population of the different indigenous breeds so that programmes for their sustainable improvement and conservation can be taken by the State Governments with the technical guidance and financial assistance of GOI. The NBAGR/ NRCE can be the nodal technical agencies for formulation and assisting in

implementation of the sustainable improvement and conservation programmes. There is a need to realize that the indigenous breeds have developed unique traits through natural selection to meet the geographical requirements. Sustainable improvement and conservation of breeds is essential and for the purpose registration of these breeds under Geographical Indicators needs to be done on priorities so as to protect the available equine germplasm for use in the country and other tropical countries. This would be a direct aid in making the equine products and services available in the country and to meet the export possibilities.

Nutritional requirements: Though equines are currently reared in different parts of the country by different sections of the society, little has been done to determine nutritional requirements and develop appropriate feeding systems based on locally available animal feed resources. Basic information on specific feed and fodder requirement of all types of working and non-working equids, foals, broodmare, yearling, stallions etc. needs to be generated through proper feeding experiments associated with laboratory analysis of feeds and their utilization for different physiological functions by different species of equids. "Area-specific Package-of-Practices" based on feed and fodder requirements and their availability along with other limiting nutrients such as minerals and vitamins need to be developed on priority in collaboration with SAUs/SVUs. For disaster management, good quality feed and fodder in the form of pellets/ blocks also need to be conserved in such areas where such disasters are common and making such conserved feeds available to the equine keepers at nominal prices.

Enhancing opportunities for utilization of equine resources

Continuous decrease in equine population is a reflection on declining demand of the DAP in general and equine power in particular. The major use of equine is in difficult terrains where no other mechanical vehicle or draft animals can reach with heavy loads and the mule is the only alternative. The equine also have importance in warfare especially in high altitude mountainous areas. However, these animals are still a source of livelihood for the poorest-of-the-poor including potter-men, washer-men, nomadic people etc. Interest of such people in enhancing production and health is required which calls for appropriate R&D programmes.

The growing interest in equine sports and other events entails creation of appropriate infrastructure and facilities and developing human resource in the areas of sports medicine including athleticogenomics for understanding the athletic potential of individual horses.

Cooperation of NRCE with State and Central Agencies

Equine production and health has remained a neglected area since independence and

later research and development efforts or even education on equine in Veterinary and Animal Science currently exists. Till date, most of the State Animal Husbandry Departments have no special fund for development of the equines through establishing equine breeding studs or placing superior breeding males both horse and donkey stallions at state veterinary hospitals for providing service to the mares of the private equine keepers. The Defence Ministry through Remount Veterinary Corps places superior donkey stallions at veterinary hospitals or with private equine keepers for providing services to the equines of private owners on nominal charges. It is necessary that the provision of services of superior horse and donkey stallions through natural service/ Artificial insemination is provided at veterinary hospitals in dominant equine breeding areas. In addition, the state veterinarians at least in areas with large equine population should be specially trained in equine breeding and health and should be assisted in providing these services to equine keepers. The research institutions and state research and development agencies are generating a number of technologies for equine production and health which are not reaching to the end-users on account of poor demand and low socio-economic status of the equine owners and further non-availability of such services at places where they are required. Thus, active involvement of the departments of Animal Husbandry of the State Governments is required for implementing the improvement programmes which may involve availability of frozen semen and AI facilities and timely testing of pregnancies and provision of reproductive health in horses.

Packages of production and health practices: Area-specific packages of practices related to equine production and health needs to be developed for (i) feed and fodder requirement of equids of all the categories, (ii) proper feeding practices, (iii) health inputs – both prophylaxis and curative, (iv) advice on production management, and (v) ensuring animal welfare.

Thrust areas for future R&D: Strengthening of research in equine health on those diseases where NRCE has already succeeded, particularly on (i) refinement of diagnostic tests and associative assays, kits and reagents; (ii) tactical preparedness for developing newer diagnostic methods and preventive and control measures against infectious diseases of equines; (ii) understanding pathogen evolution through mutation or interaction of exotic genetic material, early warning against emerging/re-emerging diseases; (iii) emergency preparedness in terms of early diagnosis of disease, forewarning, and taking strategic control measures for the diseases. Emphasis to be given to clinical proteomics and whole genome sequencing in disease diagnosis and pathogen characterization and nanonized molecule(s) - targeted drug/vaccine delivery;

(iv) use of bioinformatics and modern biotechnology tools in designing vaccines, drugs and stem-cell therapy approach for control of important equine diseases, (v) a national policy on disease control, prevention and management is required to be developed where NRCE can provide knowledge and technology for control of endemic, re-emerging and exotic equine diseases and this should be in compliance with OIE norms, (vi) to conduct epidemiological investigations especially in widely distributed working equine populations with a statistically based population sampling survey framework so as to formulate disease forecast and control measures, (viii) establishment of equine sanctuary and *in situ* conservation of indigenous breeds of horses and donkeys by way of perfecting artificial insemination (AI) and embryo transfer technology (ETT), (ix) to collaborate with NBAGR in undertaking indigenous breed conservation approaches and initiate immediate action plans with the respective state government's /NGO/ SAUs and, agencies/department approved by Government of India, and (x) to initiate research work on equine welfare issues *viz*., harness design, cart improvement, shoeing, improving weight carrying capacity, and shelter management, etc., (xi) database and validation of ITKs in equine production and utilization, (xii) undertake research through collaboration with NBAGR and SAUs/SVUs for genetic improvement of mules, donkeys and ponies used for draught purposes, (xiii) promotion of research for enhancing nutritional quality of indigenous feed/fodder for formulation of ration for equids, (xiv) training of personnel including veterinarians and livestock assistants, educating equine breeders and farmers on training/adopting scientific equine practices for overall improvement of equine health and productivity, (xv) standardization of artificial insemination techniques in horses and donkeys for production of pony and mules using frozen semen of true-to-breed indigenous stallions both of the consortium of threatened breeds and for bringing genetic improvement in indigenous equines in India, (xvi) explorative research for value addition of equine products and byproducts, *viz*., blood/serum, dung, urine, milk, placenta and hair, (xvii) development of TOT activities through information technology and institute development programmes for the upgradation of the indigenous breeds of equids in the different parts of the country in collaboration with the State Animal Husbandry Departments, (xviii) converting biowaste arising out of equine husbandry to wealth for employment generation, augmenting income of the stakeholders including rural equine owners, ensuring animal/human health, and environmental sustainability, (xix) studies on equine work physiology of horses, ponies, donkeys, and mules, (xx) evaluating endurance potential of Marwari horses for equestrian events like Thoroughbred horses. Training of these horses is important to harness the potential of these horses in equestrian events, (xxi) evaluate donkey gut

physiology and microbiome to pinpoint the markers for efficient nutrient assimilation and utilization (donkeys and mules are thought to be efficient in nutrient utilization and assimilation as compared to other animals) which can give a lead for other animal species, (xxii) assess potential of horse milk and donkey milk as of cosmetic value, sports drink for athletes, and therapeutic drink for ailing and recovering human patients for their rejuvenation and popularize for world markets, and (xxiii) establish equine work physiology and equine sports medicine with special emphasis on creating infrastructure for studies on body scanning/mapping for kinetics of racing, athleticogenomics, and training of horses/riders/jockeys. Riding schools are required to be established in veterinary schools and universities which can later follow other general colleges and universities for motivating the younger generations in equine sports.

3. OPERATING ENVIRONMENT

Services offered

NRCE provides various services to the farmers, equine breeders, and other stakeholders which include: (i) disease diagnostic services for various infectious and non-infectious equine diseases to equine owners, breeders, state animal husbandry departments, police and army horses, (ii) Artificial insemination to augment the production of superior quality Marwari horses, mules and donkeys, (iii) Quality jacks and jennies are supplied to various states, breeding societies and farmers, for production of superior quality mules and donkeys, (iv) NRCE is providing health certification for movement of equines within and outside the country. This facility has helped in promotion of export of horses, (v) Assessment and transfer of technology to the end users using the latest know-how of information technology is done. The scientific and technical staff provides clinical and diagnostic (including pregnancy diagnosis) services and consultancy to the farmers on demand in the areas of equine health and production. Farmers are imparted trainings and supplied education materials for equine management, production and health, (vi) Extension activities to receive feedback from the equine owners, various activities like health camp, awareness and farmers meets are organized on regular basis in different areas of the country. Brief about these services is mentioned as below:

Surveillance and monitoring and Disease Investigation of equine diseases in India: NRCE is involved in nation-wide sero-surveillance and monitoring as well as disease investigation of important equine infectious diseases, with a view to manage, control and eradicate diseases. Important achievements of the Centre in disease surveillance include (i) information generated by NRCE about the status of AHS in the country helped in declaring India free of African horse sickness in 2006 by Office International des Epizooties (OIE), (ii) outbreaks of glanders in equine during 2006-07 were detected and control measures were taken to prevent its further spread. Since, then there were no reports of glanders for two years from India. However, in December 2010 the disease was once again confirmed by NRCE from Chandpur area of Bijnor district on the basis of clinical symptoms, microbiological investigations (agent isolation and identification), molecular techniques (PCR) and serological tests (CFT and ELISA). In 2012 team of scientists from NRCE investigated the cases with respiratory illness and cutaneous lesions upon information from Veterinary Officer of Bulandshahar, Uttar Pradesh during March, 2012. Four mules in Ahmedpur village of Agotta Block (District Bulandshahar) and two mules in Shikarpur of the same district were found positive for glanders in clinical and serological examinations (CFT and ELISA). Cutaneous and

nasal forms of glanders were observed in the affected mules. To contain the disease, the follow up monitoring and surveillance programme needs to be strengthened by the State Animal Husbandry department, with the technical support from NRCE, in the area in view of the recurring cases of glanders from this region(iii) NRCE diagnosed equine influenza (EI) in India in 2008 from Jammu region (July, 2008) that subsequently affected equines in 13 different states. The biosecurity measures were implemented in collaboration with various state animal husbandry departments. No new cases of EI have been reported from India since May 2009, and (iv) NRCE has continuously been screening equines for equine infectious anemia from 1998 and only one mule was found seropositive during 2009-10.

Contractual services for disease testing for certification: NRCE has been recognized as National Referral Lab for testing of 10 equine diseases [Equine Infectious Anaemia (AGID), Equine Influenza (HI), Equine rhinopneumonitis (CFT), Equine Piroplasmosis (CFT), Contagious Equine Metritis (Agent Identification), Equine Viral Arteritis (VNT), *Salmonella* Abortusequi infection (Agglutination), Dourine (CFT), Glanders (Mallein/CFT), Trypanosomosis (Agent Identification)] for the purpose of import or export. Besides testing of the samples from imported equines received from Animal Quarantine Stations located at Airports in India, the Centre also tests samples received in routine from Race clubs, Turf Authorities, Polo Clubs, Equestrian Federation, Thoroughbred Breeders, etc. on prescribed fee charge basis. Annually, NRCE earns approx. Rs 40-45 lakh from testing of such samples.

Artificial insemination and Pregnancy diagnosis: NRCE provides the artificial insemination services to farmers in the filed. The farmers of Rajasthan, Haryana, and Gujarat have embraced AI for mule production while AI for foal production has picked up in Rajasthan and Gujarat. The NRCE also provides the services of pregnancy diagnosis by Ultrasonography and rectal examination in all the states where the NRCE team goes for animal health camps, animal fairs, and kisan mela. NRCE also provides pregnancy diagnosis services employing the Pregmare Kit as and when samples are received from field.

Training of farmers and field vets, information dissemination through visits of stakeholders, farmers, field vets, and students: NRCE scientists provide timely help and support to under-privileged equine owners by organizing health camps, kisan goshthis and farmers interactive meets, etc. by disseminating the knowledge and technologies on equine health, production and management for optimal rearing of the animals to meet their livelihood. To popularize the technologies developed by NRCE, we regularly

participates in different animal fairs, exhibitions, and Kisan Melas. A total of 31 course/workshops/conferences/training; 70 health camps, kisan gosthis; 39 animal fairs, kisan melas, and exhibitions have been organized so far besides smaller activities at individual or small group level interactions. The groups of stakeholders, farmers, field vets, Paravets, and students visit farms at Hisar and Bikaner farms and these visiting groups are briefed about the R&D activities and the services provided to the stakeholders so that the information is widely disseminated to the stakeholders and the general public.

24-hour InfoEquine Helpline (Kisan Call centre): NRCE has started 24-Hour Helpline at Hisar (1800-180-1233) and Bikaner Centre (1800-180-6225) with call transfer facility beyond working hours to the cell phones of the scientists to provide information to the stakeholders including the farmers and equine owners on 24-hour basis. This service has become popular and helpful in advising the farmers about treatment of the animals and AI services.

Updation of equine diagnostic laboratories and recognitions as referral labs at NRCE: The NRCE laboratories have been recognized as (i0 National R referral Labs for 10 equine diseases by DAHD&F, GoI, (ii) as National Referral Lab on Human Glanders by Ministry of Health & Family Welfare, Government of India, and (iii) OIE-Twinning Labs on Equine Piroplasmosis, Glanders, and Equine Influenza. Such updation of laboratories is important in respect of validation by national and international agencies so as these labs can be put to use at regional basis when there is an emergency situation, besides routine activities.

Horse breeding and racing has picked up: Horse breeding and racing has picked up not only abroad but in India as well. The Marwari horses have proven their potential for use in racing and equestrian events as has been d3emonstrated by endurances races being held for the last 5-7 years. The Punjab government has approved establishment of a race course and also of an Equine Polyclinic. Punjab state is a Thoroughbred horse breeder state and also promoted indigenous horses in equestrian activities. The national animal shows every year in Punjab have motivated equine breeders and keepers. Polo and other equestrian sports and events have picked up in the country and therefore need to be promoted further.

Ancillary horse activities which have picked up: Thoroughbred breeding has been an old activity which also needs further thrust so as they contribute to national GDP. Hippotherapy has also picked up globally and is bound to have more practical application in time to come towards human welfare in view of the ever increasing stress

on human population. Mushroom cultivation was originally done using horse manure/compost as base material which later shifted towards cow dung. Horses have much less diseases in comparison to cattle and buffalo and, therefore, it is presumed that less number of pathogenic organisms are found in equine dung. This can scientifically be proven so that equine dung can once again be used in mushroom cultivation.

4. OPPORTUNITIES

Historically, equine enterprises have not actively accessed rural funding yet they perform varied and valuable functions in rural areas. As well as the economic benefits, our equine breeders and owners play their role in land management and environmental enhancement. With the continuing development towards use of equines in agricultural operations and tourist sector/horse safaris, we must recognise that the equines have a significant part to play as a land based activity and we must invest resources to ensure we capitalise on this. Equines are an important part of rural life and this sector also provides a unique opportunity for rich and poorest of the poor people. In view of the contribution of equines in regional and national agrarian economy and also the futuristic roles the equines will play in Indian agriculture and through rural transport of goods and materials and providing non conventional energy source for household and industrial sources under the changing climate scenario, the research strategies and goals will therefore have to be re-oriented with a view to help the equine husbandry.

Opportunities in equine sector

The opportunities in equine sector (i) potential of export of both Thoroughbred and indigenous horses to other countries, (ii) increasing demand of Thoroughbred and crossbred horses in the country for racing, riding and equestrian activities, (iii) employment generation at Stud Farms, Turf Clubs, Race Clubs, Riding Clubs and Equine establishments, (iv) use for preparation of pharmaceuticals like PMSG, ATS, anti-snake venom and antibacterial fraction from milk proteins, (v) use of AI using frozen semen for upgradation of indigenous donkeys and quality mules, (vi) use of horses for ceremonial, social, security and defense purposes, (vii) establishing equine work physiology and equine sports medicine, especially creating infrastructure for studies on body scanning/mapping for kinetics of racing, athleticogenomics, and training of horses/riders/jockeys, and (viii) riding schools are required to be established

Linkages and transfer of technologies

Strong linkages already exist with states having all the six recognized breeds (Marwari – Rajasthan, Kathiawari – Gujarat, Manipuri – Manipur, Bhutia – Sikkim, Spiti – Himachal Pradesh, Zanskari – Jammu & Kashmir) as well as other states which have good equine population like UP, Uttarakhand, Punjab, Gujarat, and, Maharashtra. However, some other states like Bihar, Andhra Pradesh, Tamil Nadu, and Karnataka need to be taken into fold. Breeds like Deccani need characterization for which linkage

with Maharashtra and Karnataka will be developed. Strong linkages with stakeholders like Donkey Owner societies, horse owner societies, private equine breeders, and Turf Authorities of India, etc. have also been developed in the past couple of years. However, further efforts are on to strengthen these linkages with more direct interaction.

Stakeholders in equine sectors

In the context of the control of animal diseases, stakeholders are defined as all those who have a direct or indirect association with animal disease and having potential impact of disease on their lives or the lives of their animals. In equine sector major stakeholders are small and landless farmers (Equine keepers), progressive equine farmers, race industry, national reference laboratories dealing with equines (CMVL, Meerut and RWITC, Pune), registered bodies/societies/association dealing with equines, army, animal husbandry officers, scientists, R & D personnel, NGOs engaged in equine husbandry/public bodies/village panchayats, tourists using equine at pilgrimage place and safari, and drug and vaccines manufacturers. Strong relationship exists between NRCE and these stakeholders. In view of the contribution of equines in regional and national agrarian economy and also the futuristic roles the equines will play in Indian agriculture and through rural transport of goods and materials and providing non-conventional energy source for household and industrial sources under the changing climate scenario, the research strategies and goals will, therefore, have to be re-oriented with a view to help the equine husbandry. A brief framework of strategies is as follows:

Equine Production Optimization, Conservation and Management

Artificial insemination: In light of poor availability of genetically superior breeding mares there is a need for establishment of a National Equine Semen Bank comprising cryopreserved semen of superior stallions of all the major equine breeds within horses and donkeys with special emphasis on Marwari and Kathiawari horses and indigenous (large white) and exotic donkeys. This bank will serve for in vitro conservation of elite germplasm of equines, and as a resource centre for equine semen for use in the breeding of mares of stakeholders . This bank will have all the facilities for production of semen of international standard in quality including microbiological quality so as to avoid transmission of infectious diseases . Technology for low-dose insemination for better utilization of good quality semen of true-to-breed equids. Beside this, sexed semen and intra-cytoplasmic sperm injection has evoked great interest in equine reproduction and work on these lines will be taken up to utilize the semen of very few elite stallions

available in India, for covering mares of indigenous breeds.

***In vivo* and *in vitro* conservation of elite germplasm of important breeds of equines, particularly endangered breeds:** Equine sanctuary: *in-situ* and *ex-situ* conservation of all the precious and endangered equine species for their future use, embryo transfer technology: for sustainable management and conservation of equine genetic resources, and good quality stallions (horses & donkeys) of high genetic merit and good with libido and semen quality and freezability for ensuring high conception rate.

Equine Nutrition and Production Management: Hormonal and ionic imbalance profiling: This is very important for assessing various reproductive disorders such as infertility, delayed and prolonged estrous and other hormonal deficiency problems commonly seen in equines. Equine nutrition and production management activities like survey and compilation of data on equine managemental practices adopted by equine owners in different agro-ecological zones, nutritional evaluation of different feed and fodder available in for area-specific package of practices to provide balanced ration & devising low cost, high energy feed for meeting natural calamities, utility of equine draught animal power in transport of men and materials and agricultural operations, equine products utilization: such as milk of horses and donkeys for cosmetics and therapeutics purposes (lactotransferrin), equine dung for organic manure/vermi-compost preparation, etc., adaptation studies on equines keeping in view the changing climate due to GHG emissions from chemical fertilizers, pesticides etc. used in crop production through research on stress physiology, shelter management, and equine behavior, training and re-training of field veterinarians, para-vets, breeders, and farmers in equine production and management.

Equine Genomics

- Phenotypic and genotypic characterization of six indigenous breeds *viz.* Kathiawari, Marwari, Spiti, Bhutia, Zanskari, and Manipuri have been completed. However, equine biological diversity of the country has not yet been addressed completely. Category of such equines which need further work on bio-diversity analysis and interrelationship among equine population include non-descriptive and geographically distinct indigenous donkeys (large white, small gray, Spiti, Zanskari, others), wild ass (Kiang and Ghorkhurkar),wild horse of Assam, and horse/pony breeds *viz.*, Deccani, Chhumurthi and Sikang breeds. Animals of these breeds will be characterized (phenotypic and genetic)during this period.
- Whole genome sequencing of indigenous breeds of horses (Marwari and Kathiawari)will be initiated with a view of (i)generating data on indigenous equines as mentioned above, (ii) establishing breed signatures, (iii) comparative data of whole genome sequence of indigenous equines *vis-à-vis* Thoroughbred

horse, (iv) studying evolutionary status of indigenous equines *vis-à-vis* Thoroughbred horse, donkeys and *vis-à-vis* Thoroughbred horse, (v) creating genomic library of important genes (reproduction related genes, disease resistance-related genes, athletics-related genes, etc.),

- Parentage testing: for registration of precious equines in studbook, for tagging performance evaluation of equines, and sale and purchase purpose *etc*.
- Athleticogenomics to identify animals at initial stages for their athletic potential and train them (rather than training every horse and then looking for its athletic potential). Specific traits need to be developed for screening of foals for their athletic potential.
- Breed signature for Marwari and Kathiawari horses.
- Export of Marwari horses is picking up. Further, Marwari horses are also now seen as alternative horse breed to Thoroughbred horses in racing and equestrian event industry. As such, parentages testing would be routinely required in time to come. NRCE would be establishing facilities for parentage testing in horses in near future.

f. Development of Diagnostics, target -driven Therapeutics and Vaccines

(i) Diagnostics

- *Diagnostics for exotic diseases:* Trans-border movement of equines is taking place for trade and sports activities. All equines that enter India (either imported or equines returning after participation) need to be tested for battery of exotic viral, bacterial and other diseases. There is also need for emergency preparedness of the Centre for exotic diseases that have the potential of emergence in India. Exotic equine diseases (like EEE, VEE, WEE, AHS, CEM, Vesiviruses, Lawsonia, and others) that have the potential of emergence in India due to global movement of equines for trade and sports need preparedness in terms of developing capacity for surveillance and diagnosis of these diseases. The Centre will develop capabilities for molecular and serological diagnosis of the exotic diseases, for emergency preparedness of the Country to face such threats.
- *Development and refinement of disease diagnostic assays:* The Centre has developed first and second generation diagnostics for emerging and existing equine diseases in India. The efforts will be focused on refinement of these diagnostics for quick, specific and sensitive diagnosis suitable for application at mass level. Special emphasis will be given to development of pen-side diagnostics, recombinant protein/peptide-based assays, real time PCR, microarray and clinical proteomics

using mass spectrometry. Refinement of field diagnostics will continue the priority of the centre. OIE Twinning program for equine piroplasmosis has already been completed and attempts are being made for obtaining referral status of this lab for equine piroplasmosis for South Asian region from OIE. Two other labs, one for Glanders and other for EI have also been strengthened further under OIE Twinning Laboratories programme to raise their level to become OIE referral labs. Capacity development through OIE-twinning program will help us in getting NRCE recognized as International Reference Centre for Equine Diseases.

(i) **Designing and development of drugs and chemotherapeutics** against important equine ailments, employing different drug designing tools. The drugs and vaccines developed will be refined by using better delivery systems, including nanoparticles.

(ii) **Stem cells in virology and equine therapy:** Various cell lines are required for cultivation of viruses for *in vitro* recovery of viruses from field samples, for production of biologicals and vaccine virus in bulk. Very little number of cell lines of equine origin are currently available. NRCE has initiated work in this direction and we have had promising results in developing all lines which gave better yield of virus. These efforts would continue to realize our goal of using stem cells in biological production which will help in developing low-cost biologicals. Further, amongst different livestock, it is only equines where stem cells have applications and have been extensively used abroad successfully for therapy of injuries causing lameness, tendonitis, etc. As such, research initiatives in this direction are most imperative. Collection, characterization, storage of adult stem cells from various sources, including bone-marrow, adipose tissue, umbilical cord blood, and umbilical cord matrix will be exploited for their potential use in therapeutics of joint, bone and other ailments of equines. Embryonic stem cells generated from inner cell mass of blastocysts collected from mares will be exploited for use in therapy and also in somatic nuclear transfer technologies for conservation of elite equine breeds.

(iii) **Vaccines:** Single and combination vaccines against important preventable equine diseases like JE, viral diarrhoea, foal pneumonia will be developed. The vaccines already developed- like EI vaccine – will be refined to make them more safe and efficacious. DIVA strategy for vaccines against equine influenza and equine herpes viruses will be attempted.

(iv) **Equine Disease Surveillance and Monitoring**

- The surveillance of equine diseases has been undertaken by the Centre during last

two plans. A baseline data of equine diseases in different states of the country has been generated. However, more exhaustive data on temporal and geographic basis on equine diseases need to be generated to develop disease mapping, forecast and development of timely control strategies using remote sensing and GIS data. A network project with centres located in areas with significant equine population will help in real-time monitoring of diseases. Various stakeholders will be proposed as partners in this Network, including SAUs, State Animal Husbandry, RVC, SVUs, etc.

- Studies on "vector biology" for important different equine diseases.
- Microbial genomics emphasizing infectogenomics, pathogenomics and clinical proteomics: Important bacterial, viral, parasitic pathogens of equines will be characterized for their genomic, proteomic and host pathogen interaction. A library of various equine pathogens and their genome will be made. The information will be utilized for development of diagnostics, vaccines and control strategies.

Keeping pace with horse breeding and racing which is picking up

- Horse breeding and racing contributed enormously to GDP as has been shown for many countries. It is time that India also embarks on large-scale thoroughbred horse breeding and export activities. The gains from equine breeding will be many folds higher than any agricultural operation and employment potential is also very high.

- Breeding of the Marwari horses should also be taken up on large-scale as Marwari horses have become very popular the world over as Marwari horses have proven their potential for use in racing and equestrian events as has been demonstrated by endurances races being held in India.

- The state governments in India should promote equine activities on the lines of the Punjab Government which has recently approved establishment of a race course and also of an Equine Polyclinic. Punjab state is a Thoroughbred horse breeder state and also promoted indigenous horses in equestrian activities. Organization of equine fairs on national scale will go a long way in motivating equine breeders and keepers.

- All the states should encourage Polo and other equestrian sports and events to make equines popular in the society which will also help in engaging younger generation who are facing unemployment.

Ancillary horse activities which have picked up

- Thoroughbred breeding in India has been an old activity and is done on limited scale. Thoroughbred breeding should be given thrust in the country as it has potential to contribute significantly to national GDP.
- Promote therapeutic horse riding of Hippotherapy as it is very useful in rehabilitation medicine. Hippotherapy has become much popular in US and other developed countries in the wake of natural disasters like cyclones and storms and also man-made problems like gun firings. In India also, hippotherapy centres have been operating in big cities like Bengaluru. This activity should be promoted by state governments as hippotherapy has potential and will become popular in human rehabilitation medicine in time to come for ensuring human welfare in view of the ever increasing stress on human population.
- Encourage mushroom cultivation using horse manure/compost as base material as horse dung is thought to be much safer than cow and buffalo dung.

HRD & Capacity Development

- Skill development/up-gradation of all stakeholders connected with equine farming.
- Building state-of-art capacity at NRCE for handling national and global training and technology requirement and to position it as a Centre of Excellence on "Equine Production and Management".
- Development of national and international linkages for up-scaling the knowledge base in equine husbandry.

Extension/Outreach program

- For augmenting income generation and improving socio-economic status of equine owners.
- Package of practices for better equine health and management etc.

5. GOALS AND TARGETS

Constraints such as poverty and lack of knowledge mean that animal welfare is being compromised internationally. When working equines can no longer work, the owners lose their livelihoods, either temporarily or permanently. The welfare of working equines in developing countries is therefore crucially important, not only for the health and survival of those animals, but also for the livelihoods of the people who are dependent on them. The benefits included increased marketing opportunities for perishable products such as milk or vegetables, access to more distant markets, a reduction in household expenditure because large quantities of staple foodstuffs and farm inputs could be bought and transported at a lower unit cost, and diversification or intensification of household activities, providing extra income. Thus, the adoption of good equine health, welfare and working practices is among the most important ways that people in poor countries can help secure and improve their incomes.

The mission of the NRCE is to advance the health and welfare of horses by promoting the discovery and sharing of new knowledge, enhancing awareness of the need for targeted research, educating the public, expanding fundraising opportunities, and facilitating cooperation among funding agencies.

1. **Vaccines for combating diseases**

   The increasing international movement of horses combined with the relaxation of veterinary regulations has resulted in an increased incidence of equine infectious diseases. Vaccination, along with management measures, has become the primary method for the effective control of these diseases. Traditionally modified live and inactivated vaccines have been used and these vaccines have proven to be very successful in preventing disease. However, there are a number of equine infectious diseases for which conventional technology has shown its limitations. The advent of recombinant DNA technology has stimulated the development of second generation vaccines, including gene deleted mutants, live virus vectored vaccines, live bacteria vectored vaccines, and DNA vaccines. These vaccines have in common that protective antigens are endogenously processed and presented along the molecules of the MHC I and MHC II complex, resulting in the stimulation of both humoral and cell-mediated immune responses similar to natural infection.

2. **Development of next generation diagnostics**

   a. Development of Lab-on-Chip (LOC devices): In order to enhance diagnostic health care services at Point-of-care, devices based on microfluidics will be

future. The goal of these chips is to provide health care in poorly developed clinics and laboratories which have virtually no equipment. State-of-the-art LOC's will work wonders in our country especially for veterinary health care due to lack of infrastructure and field veterinarians will be able to perform immunoassays and nucleic acid assays in the field conditions with no laboratory support.

b. Microchips as early warning system in disease diagnosis: Concentration of certain micro-RNA in body fluids increases with the progression of diseases such as cancers. These short RNA may hold the key to faster, more accurate diagnoses. Development of micro RNA based microchips to work as early warning system for the body before the disease process can damage the body functions will be future successful diagnostic laboratory.

c. Biosensors: Development of biosensors to detect biomarkers related to a particular disease is required with be a thrust in the future for better disease diagnosis and control. In the medical field, a majority of biosensors are included in glucose meters, blood gas analyzers, electrolyte analyzers, and metabolite analyzers. There is an urgent need for developing hand held devices for use by Veterinarian/ stakeholders for point-of-care diagnosis.

d. DNA probes to understand complex multiple gene expression: The future envisages DNA probes with an ability to detect complex interrelationships between multiple gene expression and environmental factors, at the molecular level. This will help in detecting diseases, which are not the result of single-gene, or monogenetic disorders.

3. **Molecular epidemiology and evolution of equine pathogens:** Various disease driving factors are adversely influencing the equine development. This trend is only to move forward with emergence and re-emergence of infectious diseases and hence heightened surveillance and monitoring of equine diseases including zoonotic ones is essential. Competence building for surveillance and monitoring is an urgent needs and we should establish clinical proteomic and whole genome sequencing platform immediately to meet this challenge in order to monitoring of evolutionary mechanism of equine pathogens and emergence of novel pathogens.

4. Total Lab Automation, quality assurance and networking with state-of-the-art GIS

a. Clinical diagnosis represents a time-consuming process, involving a wide array of processes, ranging from obtaining samples to the final reporting. Total laboratory automation is a must along with use of advanced information systems that will be developed and lead to more integration of laboratory and clinical data for outcomes management, access by regulators, and research.

b. Stronger formal links need to be developed between animal health laboratories and public health agencies. A formally linked network involving Institute laboratories, state laboratory and private laboratories must develop in future so that a fast channel of communication can be developed to communicate quickly and respond promptly and effectively in order to address animal health problems without any time lapse.

c. New modeling and geographic information system (GIS) tools will be developed to provide additional supports to information exchange between the laboratory and the field.

d. The delivery of faster and accurate diagnosis due to rapid growth in globalization of trade, zoonotic diseases, threats of bioterrorism is a must along with rigorous International Standards for quality assurance. For this certification will be obtained from various accreditation agencies from India and abroad.

5. **Microbial genomics emphasizing infectogenomics, pathogenomics and clinical proteomics:** Important bacterial, viral, parasitic pathogens of equines will be characterized for their genomic, proteomic and host pathogen interaction. A library of various equine pathogens and their genome will be made. The information will be utilized for development of diagnostics, vaccines and control strategies.

6. **Artificial insemination:** Technology for low-dose insemination for better utilization of good quality semen of true-to-breed equids. Beside this, sexed semen and intra-cytoplasmic sperm injection has evoked great interest in equine reproduction and work on these lines will be taken up to utilize the semen of very few elite stallions available in India, for covering mares of indigenous breeds.

7. **Equine Genomics:** Phenotypic and genotypic characterization of six indigenous breeds, *viz*, Kathiawari, Marwari, Spiti, Bhutia, Zanskari, and Manipuri has been completed. However, equine biological diversity of the country has not yet been addressed completely. Category of such equines which need further work on bio-

diversity analysis and interrelationship among equine population include non-descriptive and geographically distinct indigenous donkeys (large white, small gray, Spiti, Zanskari, others), wild ass (Kiang and Ghorkhurkar), wild horse of Assam, and horse/pony breeds viz., Deccani, Chhumurthi and Sikang breeds. Animals of these breeds will be characterized (phenotypic and genetic) during this period.

8. **Whole genome sequencing** of indigenous breeds of horses (Marwari and Kathiawari)will be initiated with a view of (i) generating data on indigenous equines as mentioned above, (ii) establishing breed signatures, (iii) comparative data of whole genome sequence of indigenous equines vis-à-vis Thoroughbred horse, (iv) studying evolutionary status of indigenous equines vis-à-vis Thoroughbred horse, donkeys and vis-à-vis Thoroughbred horse, (v) creating genomic library of important genes (reproduction related genes, disease resistance-related genes, athletics-related genes, etc.),

9. **Development of Genetic tests:** The horse genome sequence was completed in 2006, with sequence available online to researchers in June of that year. This wealth of new data will be exploited to provide some very powerful tools that can be used to define more simply inherited diseases in horses at the molecular level, as well as potentially more complex diseases.

10. Parentage testing: for registration of precious equines in stud book, for tagging performance evaluation of equines, and sale and purchase purpose etc.

11. Athletico-genomics: Athletic-o-genomics to identify animals at initial stages for their athletic potential and train them (rather than training every horse and then looking for its athletic potential). Specific traits need to be developed for screening of foals for their athletic potential.

6. WAY FORWARD

In view of the contribution of equines in regional and national economy and also the futuristic roles the equines will play in Indian agriculture and transport in changing climate scenario, the research approaches to be re-oriented with a view to help the equine industry to grow further, but keeping in mind the realization of output maximally with limited resources available to us– which is detailed below:

1. Equine Genomics

Phenotypic and genotypic characterization of six indigenous breeds viz, Kathiawari, Marwari, Spiti, Bhutia, Zanskari, and Manipuri has been completed. However, equine biological diversity of the country has not yet been addressed completely and several other categories – not yet recognized as breeds – of equines still need to be characterized. Category of such equines which need further work on bio-diversity analysis and interrelationship among equine population include non descriptive and geographically distinct indigenous donkeys (large white, small gray, Spiti, Zanskari, others) and horse/pony breeds viz., Deccani, Chhumurthi and Sikang breeds. Animals of these breeds will be characterized (phenotypic and genetic) during this Plan period.

Whole genome sequencing of indigenous breeds of horses (Marwari and Kathiawari) will be initiated with a view of (i) generating data on indigenous equines as mentioned above, (ii) establishing breed signatures, (iii) comparative data of whole genome sequence of indigenous equines vis-à-vis thoroughbred horse/ Kahtiawari, (iv) creating genomic library of important genes (reproduction related genes, disease resistance-related genes, Athletics-related genes, etc.,

Parentage testing: for registration of precious equines in stud book, for tagging performance evaluation of equines and sale and purchase purpose etc.

Athleticogenomics: Human athleticogenomics is an established science that has been proven now to identify potential of individual sports person. The similar approach has been developed for cameline and equine sports but to a very limited extent. It is now time to focus on developing facilities and creating trained human resource for athleticogenomics work which will help in identifying potential equine athlete in very early stages. Once equine athletes are identified in early stages, it would be pertinent to train them exhaustively so as to prepare them physically, mentally and emotionally for excellent performance in equine activities. This will also minimize expenditure on training of horses which are otherwise not fit for athletic activities.

2. Equine Production Optimization and Conservation

(A) Artificial insemination: entails the following:

(a) Establishment of Equine Semen Bank comprising of cryopreserved semen of all the equine breeds with special emphasis on Marwari and Kathiawari horses, exotic Poitu and indigenous large white donkey. This bank will serve for in vitro conservation of elite/precious germplasm of equines, and as a resource centre for equine semen for use in the field by stakeholders. This bank will have all the facilities for production of semen of international standard in quality including microbiological analysis.

(b) Technology for low-dose insemination for better utilization of good quality semen of true to breed equines. Beside this, sexed semen and Intra-cytoplasmic sperm injection has evoked great interest in equine reproduction and work on these lines will be taken up to utilize the semen of very few elite stallions available in India, for breeding in mares of indigenous breeds.

(B) *In vivo and In vitro* conservation of elite and endangered breeds

(a) Equine sanctuary: in-situ and ex-situ conservation of all the precious and endangered equine species for their future use

(b) Good Quality stallions (horses & donkeys) for high quality semen

(C) Reproductive disorders for optimizing production

(a) Identification of sexually-transmitted diseases (STDs): The STDs are an issue with equine productivity and hence it is important address this issue.

(b) Hormonal and ionic imbalance profiling: This is very important for assessing various reproductive disorders such as infertility, delayed and prolonged estrous and other hormonal and ionic deficiency problems commonly seen in equines.

3. Biological Resource Repository

Biological resources constitute the basic resource for research and hence establishment of a strong resource repository is required. Following resource repositories are proposed to be strengthened/established at the Centre.

- Equine Microbial Collection
- Equine Semen Bank
- Equine Cell Line Bank including Equine Stem Cell Banking

4. Equine Nutrition, Physiology and Production Management

- Survey and compilation of data on equine managemental practices adopted by equine owners in different agro-ecological zones.

- Nutritional evaluation of different feed and fodder available in for area-specific package of practices to provide balanced ration & devising low cost - high energy feed for meeting natural calamities.
- Utility of equine draught power in field and agricultural operations.
- Equine byproducts utilization: Use of donkey milk for face cream preparation, use of equine milk (lactotransferrin) for therapeutics, equine dung for organic manure / vermi-compost preparation, etc.
- Adaptation studies on equines keeping in view the changing climate through research on stress physiology, shelter management, and equine behavior.
- Development of equine health calendar and disease management practices for use of farmers.
- Validation of technologies using participatory mode of stakeholders, refine them wherever necessary for adoption.
- Technology access and service delivery using ICT.
- Strengthening of national and international linkages for up-scaling the knowledge base in equine research and development.
- Training and re-training of Veterinarians, paravets, breeders, and farmers in equine reproduction, production and management.

5. New Generation Diagnostics and vaccines

- **Diagnostics for exotic diseases**

  Trans-border movement of equines is taking place for trade and sports activities. All equines that enter India (either imported or equines returning after participation) need to be tested for a battery of exotic viral and bacterial diseases. There is also need for emergency preparedness of the Centre for exotic diseases that have the potential of emergence in India. Exotic equine diseases (like EEE, VEE, WEE, AHS, CEM, Vesiviruses, Lawsonia, and others having risk as may be assessed at any point of time) that have the potential of emergence in India due to global movement of equines for trade and sports need preparedness in term of developing capacity for surveillance and diagnosis of these diseases. The Centre will develop capabilities for molecular and serological diagnosis of the exotic diseases, for emergency preparedness of the Country to face such threats.

- **Development and refinement of disease diagnostic assays**

  The Centre has developed first and second generation diagnostics for emerging and existing equine diseases in India. The efforts will be focused on refinement of these diagnostics for quick, specific and sensitive diagnosis suitable for application at mass level. Special emphasis will be given to development of pen-side diagnostics, recombinant protein/peptide based assays, Real time PCR, microarray and clinical proteomics using mass spectrometry. Refinement of field diagnostics will continue the priority of the centre. Twinning program has already been initiated at the centre. OIE-Twinning for Piroplasmosis is already in place. Further attempts are being made this year for twinning of labs for Glanders, EI, and EIA. Capacity development through OIE-twinning program will help us in getting NRCE recognized as International Reference Centre for Equine Diseases.

- **Vaccines**

  Single and combination vaccines against important vaccine-preventable equine diseases like JE, viral diarrhoea, foal pneumonia will be developed. The vaccines already developed - like EI vaccine - will be refined to make them safer and efficacious. DIVA strategy for vaccines against equine influenza and equine herpes viruses will be attempted.

- **National Referral Laboratory on Equine Diseases (or Centre of Excellence for Equine Disease Diagnosis**

  NRCE has through its pioneer work over last 25 years equipped itself with reliable, precise and quick diagnostic tests / kits for diagnosis of various diseases. The Centre envisages dedicating its knowledge in disease diagnosis with a focus to provide quick and early diagnosis to the stakeholders for the betterment of the health conditions of equines and to act timely for the control of the diseases. Also as clinical pathology is a back bone to successful diagnosis, treatment and prognosis of any disease and clinical decisions require a critical and sound analysis of various body systems of the diseased animal, we intend to develop core facilities for the strengthening of the clinical pathological aspects of the diagnosis.

6. Disease Surveillance and Monitoring

- All India network: The surveillance of equine diseases has been undertaken by the Centre during last two plans. A baseline data of equine diseases in different states of the country has been generated. However, more exhaustive data on temporal and geographic basis on equine diseases need to be generated to develop disease mapping, forecast and development of timely control strategies using remote sensing

and GIS data. A network project with centres located in areas with significant equine population will help in real-time monitoring of diseases. Various stakeholders will be proposed as partners in this Network, including SAUs, State Animal Husbandry, RVC, SVUs, etc.

- Outsourcing of sample collection - However, it seems that network may not be an economically-viable option in longer term. Another strategy could be outsourcing of sample collection services to private companies as has now been the practice at many multi-national companies working on veterinary biologicals. The NRCE also has this kind of experience under Contractual research project from Pfizer.
- Studies on "vector biology" for important different equine diseases.
- Microbial genomics emphasizing whole genome sequencing, infectogenomics, pathogenomics and clinical proteomics: Important bacterial, viral, parasitic pathogens of equines will be characterized for their genomic, proteomic and host pathogen interaction. A library of various equine pathogens and their genome will be made. The information will be utilized for development of diagnostics, vaccines and control strategies.

7. Therapy, drug designing, development and delivery

- Designing and development of drugs and chemotherapeutics against important equine ailments, employing different drug designing tools. The drugs and vaccines developed will be refined by using better delivery systems, including nanoparticles.
- Stem Cell in therapeutics: Among different livestock, it is only equines where stem cells have applications and have been extensively used abroad successfully for therapy of injuries causing lameness, tendonitis, etc. As such, research initiatives in this direction are most imperative. Collection, characterization, storage of adult stem cells from various sources, including skin/organ, bone marrow, adipose tissue, umbilical cord blood, and umbilical cord matrix needs to be exploited for their potential use in therapeutics of joint, bone and other ailments of equines.

8. HRD & Capacity Development

- Skill development/up-gradation of all stakeholders connected with equine farming
- Building state-of-art capacity at NRCE for handling national and global training and technology requirement and to position it as a centre of excellence
- Development of national and international linkages for up-scaling the knowledge base in equine husbandry.

Initiation of (i) Diploma in Equine Health and Management and (ii) Training course for Equine Paravets is important. NRCE is the only institute responsible for researches on equine production, health, management, and husbandry in the country. The activities include addressing researchable issues in disease surveillance and monitoring, diagnosis, prevention, production including reproduction, nutrition, feeds and fodder, and all aspects of management and husbandry. Most of the veterinarians posted in field do not get any exposure – beyond their BVSc & AH course – on equine management of equine health, production and husbandry practices. There is acute shortage of veterinarians and paraveterinarians trained in equine husbandry. The Centre gets flooded with requests from veterinarians, paraveterinarians, breeders, owners, farmers, paramilitary forces and police for training and re-training of stakeholders in equine production and management. Centre organizes training programmes on various issues of equine production and management. However, facilities which should be required to carry out such trainings to this high-end animal are not available. As such, it is proposed to initiate a (i) Diploma course in "Equine Health and Management, and (ii) Training course for Equine Paravets. This will help in increasing the human resource in equine husbandry. While we develop diagnostic and health research facilities at Hisar, the strengthening of existing Equine Reproduction and AI Labs as well as establishment of a "National Equine Semen/Embryo Bank" is required at EPC Bikaner. Creating such a Bank will be useful for cryopreservation of quality assured semen for use of AI in equines for production of true-to-breed horses/donkeys and superior quality mules. The practice of AI in horses is picking up fast and the Centre will have to develop its capacity to meet the requirement of the stakeholders.

- National Referral Lab on Equine Disease Diagnosis: Envisaging the national referral status for the equine disease diagnosis will entail setting up a new "Disease Diagnosis Laboratory including clinical virology, clinical bacteriology and clinical pathology". Establishment of "Clinical Proteomics and Whole Genome Sequencing Platform" will go a long way in earliest diagnosis and pathogen identification will go a long way in equine production and health management. Currently, the diagnosis work is done in different labs which are actually research labs not the diagnostic labs. Since NRCE provides diagnostic services to for import/export certification, it is essential that NRCE has NABL-Accredited labs, especially the diagnosis lab.
- Equestrian endurance and sports activities: The declining use of equines in agricultural and transport sectors due to mechanization has led to renewed interest in equestrian sports and leisure activities, which is in likely to get more thrust in

coming future. The NRCE - being the only centre on equines – should start work on endurance (since we already have good horses) and on equine sports medicine.

9. Flagship program on Donkey Production and Utilization

The donkeys constitute substantial population of equines and are used for carting, carriage, and agricultural operations. Donkeys have further contributed in production of mules which constitute important animals in carriage, transport, carting, tourism, building construction, and agriculture. Donkeys have further utility as companion animal, hippotherapy for human well-being, and in leisure sports. The contribution of donkeys has been enormous in agriculture; herding and carrying materials with migratory herds of cattle and migratory flocks of sheep and goats; transportation of agricultural produce and provisions, house-hold items; and also in building construction. In spite of these tremendous contributions, donkeys still remain without any breed. In India, donkeys are found in almost every state but noteworthy population is in Rajasthan, Gujarat, Uttar Pradesh, Bihar, and hilly states like Jammu and Kashmir, Himachal Pradesh, Uttarakhand, etc. donkeys in India are described as small grey and large white donkeys as there are still no identified breeds. However, various donkey populations like Zanskari in Zanskar valley, Spiti in Lahaul and Spiti valley, as well as large white and small grey donkeys in Rajasthan and Gujarat have a lot of differences phenotypically. Our experience has shown that donkeys also survive on refuse and scarce feed/ration/grasses. However, scientific studies are required on following areas:

1. Establishment of breed of indigenous donkeys
2. Nutritional requirement, feed uptake, and nutrient utilization capabilities
3. Immunology and reproduction of donkey
4. Utilization of male donkey (jacks) in superior mule production
5. Upgrading of indigenous donkeys to harness their draught power more efficiently

The program proposed as above will result in generation of quality scientific data on donkey genetics/nutrition/reproduction/immunology which will ultimately help in improvement in donkey population by scientific breeding, augmenting in production and utilization of superior indigenous donkeys, and ultimately conservation of diverse donkey population in the country.

Vision 2050

Part-II

Veterinary Type Culture Collection (VTCC)

[National Research Centre on Equines, Hisar]

1. CONTEXT

Microbes have shaped the human evolution, are continuing to do so now, and will continue to influence human and animal life in future as well. Microorganisms have acquired a special status since time immemorial for their use in enhancing livestock productivity and role in causing diseases in animals and human beings. Woolhouse and Gowtage-Sequeria (2005) described the main categories of factors associated with the emergence and re-emergence of human pathogens that include changes in land use or agricultural practices, changes in human demographics and society, poor population health (e.g., HIV, malnutrition), hospitals and medical procedures, pathogen evolution (*e.g.* antimicrobial drug resistance, increased virulence), contamination of food sources or water supplies, international travel, failure of public health programs, international trade and climate change. Overwhelming evidence shows that climate change presents growing threats to livestock, human and environmental health. The emergence and re-emergence of a number of diseases both in human and animals including wider spread of vector-borne diseases - majority of them are of zoonotic potential – pose significant challenges to health researchers, policy planners, administrators, public health officials, governments, and even general public not for a nation, or a region, but globally. With ever-changing climate, the infectious disease will further emerge and re- emerge and many new diseases are also to emerge which is worrisome challenge to all the stakeholders. The research in microbiology is based on harnessing the immense potential of the microbes to make animal and human lives secure and to study the ways in which microorganisms act for utilizing resources or causing disease. The research pertaining to use of microbes of animal origin is based on the following fundamental features; firstly to search for novel products from the microbes for the benefit of human kind; secondly, to study the pattern in which these organisms behave so as to harness the most from them in terms of overall livestock development and improving human lifestyle through searching for newer molecules, products, and processes in order to develop safer and cheaper diagnostics, vaccines and therapeutic strategies to combat the harmful organisms on one side and utilizing the best of the useful microbes for efficient utilization of feed and fodder, and developing livestock products (including dairy products) where in dairy and rumen microbes play significant roles, and thereby to understand microbial evolution and the changing pattern of infectious diseases to be in preparedness for emergency situations.

Microbial Biodiversity: Our Genetic Mine

In the "Rare Earth" hypothesis proposed by Ward and Brownlee (2004), they argue that "not only intelligent life but even the simplest of animal life, is exceedingly rare in our galaxy and this Universe". The hypothesis states that bacteria-like life might be common in the Universe, however complex life is uncommon. We humans must agree thus, that Earth is a valuable cradle and the life on/in it is a rare precious entity. The United Nations proclaimed 2010 to be the International Year of Biodiversity. All over the world, people in different walks of life, are working to safeguard this irreplaceable natural wealth and reduce the biodiversity loss. The biodiversity is essential for the ability of life to exist and evolve. However, obvious questions about the nature of biodiversity and its critical importance for existence of life on this earth and beyond need to be clear and ingrained in as many minds as possible. On this will depend, how we are able to stem the tide against its loss! That is why, in order to raise public awareness, the theme "Biodiversity is life. Biodiversity is our life", was coined by United Nations Secretariat of the Convention on Biological Diversity (SCBD).

The hypothesis of Ward and Brownlee (2004), states that bacteria-like life might be common in the Universe, there originates a thought that microbes are the life forms, the ultimate diversity, which has existed for ever, and the resultant intermediary forms and climax humans have evolved in a relatively calm environmentally suitable location like earth. According to International Union for Conservation of Nature (IUCN), Biodiversity is "the variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems". The term was used first by wildlife scientist and conservationist Raymond F. Dasmann (1968) in a book. In other words, it refers to the totality of variety of life, as it exists on a given location. However, as we know that a given life form does not and cannot exist in isolation, and it depends on the abiotic components and other biotic entities of that given location. There exists a dynamic equilibrium between the physical, chemical and the energy cycle abiotic components and the microscopic and macroscopic life-forms of the geographical location where this drama unfolds. The forces of this interaction act in both directions; and in turn shape the outcome of the geographical location and the richness of the life itself. The components of abiotic system like soil (chemicals, nutrients), water (solvent) and energy (insolation and its meteorological manifestations) interact among themselves to shape the geological landscape. The biotic systems like microbes, plants, insects and animals also interact with each other in a myriad of relationships. These biotic and abiotic components also interact in a natural probabilistic way. The dynamism of the interactions not only changes the geographical landscape but also leads to evolution of species. This brings us to the concept of eco-system, which is "a community of plants, animals and smaller organisms that live, feed,

reproduce and interact in the same area or environment". There exists a dynamic balance in the ecosystem, until the occurrence of a cataclysmic event! The biodiversity of plants and animals is largely known to us. However, the extent of microbial diversity is virtually unknown (less than 0.2% is known). The microbes form the roots of the tree of life. As such, in this genetic biodiversity lie mines of precious genetic information. Among the variety of environmental niches, the animals including wild animals, various organisms, fishes and birds are also one of the important locations of microbial life. Even the locations and niches harboured by animals and insects are teeming with myriad forms of microbes. Animals harbour various forms of microorganisms in and on their body in different role of associations which can be described as commensals, opportunists, mutualistic, beneficial or pathogenic. A majority of microorganisms are directly or indirectly beneficial to us in one form or other, many of these are either outrightly pathogenic like rabies, anthrax, brucellosis or aspergillosis, or they lie on the borderline of living peacefully on animals and suddenly showing the traits of being harmful, like Staphylococcus spp.. Many of bacteria and viruses living in the gastrointestinal tracts of animals and man like *Escherichia coli*, *Salmonella*, Rota virus and *Campylobacter* spp, and those living on body surface such as *Staphylococcus* are examples of such dubious kinds.

An important aspect of our understanding of host-microbe interaction is the ability to detect, identify and isolate microorganisms and to recognize diseases caused by them. Our abilities and achievements in this aspect have been so far limited. This has been due to use of conventional methods of pathogen research like dependence on microbial propagation methods, nonspecific clinical and epidemiological indicators, insensitive imprecise and sometimes cross-reacting serological tests, and an almost nil understanding of the microbial "background" in the external and internal host environment. In order to control disease in animals and humans a molecular understanding of pathogens and pathogenesis is imperative.

Genes are preferentially exchanged among microbes growing in similar environment. Therefore study of a microbial community inhabiting a niche can give us an idea about the tide and flow of genetic information in such a community. The genetic studies can only take place if after isolation, we develop a long term preservation environment which includes methods of cataloguing the isolates, their DNA isolation and preliminary 16S rRNA based identification and classification. This would be read in conjunction with metadata collected during the collection of samples from which pathogens are isolated. Such a data would constitute all the information concerned about the circumstances of isolation of pathogen thus providing a real epidemiological

backdrop of the pathogen. Example of such information is information on host, environment including meteorological data and type of samples.

The richness of these components is not equal all over the earth. As a result, the biodiversity itself is not equal all over our planet. As is obvious, there are certain geographical areas, like tropical rain forest, or the pristine depths of lake Baikal, or lake Chilka, where the biodiversity is immense. These have been termed as biodiversity hotspots. A biodiversity hotspot is a biogeographic region with a significant reservoir of biodiversity that is under threat from humans. India has a rich heritage of biodiversity that needs to be conserved. In the world, the major biodiversity hotspots have been listed. In the twenty-five biodiversity hotspots that were indicated (Myers *et al*. 2000), the three which belong to India are islands of Indian Ocean, the Western Ghats and the Sunderbans. We thus also needs to develop a thought on the biodiversity of our animal dwelling microbes, as these biodiversity hot-spots also have a huge diversity of wild ruminant and other animals, holding a reservoir of microbes, which can threaten novel epidemics or may mitigate the already existing one.

Microbial Scenario

The projected global increase in the distribution and prevalence of infectious diseases with climate change suggests a pending societal crisis. Climate, along with many other factors, can affect infectious diseases in a nonlinear fashion. The globe is significantly warmer than it was a century ago; similar trend is likely to follow through 2050; there are projections of changing and increase in infectious diseases with the drastic changes in the climate. This would make the research in microbiology more important in the changing scenario. The availability of microbes from current and past episodes would be of immense use to understand the evolutionary process in microbes, making it possible to search for mitigation strategy by manipulating host system/microbe.

Though the microbiological research in India is advancing well, with varied amount of success, we need to have a strong back up of microbial resources to get the research in Indian Institutes appreciated by the global fraternity. In microbiological research, the most important of the resources include the microbial repository to understand the mechanism of action of the variety of microbes vis-à-vis livestock health & production with consequent advantage to the mankind. A number of microbes are acquired and lost every year by different researchers which are of tremendous value. These may be of great use in future for retrospective studies and comparisons for understanding pathogen evolution and developing newer diagnostic tools or immunobiologicals. The microbes would be invaluable for research and development in improving livestock production either through direct interventions or by way of improvement in health. This would help in food security and advances in human health researches apart from the direct benefit of enhancing livestock productivity and production.

A number of small repositories are existent but they became practically non-functional over a period of time or they became specialized. For examples, MTCC repositions include microbes of medical importance, NIV repositions include viruses (mainly

of medical and zoonotic significance), and National Collection of Industrial Micro-organisms maintains only organisms of value to research and industry. However, none of them covers the microbes of animal origin comprehensively. World Federation for Culture Collections lists more than 20 such repositories in India but most of them are not very comprehensive ones.

A number of international repositories like ATCC, NCTC etc. are presently working which cover a wide variety of reference microbes for use by industry, however, similar facilities in India, especially in agricultural and livestock sectors, were initially lacking. Considering this, NAIMCC, dedicated to the microbes in agriculture, has been established at NBAIM, Mau Nath Bhanjan in Uttar Pradesh by ICAR in agriculture sector and similar mandate is given to NRCE/VTCC Hisar by establishing VTCC in livestock sector which will include animal microbes comprising of veterinary microbes, rumen microbes, and dairy microbes.

Issues

General

- In the present context, the issues of apprehensions of depositors regarding the ownership of cultures, access and use of these cultures and re-distribution of deposits need a special mention. These issues are being addressed effectively through fast-track communications about making the Depositor institutions and their scientists aware about the unambiguous mechanism developed by VTCC which will always safeguard their IPR issues and related interest.
- The time-consuming process of microbial identification and characterization need to be overcome by installing high-end instruments and platforms like, automated bacterial identification system, sequencing machines, mass spectrometer, computing systems, and bioinformatics software.

Specific to VTCC

- Further, the constraints like limitations of manpower and space as well as concerns about cross-contamination in cell-lines and microbes of varying origins and nature (bacteria/virus/recombinant clones etc.) are also being taken care of through adopting "Safe Microbiological Techniques (SMTs)" and "Good Laboratory Practices (GLPs)". All the laboratories under the network will have a minimum of BSL-II facilities for work and also adequate facilities for freeze-drying and cryopreservation.
- Biosafety and biosecurity issues also need to be addressed.
- Mechanism for selection of cultures especially bacterial and fungal cultures needs to be in place.
- Automation in microbial identification and reposition.

2. CHALLENGES

Global warming now and in future: the infectious disease threat looms large

Global warming is the gradual increase in the earth's surface atmospheric temperature caused by man-made release of trapped carbon dioxide and some other gases in the atmosphere by large scale use of fossil fuels. A conservative World Health Organization estimate of excess mortality resulting from the 0.8°C global warming experienced over the past century. The average global temperature may climb by a projected 1.4°C–5.8°C over the century, the annual mortality may double by 2020. Stephen Hawking summarized the spectacle resulting from global warming in much the macabre way, when he said that 'Earth might end up like Venus, at 250 degrees centigrade and raining sulfuric acid.' It can be thus observed that increase in population, the rapid industrialization for economic growth fueled by demand from this populace and consequent high consumption of fossil fuels has led to release of increased amounts of green house gases into earth's atmosphere. The average global air temperature near the Earth's surface increased 0.74 ± 0.18 °C (1.33 ± 0.32 °F) during the hundred years ending in 2005 (Hegerl *et al*. 2007). Rates of temperature change over the next fifty years range from 0.1 to 0.2°C/decade.

The primary effects of increasing global temperature include rise in sea levels, increased extreme weather events like increase in floods and drought events, and change in the amount and pattern of precipitation. This will, in turn, have other effects like changes in agricultural yields, trade routes, glacier retreat, species extinctions and increases in the ranges of disease vectors. Close to 300 species of plants and animals are geospatially affected by climate change evidenced by moving closer to the poles. Increase in temperature has the potential to expand the range of infections that are normally constrained by temperature. This has led to thinking that vector-borne diseases could spread to hitherto pristine areas of Europe and North America. A graver scenario is envisaged in the areas of highlands within tropical countries such as East Africa and South America. In such areas where the temperature minima due to high altitude prevented the presence and breeding and therefore transmission of vector borne diseases have now come under the zone of temperature where evidence of insect activity is now increasing. Many vector borne diseases are now found at higher altitudes.

Global warming, animals and disease

Several aspects of global environmental change, including international travel, climate change, and the trade in livestock and plants have been explicitly linked to emerging infectious diseases (EIDs) in humans and other species (Weiss & McMichael, 2004; Anderson, et al 2004). EID origins are significantly correlated with socio-economic, environmental and ecological factors, and provide a basis for identifying regions where new EIDs are most likely to originate (emerging disease 'hotspots') (Kate

et al., 2008). The major concern of increase in disease due to global warming has been from Europe and US, however most severe effects of global warming may be seen in developing African and Asian regions with its high population density.

Global warming is also an issue with farm animals which are ruminants. This is because these animals emit methane into the atmosphere. Methane is second in terms of its effect to global warming after carbon dioxide. Methane is also produced from peat-bogs, and wetland marshes and rice paddy fields as a result of anaerobic fermentation. Ruminants produce methane by digesting plant materials. It has been said that cattle and other ruminants are the important sources of ozone-destroying global warming gases. Methane accounts for 4-9% of the world's green house gases and only 7% of world's methane is produced by all ruminants (domestic and wild). Although cattle may be major producer of methane into atmosphere by enteric fermentation, they are also important to humankind in converting fiber into food (Moss et al, 2000).

Antimicrobial resistance – a present and clear danger

The reductionist attitude of classic antibacterial therapy, crystallized in the dominant 'culture of monotherapy' has contributed to perversely fix the old perception of 'one disease-one pathogen-one drug'. Bacterial diseases are always the result of a complex array of pathogenic factors, and bacterial diseases are not only diseases of the individual, but complex diseases involving the groups and the environments. The renounce of recognizing the complex nature of bacterial diseases is a major threat for its control (Bacquero, 2013). Antimicrobial drugs are essential part of treatment management regimen for achieving optimum veterinary animal health and welfare goals for such disease control. An antimicrobial is an agent that kills bacteria, fungi or protozoa or suppresses their multiplication. Antibiotics and antimicrobials are normally considered to be most important tools in the therapeutic management of Livestock with a variety of illnesses. Commonly, diagnostic tools and insights are not available in the field conditions, or antimicrobial therapy decision is based on systemic manifestations, and infectious diseases are considered. Thus the aspect of adverse effects of antimicrobial due to inappropriate choice of antibiotics, or development of antimicrobial resistance may take place. It is therefore critical that antibiotic use should be based on sound rational principles. An infectious agent must be involved in the disease process for antimicrobial therapy to be effective. Consequently, certain principles should be used as guide for antimicrobial use in Livestock.

The major disease bacterial agents affecting livestock vary by body system, age of animal, use, geographic location, and the type of farming system. There is increasing referral of resistant bacteria including *Salmonella* sp, other enteric species, and Methicillin resistant

Staphylococcus spp (MRSA). In general, the most commonly encountered pathogens are: β-hemolytic *Streptococcus* sp, *Actinobacillus* sp, *Pasteurella* sp, *Escherichia coli, Klebsiella pneumoniae, Enterobacter* sp, *Pseudomonas aeruginosa, Bordetella bronchiseptica, Staphylococcus* sp, non-hemolytic *Streptococcus* sp, and anaerobic bacteria, particularly *Bacteroides* sp and *Clostridium* species.

During the past decade, the threat of antimicrobial resistance has become real and it now affects us globally due to increase in trade of agriculture products. Antimicrobial resistance is defined as a property of bacteria that confers the capacity to inactivate or exclude antibiotics, or a mechanism that blocks the inhibitory or killing effects of antibiotics, leading to survival despite exposure to antimicrobials. Due to this property of microbes some bacteria acquire multi-drug resistant genes. Such bacteria may get transmitted to human population and prove difficult to treat in life-threatening situations such as septicaemia. Increasing reports of outbreaks of antimicrobial resistant bacteria, such as hospital outbreaks of vancomycin-resistant *Enterococci* (VRE), community outbreaks of antimicrobial resistant *Streptococcus pneumoniae* and human and animal outbreaks of multi-resistant *Salmonella* Typhimurium definitive type 104 (DT104) calls for immediate concern of the international public and animal-health communities, medical and veterinary clinicians, and the general public. The problem is further accentuated by slow research and development of new antimicrobials due to the cost and time involved. Antimicrobial resistance issues have the potential to impact animal agriculture. In the European Union (EU), four antimicrobials (bacitracin zinc, spiramycin, virginiamycin and tylosin phosphate) which are considered important in treating humans were banned for use in animal feed from 1999. Controversy over antimicrobial resistant pathogens and use of antimicrobials in food animals could impact future trade decisions also. The issue of antimicrobial resistance has become more complex and requires multidisciplinary attention and coordination from the public and animal-health and agricultural sectors. One of the most important functions a microbial collection can impart is in isolation, identification and reporting of antimicrobial resistance isolates of serious economic and public health impact. Bacteria like *Salmonella, Pasteurella, Staphylococcus, Streptococcus and Escherichia coli* not only cause a number of diseases in animals, but they are also transmitted through food-borne routes causing zoonoses and business losses.

Genomics of bacterial pathogens will help reveal their weapons

"They run pages and pages filled with A, T, C and G". This comment, which appeared in a biology major textbook published in 1984, refers to entire base sequences of DNA in bacteriophages, plasmids, polio virus and human mitochondria whose genomes were sequenced at that time after the first ever sequencing of phi-X 174 bacteriophage in 1977. Surely, had these not been a parallel revolution in computation technology, the reams and reams of genome sequences stacked in a brick and wall library could not have been gleaned in a way it is being done now.

The method of shot-gun sequencing approach pioneered by Fredrick Sanger in 1977 is about to enter its 30th year and is gaining steam on to the third stage of the genomic revolution

in microbiology. The initial stages of genome sequencing data collection moved on to genome sequencing of important human pathogens and laboratory organisms. The Institute of genomic research published the first complete genome sequence for a free living organism, *Haemophilus influenzae* in 1995(1), the year in which 2 prokaryotic genomes were sequenced. Since then the number of prokaryotic genomes sequenced have increased rapidly, however the real growth has mainly started from year 2000 in which 18 small genomes were sequenced, and it is now reaching a level of 2000 small bacterial genomes sequenced and more than 2000 in pipeline. This is thus a period of explosive growth in genomic sequencing and analysis. Up to now in 2013, a total of 26,547 ongoing or completely sequenced genome projects are listed in Genomes OnLine Database (GOLD).

The enormous database of prokaryotic genomes now getting sequenced will prove a cornerstone of genome-based microbiology. The analysis of the entire available microbial sequences is already opening innovative research ideas and insights. What will be the potential impact of this database on human society when the projected database of over 2000 small genomes of each species will be available to the community of scientists by the end of 2020. Certainly, a culture collection like VTCC will be the best place, which will be able to provide the pivot point from where suitable, critical bacterial isolates can be recognized for Whole Genome Sequencing work. It will be useful, because the cultures will be backed up by its disease metadata information also. VTCC has already embarked upon ambitious attempt to WGS some important pathogenic isolates like *Bordetella bronchiseptica, Truperella pyogenes, Pasteurella multocida, Actinobacillus equilli,* and *Salmonella* Gallinarum.

Whole genome sequence (WGS) data are increasingly used to characterise bacterial pathogens. These data provide detailed information on the genotypes and likely phenotypes of aetiological agents, enabling the relationships of samples from potential disease outbreaks to be established precisely. It is being pointed out that elucidation of functions of these sequences and assigning them with the respective biochemical, physiological and geographical contexts is the next important thing to do. Cursory survey of genomes sequenced till now has revealed a vast tract of base-pair stretches whose biological function is yet unknown. While the formidable investigations on definition of each gene and its role in the cellular machinery and regulatory mechanisms of prokaryotic genomes gains speed, the other more obvious and preliminary insights from the field of Comparative genomics have started trickling.

The virtual storehouse of genetic information of multiple genome sequences of closely related organisms and metagenomic sequences of microbial communities is announcing its arrival on to the third stage of its radical effect on microbiology. The sequencing projects now include several bacterial pathogens and different isolates of the same bacterial species that differ with respect to virulence and physiology. Whole and part genomic sequences of a variety of related species and strains from medically important genera viz., *Helicobacter, Escherichia, Streptococcus, Staphylococcus, Mycobacterium, Bacillus, Burkholderia* and *Listeria* are available. One of the themes emerging from the range of possibilities is exploration of genome sequence

information to understand the differences and similarities between the genomes of closely related pathogens to understand their biology. Comparisons of genome sequences of closely related pathogens and non-pathogens belonging to same generic group have the potential to provide quick and useful methods for appreciating the bacterial pathogenesis (Strauss & Falkow, 1997). Comparison and contrasting of data derived from computation, genome and proteome promises a better understanding of genome function.

To understand the genetic basis of pathogenicity of *Listeria* spp., the genomes of *Listeria monocytogenes* ESD and *Listeria innocua* were sequenced and compared (Glaser et al, 2001). *Listeria monocytogenes*, a motile gram-positive rod, is a major food-borne pathogen responsible for outbreaks of Listeriosis. *Listeria innocua*, on the other hand is also isolated from food of animal origin but is not considered to be pathogenic. The comparative genome sequence analysis indicated that the pathogenicity of *L. monocytogenes* could be due to 270 genes present in that species which are absent in *L. innocua*. The team also discovered that such genes unique to *L. monocytogenes* were randomly distributed across 100 different locations of the 2.94 mega bases (mb) chromosome. This is an indication of acquisition of virulent genes by the pathogen as a result of many historic events of Horizontal gene transfer (HGT) and loss of genes by deletions. Comparative analysis of genome sequence of invasive serovar 4b of *L. monocytogenes* also helped identify novel genes.

Pasteurella multocida is a major pathogen of livestock and can cause disease in humans through the agency of animal bites. The pathogen is of immense economic importance at it causes losses during transport of animals on long haul. In spite of a large number of studies on the biology of this bacteria an effective vaccine has not been developed. Through genome sequence comparison a very large gene encoding a putative virulence factor, the filamentous haemagglutinin has been discovered (May et al, 2001). It has been found that inactivation of this gene results in a significant reduction in virulence. The antigen is an attractive candidate for vaccine. New candidates for vaccine and diagnostic reagents in the strains of pasturellae afflicting the buffalo, cattle, sheep, goat and poultry are needed, which can be achieved by systematic genomic analysis of Indian strains. That analysis of such genomic data will entail human and material inputs for Bioinformatic analysis. Availability of a large set of genomic data has also lead to the development of visualization tools for rapid visualization and subsequent comparison of several microbial genomes (Ghai et al, 2004). Software tools such as Microbial Genome Viewer (16), GenoMap (17), GenomeAtlas (18), GenomePlot (19), BugView (20), Genome2D (21), Artemis (22) and ACT (23) are some applications that allow comparative analysis of microbial genomes. The future will see increase need of sophisticated bioinformatics analysis programs, which may be able to run parallel, crunching a much bigger database in shorter period of time to give tangible results and insights.

Advances in typing methodologies have been the driving force in the field of molecular epidemiology of pathogens. The development of molecular methodologies, and recent "Next Generations Sequencing (NGS)" methods to complement and improve phenotypic

identification methods, was accompanied by the generation of large amounts of data. There is a need to develop ways of their storing, analyzing and retrieving the 'information'. Integration of data of already established microbial typing methods, genomic and epidemiological databases and NGS data will be the next frontier in bacterial epidemiology. Once NGS becomes widely adopted, the development of software that analyzes information from different data sources will be key to the synthesis of available knowledge. Standards for analysis and reporting are required to produce the desired reproducibility to be useful in clinical settings, which would be followed by VTCC. For this, genomics and proteomics as well as bioinformatics platforms with high-end computational facilities would be established over the next two five-year plans.

Technological development

With the advancement of science on the current rate (we are expecting exponential development), breakthroughs are expected in various fields having direct bearing on VTCC like biotechnology, nanotechnology, genomics, proteomics, metabolomics, transcriptomics, and ICT. We are bound to get new insight of various microbes through information and knowledge gathered world over on them using these tools. This will lead to changed understanding about the microbes and their role in life of livestock, which needs to be exploited. The VTCC envisaged coping up with the changing situation through improved infrastructure and adopting new sciences and technologies. This will not only lead VTCC to meet the challenges posed on it due to changing technological environment but will be utilized as opportunities for accelerating R&D to establish itself as leader. We are gearing up with latest tools in bacterial identification, microbial reposition and bioinformatics to keep updated with the changing technologies.

3. OPERATING ENVIRONMENT

Many institutions in National Agricultural Research System (NARS) are engaged in researches involving microbes. while NBAIM takes care of agriculturally important microbes in terms of their collection, characterization and reposition for use in plant research, a need was felt to have an institution-on the lines of NBAIM- for veterinary, dairy and rumen-microbes. In this endeavor, ICAR promptly sanctioned a network project on Veterinary Type Culture.

Veterinary Type Culture Collection (VTCC) was sanctioned by DARE, ICAR in April, 2004 during the X Plan period as a new activity with National Research Centre on Equines, Hisar. However, the actual functioning of Veterinary Type Cultures started at NRCE in June, 2005 and the work of establishment of the VTC facilities began in right earnest in June 2006. During XI Plan, further strengthening and overall expansion in terms of scientific and technical manpower, supporting staff, works and equipments was proposed to achieve the proposed objectives being a new Centre. The XI Plan was approved with an overall budget of Rs 2897.42 lakh. However, no additional posts of technical, administrative or supporting staff could be created during the period, although posts in the technical and supporting categories were approved. Presently, there are eight scientists in position against cadre strength of ten.

The VTCC facility is a not-for-profit, governmental biological resource center whose mission focuses on the acquisition, authentication, production, preservation, development and distribution of standard reference microorganisms, cell lines and other microbial materials for research in the Veterinary Sciences and life sciences. It was initiated to serve as a national repository and distribution center for cultures of microorganisms of Veterinary importance. VTCC plans to develop into the global leader in research and development expertise for identifying, characterizing, preserving and distributing a wide range of cell lines and microbes of Veterinary importance. VTCC also plans to serve India by characterizing, bacteria, viruses, fungi protozoa and cell lines of veterinary relevance/significance; as well as developing and evaluating assays and techniques for validating research resources and preserving and distributing microbial biological materials to the public and private sector research communities. In order to rise to the aspirations and expectations of our nation, emphasis of VTC is on need to customer satisfaction, value addition, economic operations and competitive benchmarking for all areas of the endeavor.

Mandate

- To act as a national repository of microorganisms of animal origin, including recombinant cultures and plasmids.
- Exploration, collection, identification, characterization and documentation of animal microbes.

- Conservation, maintenance, surveillance and utilization of animal microbes for R&D.
- Human Resource Development (HRD)

Present Scenario

The activity was approved to function in Network mode during the XI Plan with 19 network units located in 12 states across the country working with VTCC, NRCE, Hisar. These include 6 units in Veterinary Microbes component [CSWRI, Avikanagar (Rajasthan), CIRG, Makhdoom (Uttar Pradesh), COVS, HPKVV, Palampur (Himachal Pradesh), COVAS, AAU, Khanapara (Assam), COVAS, SKUAST, (Jammu & Kashmir), COVAS, TANUVAS, Chennai (Tamil Nadu)]; 4 units in Dairy microbes component [NDRI, Karnal (Haryana), COVAS, AAU, Anand (Gujarat), COVS, GBPUA&T, Pantnagar (Uttarakhand), Dairy Science College, UAS, Hebbal, Bengaluru (Karnataka)]; and 8 units in Rumen Microbes component [NIANP, Bengaluru (Karnataka), NDRI, Karnal, (Haryana), IVRI, Izatnagar, Bareilly (Uttar Pradesh), CIRG, Makhdoom, Mathura (Uttar Pradesh), CSWRI, Avikanagar, Jaipur (Rajasthan), NRC on Yak, Dirang (Arunachal Pradesh), NRC on Camel, Bikaner (Rajasthan), NRC on Mithun, Medziphema (Nagaland)].

The Centre is in the process of development of laboratory and infrastructure facilities and equipping them with modern instruments. First phase of the lab building has been constructed and its interior furnishing is likely to be completed shortly. The facilities available at the Centre were utilized to achieve the proposed objectives. Being a relatively new Centre, it needs further strengthening and overall expansion in terms of scientific and technical manpower, supporting staff, works and equipments. Moreover, for wider coverage of the programmes in the country, some additional Units are being proposed to be added in the network from southern, western and north western region like College of Veterinary Sciences, Sardarkrushinagar, Dantiwada Agricultural University, Sardar Krushi Nagar, Gujarat, College of Veterinary and Animal Sciences, RAJUVAS, Bikaner, Rajasthan and College of Veterinary Sciences, Sri Venkateswara Veterinary University, Tirupati, Andhra Pradesh and may be some more during XII Plan period and beyond.

Role of Veterinary Type Culture Collection in capturing microbial biodiversity

Since the inception of modern microbiology, a huge numbers of microbes were isolated from a wide variety of animals, including domestic and wild animals as well as their products like meat, milk and their environment. The importance of such a range of pathogenic, opportunistic, saprophytic and commensal and/or beneficial organisms is well known. Their use for the scientific research and for the animal and dairy industry is well understood. However routine preservation and long term conservation and the identification, characterization and cataloguing of variety of microbes is not possible for a small clinical or microbiology laboratory. Because of this, a number of cultural isolates of importance have been lost for posterity. As the molecular and biotechnological

evolution enters the next stage of rapid molecular deciphering of the genomic data by whole genome sequencing of a variety of life forms along with microbes, a new potential level of understanding the microorganisms and emergence of knowledge in this field with application for human and animal welfare is emerging. It is in this context that the importance of suitably funded microbial repository needs to be understood. The future harvesting of this knowledge depends on existence of a professionally managed Veterinary Type Culture collection, in which microbes are maintained properly and supplied securely on demand.

In the field of Animal health, for fruitful research, an adequate and reliable source of properly preserved bacterial, viral, gene clones is imperative. At Veterinary Type Culture Collection, National Research Centre on Equines, Hisar, we have a tradition of attending to disease outbreaks in domestic animals like buffalo, sheep, horses, ponies & donkeys, when the report of an epidemic is received, whether in industry, defense and/or farmer's background. The routine attending of outbreak's and post-mortem leads to collection of pathological samples. At VTCC, NRCE microbiological laboratory, such a processing has lead to isolation of a large diversity of animal microbial isolates. As a collective effort of our research team, a large numbers of microbial strains have been isolated for the study of microbial diversity, antimicrobial profile study, molecular, genomic and epidemiological studies. The isolates are also characterized by molecular methods of gene cloning, and sequencing and bioinformatics analysis.

We have a whole range collection of pathogenic and well characterized *Rhodococcus equi* isolates as well as saprophytic typical and atypical *Rhodococcus equi* isolates from equines. Significant new isolations have been made including *Nocardia asteroides* complex from equine granulomatous pneumonia, identified as *Nocardia otitidiscaviarum*. VTCC Scientists have isolated novel Glander's bacilli from outbreaks in India, and research in collaboration with OIE is taking place. New *Bordetella bronchiseptica* isolates from pneumonic foal, 3 *Staphylococcus sciuri* (methicillin resistant, *mec*A gene sequenced), *Bacillus licheniformis*, *Actinobacillus equuli* sub spp *hemolyticus* have been isolated and preserved. From various equine nasal swab, lung samples, endometritis, saddle sore, Foal pneumonia and foal diahhorea, *Corynebacterium* spp, *Bacillus* spp, *Streptococcus equi, Staphylococcus* spp, *Escherichia coli, Enterobacter* have been isolated, characterized and preserved. We are also working on Equine semen microbiology & microbial isolates have been identified as *Streptomyces* spp, *Flavobacterium* spp., *Escherichia coli*, *Pseudomonas* spp., *Pseudomonas aeruginosa*, *Acinetobacter*, *Achromobacter* spp *Nocardia* and *Alcaligenes*. Some of our prized equine

origin microbial isolates include *Bordetella bronchiseptica, Actinobacillus equilli, Burkholderia mallei, Streptococcus equi* sub spp. *equi, Streptococcus canis, Streptococcus equi* sub spp. *zooepidemicus, Salmonella* abortus equi, *Lysinibacillus fusiformis,* many *Staphylococcus* spp. isolates, *Pseudomonas aeruginosa, Klebsiella pneumoniae, Pseudomonas putida, Bacillus cereus, Bacillus pumilus,* and *Nocardia spp.* among others.

Our country - being a nation rich in flora and fauna - is also rich in microbial diversity, but the exploitation of Micro-organisms in such areas have not been completed. Large numbers of microbial strains will be isolated from a wide variety of sources in future. The utilization and characterization of such strains and development of improved strains in biotechnology will depend on our readiness and preparation to be able to characterize the isolates on a polyphasic level. Thus will help in improvement of culture collections and crucial for the further development of microbiology, microbial industry, and biotechnology.

Current status of VTCC

The Veterinary Type Culture (VTCC), a network project with seventeen network units located across the country for catering to the conservation of veterinary, dairy and rumen microbes, strengthened its activities entailing collection of samples from different livestock species across different geographical regions, acquisition of microbial isolates from different institutes/network units along with their characterization and preservation.

The Centre had many opportunities to record the many new isolations of the bacteria from several species of animals *viz.*, buffaloe (*Trupenella pyogenes*), horses (*B. bronchiseptica*, *Corynebacterium pseudotuberculosis*, *C. bovis*, *Enterococcus asini*), foals (*Actionobacillus equilli*), pig (*Staph. hyicus*, methicillin-resistant coagulase-negative *Staphylococcus sciuri* from pigs, *Exiguobacterium* spp.), double-humped camel from Leh region (*Rhodococcus equi*), fish (*Aeromonas hydrophila), etc*. The Centre also identified two bacteria belonging to two new Genus *viz.*, *Brevibacterium* spp. and *Brevibacillus spp.* from equine faeces, and 22 atypical *R. equi* isolates.

Dairy microbes in commercial use: Manufacturing units of various cooperative dairy federations (Mother Dairy, Delhi; Mother Dairy, Kolkata; Dudh Sagar Dairy, Mahesena, Gujarat; Creamline Dairy Products Ltd., West Godavari, Andhra Pradesh; Verka Milk Plant, Hoshiarpur, Punjab; Verka Milk Plant, Sangrur, Punjab; Jind Milk Plant, HAFED, Haryana; D'souza Biotech, Goa; Dehradun Milk Plant, Uttrakhand) are using Dairy cultures (Dahi (thermophilic and mesophilic) and yoghurt cultures as freeze dried ampoules) from NDRI culture collection (VTCC) to produce curd and other products from milk for commercial purpose.

Present Status of the Microbial Repository

Microbial Resources	2009-10	2010-11	2011-12	2012- 13	Total
Veterinary Microbes					
Bacteria	-	255	185	187	627
Virus	24	68	11	21	124
Fungus	-	-	-	-	
Recombinant clones	34	76	81	76	267
Phage library	27	-	-	-	27
Genomic DNA	-	-	-	138	138
Total	**85**	**399**	**277**	**422**	**1183**
Rumen Microbes					
Anaerobic bacteria	-	-	19	19	38
Fungi/Yeast	-	-	76	18	94
Methanogenic Archeae	-	-	-	8	8
Total	**-**	**-**	**95**	**45**	**140**
Dairy Microbes					
Bacteria	**40**	78	89	**100**	**307**
Year wise strength	**125**	**477**	**461**	**567**	**1630**
Overall Strength	**125**	**602**	**1063**	**1630**	**1630**

4. OPPORTUNITIES

The disease emergence and re-emergence is a dynamic process as the driving factors for the emergence and re-emergence of infectious diseases are always changing. This is the reason we always witness changing patterns of diseases with time, space, host, and geography which can also be linked with global climate change and evolution of disease driving factors. These challenges provide us an opportunity by modulating the operating environment in such a way which provides us a pathway to march ahead but at the same time also helps in sustenance of the resources for posterity. Some of the most important opportunities are listed below:

- Climate change is one of the important factors in animal disease emergence. As such, it is imperative to devise R&D strategies as well animal husbandry management practices. Some of the actionable points which almost always are considered by animal husbandry Experts include (i) introducing "Good Animal Husbandry Practices (GAHPs" in animal farm management, (ii) incorporating the elements of conservation livestock agriculture, as far as possible, in the intensive livestock production system, (iii) chalking out the strategic plan in terms of animal production management scenario vis-à-vis global and local climate change scenario, (iv) developing stress-/disease-tolerant animals, where ever possible by selection and/or transgenic technology, (v) developing disease-/stress-tolerant plants - on the similar lines as for disease-/stress-tolerant animals - for meeting feed and fodder requirement, etc. However, whatever action we might take, the climate change disease emergence will always be there and we have witnessed this over a period of last 20 years. Therefore, our efforts need to concentrate on understanding pathogen evolution vis-à-vis climate changes and host adaptability. Collection, characterization, and reposition of microbes and vectors over a period of time is thus essential to understand pathogen and vector evolution. It is important to add here that the climate change will also have impact on microbes of dairy and rumen origin because of the adaptability issues. As such, the VTCC has to utilize this opportunity to have more and more microbes of veterinary, dairy, and rumen niche in their repository.
- The antimicrobial resistance is another issue which has been complicated by availability and indiscriminate use of antibiotics and anthelmintics in livestock husbandry over decades. The intensification of agriculture in total and livestock agriculture in particular has culminated in presence of antibiotic/anthelmintics/pesticide/insecticide residues in whole

agriculture/livestock production value chain. Isolation of microbes with antimicrobial resistance to majority of antibiotics is very common. The sustained presence of residues in production value chain affects immune response of the animals as well which, in turn, helps in evolution of an array of microbes. The altered immune system of the animals due to these residues leads not only to the development of disease-causing microbes and parasites but also alters the microbial population of rumen and dairy products. The major disease bacterial agents affecting livestock vary by body system, age of animal, use, geographic location, and the type of farming system. There is an increasing referral of resistant bacteria including *Salmonella* sp, other enteric species, and Methicillin resistant *Staphylococcus* spp (MRSA). In general, the most commonly encountered pathogens are: β-hemolytic *Streptococcus* sp, *Actinobacillus* sp, *Pasteurella* sp, *Escherichia coli, Klebsiella pneumoniae, Enterobacter* sp, *Pseudomonas aeruginosa, Bordetella bronchiseptica, Staphylococcus* sp, non-hemolytic *Streptococcus* sp, and anaerobic bacteria, particularly *Bacteroides* sp and *Clostridium* species. Such a diverse microbial evolution provides a wealth of microbes and parasites which makes an important resource for posterity. The emergence of microbial strains with various kinds of traits will definitely have impact the significance and dimensions of which will always be less understood or totally unknown. This is again an opportunity for VTCC to collect, characterize and re posit the microbes and parasites in the arsenal of VTCC so as a resource of this kind is available in time to come to understand the evolution of antimicrobial resistance over a period of time, space, and geography. The issue of antimicrobial resistance has become more complex and entails multidisciplinary attention and coordination from the public and animal-health and agricultural sectors. One of the most important functions a microbial collection can impart is in isolation, identification and reporting of antimicrobial resistance isolates of serious economic and public health impact. Bacteria like *Salmonella, Pasteurella, Staphylococcus, Streptococcus and Escherichia coli* not only cause a number of diseases in animals, but they are also transmitted through food-borne routes causing zoonoses and business losses.

- The genomics and proteomics of microbial isolates has led to enormous data and it is bound to increase exponentially in time to come. At this point of time, we can not afford to ignore these emerging fields of science as they are essential part of the microbial identification and characterization. As such, this is also an opportunity to NRCE to gear up with its infrastructure and human resource so as to handle the enormous microbial genomic and proteomic data so as to mine the data in due course of time. The physical infrastructure related to genomic and proteomic data needs to be created at VTCC in coming plan or the next one, as the enormous

database of prokaryotic genomes now getting sequenced will prove a cornerstone of genome-based microbiology. The analysis of the entire available microbial sequences is already opening innovative research ideas and insights. What will be the potential impact of this database on human society when the projected database of over 2000 small genomes of each species will be available to the community of scientists by the end of 2020. Certainly, a culture collection like VTCC will be the best place, which will be able to provide the pivot point from where suitable, critical bacterial isolates can be recognized for Whole Genome Sequencing work. It will be useful, because the cultures will be backed up by its disease metadata information also. VTCC has already embarked upon ambitious attempt to WGS some important pathogenic isolates but more thrust needs to be given to this area of research and development including human resource upgradation.

- With the advancement of science and technology on the current rate (we are expecting exponential development), breakthroughs are expected in various fields like biotechnology, nanotechnology, genomics, proteomics, metabolomics, transcriptomics, and ICT which will have direct bearing on VTCC. This provides VTCC scientists an opportunity to get new insight of various microbes through information and knowledge gathered world over on them using these tools, leading to changed understanding about the microbes and their role in life of livestock which will need to be exploited on urgent basis. The VTCC envisaged coping up with this changing situation through improved infrastructure and adopting new sciences and technologies. This will not only lead VTCC to meet the challenges posed on it due to changing technological environment but will be utilized as opportunities for accelerating R&D to establish itself as leader. We are gearing up with latest tools in bacterial identification, microbial reposition and bioinformatics to keep updated with the changing technologies.

The disease emergence and re-emergence thus provides an enormous opportunity to VTCC to strengthen its repository over a period of time which will entails sincere effrrts and strategic planning to harness this rich microbial diversity being generated due to dynamism of various disease-driving factors in the ever-changing context of changing climate, population explosion, practices of agriculture including livestock agriculture to meet goals of food security, and socio-economic scenario.

5. GOALS AND TARGET

The overall benefit by the activities of VTCC may result in enhancement of knowledge in all the spheres of animal microbes and utilization of important microbes or their useful characters. The collection, identification and characterization of microbes including fungi and parasites at phenotypic and molecular level and their biotyping would result in development of a repository of the animal microbes and parasites, along with the understanding of their signature characteristics and evolutionary dynamics which will ultimately will help in (i) developing newer approaches towards development of diagnostics, drugs, vaccines, functional foods/feeds; (ii) enhancing utilization of cellulosic fodder and non-conventional feeds/fodder; and (iii) ensuring human and animal health and welfare as well as ecosystem sustenance.

The microbes and parasites collected and maintained in VTCC would be of immense use to researchers as these cultures would act as reference in future for prospective and retrospective studies and as basic resource for product development and validation . Their understanding using the contemporary biotechnological tools would facilitate researchers to understand the intricacies in their mechanisms of action, whether involved in causation of a disease or helping livestock in efficient feed utilization or else in post-harvest food technologies (like fermentation processes in food industry). The future tools may be more sensitive and may make it possible to understand the existing organisms in better details to exploit them more effectively. This would also assist the researchers in understanding the dynamics of changes in the microbes over time, geography, space, and host. Search for new microbes would also be strengthened as microbial diversity is vast and changing paradigms of diseases and pathogen evolution will result in evolution and emergence of modified and/or new strains related to known microbes. Further, the unknown microbial diversity is vast and will definitely be an agenda at VTCC with clear focus on identification, characterization, and reposition.

Microbial Resource Management

The programme on development of a comprehensive microbial repository management system would yield development and implementation of the SOPs and standards for acquisition, conservation and distribution of microbes and acquisition of knowledge on animal microbe signatures and their exploitation with time passage. The conserved organisms and knowledge acquired through gene mining would be of great use in developing future strategies in dealing with the microbes and their exploitation for understanding pathogen evolution, enhanced livestock productivity, food safety, nutritional security, ecosystem and biodiversity utilization, as well as human and animal welfare.

Development of an **Interactive Microbial Resource Database System** would provide metadata on animal microbes. For this, a resource portal would be developed to share the knowledge acquired through the programmes. The available data would be shared and used by different work groups for application in technologies for enhanced livestock productivity and betterment of human health.

Since the fruits of modern day research are effectively acquired by the synergism from various fields of science like biotechnology, bioinformatics, nanotechnology, information and communication technology, their use in the repository would be of immense help in attaining the goals of the collection. The assistance of these branches will help in preserving and utilizing the collected microbes in a better way through understanding and taking advantage of intricate mechanisms involved in their functioning.

While developing the repository and its management system as per international standards, the emphasis would be laid on:

1. Quality Assurance: The Microbial repository is the sound basis of biotechnological revolution. A million of genes and products are the potential results of a well maintained and quality assured repository. The modern automated strain identification systems based on cell wall analysis, biotyping, genomic analysis, ribotyping, sequencing, phenotyping need to be in place for an accurate, quick and thorough strain analysis, tracking and naming. The naming of the strains should be linked to assured international standardized taxonomic basis.

2. Quality Management: The strengthening of ex-situ collection will not be achieved by only increasing the collection but mainly by proper cataloguing, documentation, and strain information data management by computer informatics system. The strain IDs need to be linked to all levels of photographic phenotypic, epidemiological, bioinformatic, genomic, metabolic, resistotypic data on a safe online platform, accessible on use-selective basis.

3. Operation Management: In order for a smooth and efficient running of the culture collection, tasks such as receipt and storage of Initial material/sample/cultures; opening of new cultures, documentation of receipt etc; preparation, culturing, processing of samples; quality control procedures; preservation; lyophilization; storage and inventory management; sale/supply of cultures etc would be optimized to match the international standards.

4. Intellectual Property Rights: With the aspiration to achieve the international depository status, the safeguarding the IPRs of depositors and institutions would be ingrained, as provided under Budapest Treaty or other such agreements *in vogue*.

Exploiting microbial diversity

It is beyond any debate that the world is full of microbes, which not only are harmful to livestock and human health but also are useful and supportive to them. Microbes originating from varying spatial/geographical regions, time and hosts would serve as the basis to understand the diversity and reasons thereof. This diversity of microbes of animal origin would be harnessed and exploited by maintaining them as references for future and mining the meta-data associated with them in order to search for traits which may be useful for the mankind. The research for utilizing such traits or microbes would lead to food safety, nutritional security, as well as human and animal welfare through disease control and eradication.

The animal microbes would be used in translational research for societal benefit through development and utilization of microbial resources for posterity. The useful traits of the

organisms would be used in veterinary biologicals, animal feeds for enhancing productivity, dairy products with value addition, products and development of probiotics. This would be helpful in enhancing overall productivity and production from livestock while ensuring their welfare.

The research on useful and friendly microbes in dairy sector would help mankind for value addition to the livestock products and making them nutritionally significant and preferred by taste. The value of livestock products would be increased and thus the processing using such microbes would be more valuable in terms of economy and nutrition.

Risk Assessment and Biosafety/Biosecurity Management

A lot of bio-waste is generated by the animals which are not being disposed off properly. Dumping of such waste is usually at the dumping grounds which are very close to human dwellings, on the sides of the road/highways, and/or near the water source which leads to contamination of water source itself and, thereby, the pathogens present in bio-waste spill back to humans and then again to humans in cyclic manner which may be bi-directional or even multi-directional. The scientists art VTCC have already identified some important microbes in equine dung many of which are also zoonotic in nature. Such attempts would be expanded to bio-waste from other animal species. It has been evident from our results that microbial count reduced in descending order from normal dung to compost to vermin-compost where only one-tenth of the microbes were present in vermin-compost. The VTCC would look at this problem and identify the pathogens in such waste and try to develop remedial measures and general health protocols which can be delivered to general public for practice in their day-to-day life for ensuring better human and animal life and definitely a safe habitat.

The collection of microbial cultures of diverse nature would enable us to understand the risk associated with different groups more deeply and devising the bio-safety and bio-security strategies. This would help researchers in understanding and following precautions for handling such microbes and utilizing them in livestock sector. The insight of these aspects would be of immense use in (i) devising strategies for animal biosecurity not only for India but may be whole of Asia, (ii) attaining international standards in manufacture of diagnostics and other biologicals, and (iii) various food products of livestock origin and feed/fodder utilization. Establishment of a Microbial Containment Laboratory (BSL-III) at VTCC has already been initiated.

New trends in infectious disease spread illustrate a greater appreciation of a strong need for better biosafety and biosecurity systems. All researchers and governments need to accept and embrace these new trends to give a significant focus on biosecurity and the related subject of biosafety. This is more so in the scenario of 'One Health' which is gaining momentum and would be the centre of focus by 2050. VTCC would be contributing a lot by virtue of its experience and working knowledge in this field.

Capacity Building and Linkages

The linkage (national and international) would be developed for knowledge and skill development and up gradation, physical infrastructure develop/upgradation, benefit sharing and devising strategies to meet the challenges at global level. Strong linkages with the national and international microbial resource and conservation Centers will be developed. In order to gain maximum output from the local resources, efforts will be made to develop strong linkages with all local institutes and other schemes and the resources would be used on sharing basis. Collaboration will be sought with a number of national and international organizations to fulfill the mandate. The established linkages will provide a platform for the workers to interact with diverse expert groups and acquire latest know-how in their respective fields. The programme will result in creating trained personnel to use the generated knowledge constructively through skill development and capacity enhancement of the network, besides developing a state-of-the-art microbial repository system including modern laboratories, animal house, microbial containment lab, and elaborate biosecurity and storage facilities. The entire physical infrastructure at VTCC would be developed so as it conforms to the infrastructure of repositories in the world.

1. **Training of staff**: As there is need of quality assurance in the operational aspect of the Microbial Centre, the staff would be trained in routine culturing, preservation, authentication and characterization work as per SOPs with quality assurance in place. The taxonomic and bioinformatics information generation on the strains and their analysis and utilization is needed in order to improve the value of collections, for which training needs are enormous.
2. **Human Resource Development**: The strengthening of repository would only be possible with the active support and participation of trained man-power outside the system. For this, trainings would be imparted to workers in diverse groups for their skill development so as to receive professional support from them as return.

Value Addition and Services

Apart from providing standard services of cultures provisions for research customers, other activities with relevant research and product development which can be developed in Cultures collection. Such products, processes and services may include

a. Nucleic acid based like development of cDNA library, clones, PCR products, DNA, phage preparations, genomic library, RNAi studies
b. Molecular epidemiological studies, sequencing, biotyping, resistotyping, polyphasic identification facilities, phenotypic analysis, serotyping, bioinformatic studies, DNA microarray, proteomics, etc.
c. Digital data collection, storage, analysis and retrieval of information on epidemiology, including disease metadata, molecular taxonomy as well as bioinformatic analysis, etc.

d. Research: Apart from provision of service of providing cultures to researchers on demand basis, the VTCC research activities would include characterization of cultures on phenotypic, genomic and proteomic levels, refinement of preservation methods for maintenance of genetic integrity of cultures and standardization and updation of protocols, etc.

Transfer of Technology

The VTCC would strive hard for reaching the stake-holders for obtaining the cultures and making them available for distribution for harnessing their beneficial traits. The know-how and technologies generated by VTCC would be show-cased to reach the end-users including students, researchers, drug-houses and biological production units, policy makers and others through sensitizing print and electronic media. The database and dynamic resource portal of VTCC would be of immense help in this endeavour.

6. WAY FORWARD

The utility of microbiology research is based on channelizing the immense potential of the microbes to secure mankind in terms of disease control, food safety, nutritional security, and ecosystem conservation. VTCC is committed to enhancing the livestock production and productivity; food safety and nutritional security; efficient utilization of resources and reducing methane production by livestock, and sustaining animal, human and ecosystem health. The VTCC is envisioned to become Nodal Centre for acquisition and management of microbial resources of animal origin for sustainable growth of the livestock sector. For this, quality research *at par* with international standards on animal microbes would be carried out. Human resources would be properly sensitized to develop their skills in the respective areas of their specialization at various levels and building the capacity of the Centre and associated agencies for overall livestock development in the country.

Strategic Framework

A. Graduating to National Repository of Microorganisms of Animal Origin

Since the VTCC is envisioned to be the nodal centre for acquisition and management of microbial resources of animal origin in India and would be responsible for exploration, collection, identification, characterization and documentation as well as distribution/supply of animal microbes, quality research on animal microbes for utilizing and exploiting their properties for the benefit of mankind through enhanced livestock productivity is expected with its support. Special drive will also be initiated to add fungal and parasitic agents in the culture.

B. Future Geographical Expansion

The network of VTCC would be expanded so as to cover whole of the geography in the country to meet its objective to have a wide collection of biological resources from different geographical locations, over varying time periods and originating from different host species for utilization by the researchers.

C. Augmenting opportunities for research on animal microbes

Conservation, maintenance, surveillance and utilization of animal microbes coupled with their management for understanding the microbial evolution would help in identifying the traits of animal microbes that are useful for livestock development and human welfare. This would also include data on techno-feasibility of microbes useful in dairy product development, modulating fibre utilization by ruminants with least contribution to GHGs, disease epidemiology, and microbial evolution.

D. Capacity Building and Linkages

Development of human resources to tackle the issues related to animal microbial research and application of scientific knowledge for the benefit of human being would be another significant approach to meet the objective of VTCC. This would result in creating a

critical pool of researchers trained in biosafety and biosecurity aspects as well as generation of skilled human resources trained for research in microbiology and biotechnology laboratories for research and implementation of scientific knowledge Development of the state-of-the-art laboratory infrastructure and biosecurity system, of international standard, would keep the VTCC in pace with other international agencies.

National and international linkages would be established for upgrading skill, knowledge, and performance. A strong network would be established with national/international laboratories and organizations through exchange and collaborative programmes, and sharing the latest development in science so as future options can be visualized and implemented in an optimal timeframe.

Proper institutional support in terms of infrastructure and administrative back up would be built up which would be of tremendous help in promoting the young innovative brains to take up research in the mandated area of the Centre. Focused approach would be made in areas of special significance and on private partnership. Mechanisms would be put in place to monitor the developments at national and international level and efforts would be concentrated on more useful aspects through prioritization by involving various stake-holders at different levels. The system would work in participatory mode, in lines with those of ICAR, to be more aware and attentive. The feeling of responsibility and sincerity in research would form a part of the system and thereby becoming the world leader in the assigned area.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