हर कदम, हर डगर
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

Agrisearch with a human touch

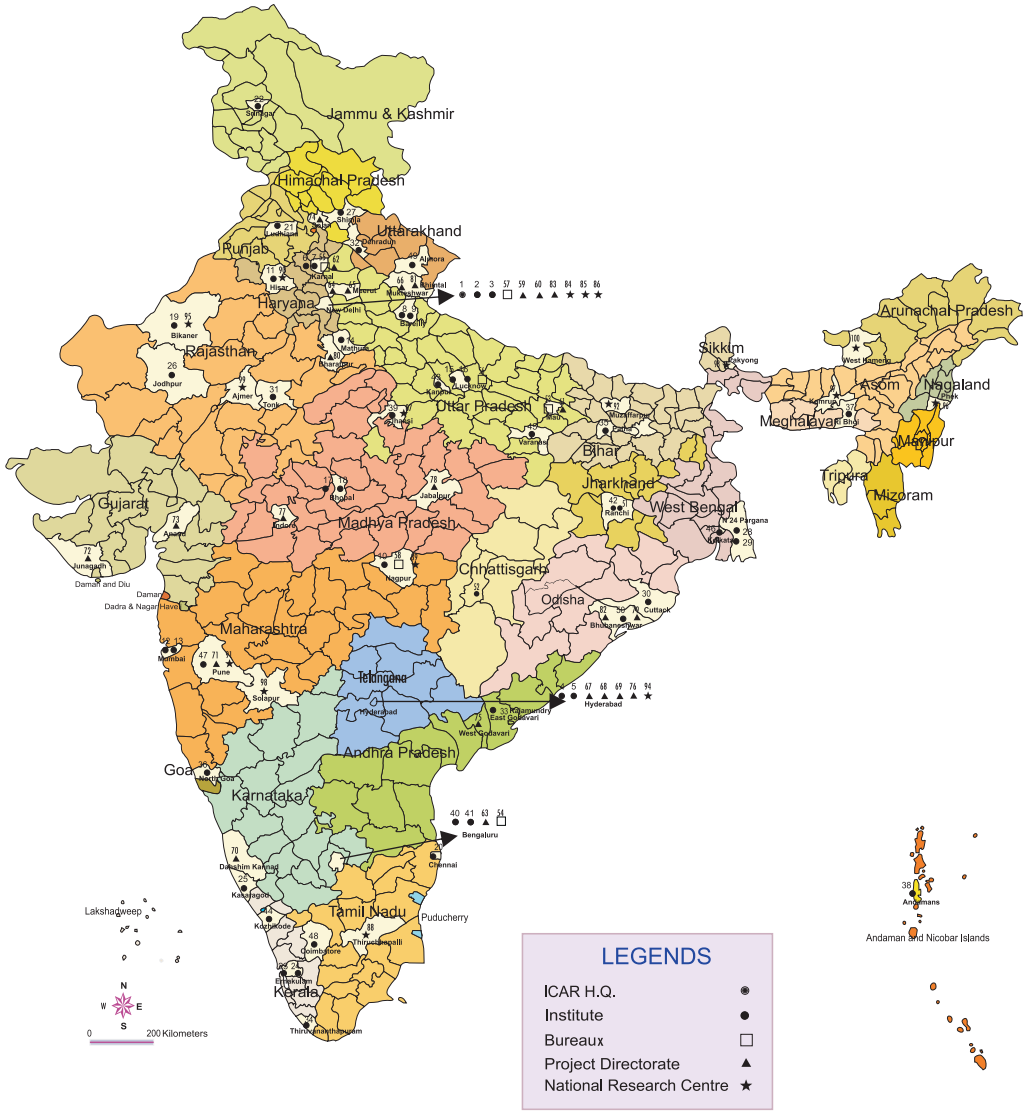
Vision 2050

National Research Centre on Yak

Indian Council of Agricultural Research

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

Institutes, Bureaux, Directorates and National Research Centres



LEGENDS

- ICAR H.Q.
- Institute
- Bureaux
- Project Directorate
- National Research Centre

● 64 Research Institutes ● 6 Bureaux ● 15 National Research Centres ● 15 Project Directorates

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

Agricultural Universities

LEGENDS

- State Agricultural Universities
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Vision 2050

National Research Centre on Yak
(Indian Council of Agricultural Research)
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Arunachal Pradesh

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संदेश

भारतीय सभ्यता कृषि विकास की एक आधार रही है और आज भी हमारे देश में एक सुदृढ़ कृषि व्यवस्था मौजूद है जिसका राष्ट्रीय सकल घरेलू उत्पाद और रोजगार में प्रमुख योगदान है। ग्रामीण युवाओं का बड़े पैमाने पर, विशेष रूप से शहरी क्षेत्रों में प्रवास होने के बावजूद, देश की लगभग दो-तिहाई आबादी के लिए आजीविका के साधन के रूप में, प्रत्यक्ष या अप्रत्यक्ष, कृषि की भूमिका में कोई बदलाव होने की उम्मीद नहीं की जाती है। अतः खाद्य, पोषण, पर्यावरण, आजीविका सुरक्षा के लिए तथा समावेशी विकास हासिल करने के लिए कृषि क्षेत्र में स्थायी विकास बहुत जरूरी है।

पिछले 50 वर्षों के दौरान हमारे कृषि अनुसंधान द्वारा सृजित की गई प्रौद्योगिकियों से भारतीय कृषि में बदलाव आया है। तथापि, भौतिक रूप से (मृदा, जल, जलवायु), बायोलोजिकल रूप से (जैव विविधता, हॉस्ट-परजीवी संबंध), अनुसंधान एवं शिक्षा में बदलाव के चलते तथा सूचना, ज्ञान और नीति एवं निवेश (जो कृषि उत्पादन को प्रभावित करने वाले कारक हैं) आज भी एक चुनौती बने हुए हैं। उत्पादन के परिवेश में बदलाव हमेशा ही होते आए हैं, परन्तु जिस गति से यह हो रहे हैं, वह एक चिंता का विषय है जो उपयुक्त प्रौद्योगिकी विकल्पों के आधार पर कृषि प्रणाली को और अधिक मजबूत करने की मांग करते हैं।

पिछली प्रवृत्तियों से सबक लेते हुए हम निश्चित रूप से भावी बेहतर कृषि परिदृश्य की कल्पना कर सकते हैं, जिसके लिए हमें विभिन्न तकनीकों और आकलनों के मॉडलों का उपयोग करना होगा तथा भविष्य के लिए एक ब्लूप्रिंट तैयार करना होगा। इसमें कोई संदेह नहीं है कि विज्ञान, प्रौद्योगिकी, सूचना, ज्ञान-जानकारी, सक्षम मानव संसाधन और निवेशों का बढ़ता प्रयोग भावी वृद्धि और विकास के प्रमुख निर्धारक होंगे।

इस संदर्भ में, भारतीय कृषि अनुसंधान परिषद के संस्थानों के लिए विजन-2050 की रूपरेखा तैयार की गई है। यह आशा की जाती है कि वर्तमान और उभरते परिदृश्य का बेहतर रूप से किया गया मूल्यांकन, मौजूदा नए अवसर और कृषि क्षेत्र की स्थायी वृद्धि और विकास के लिए आगामी दशकों हेतु प्रासंगिक अनुसंधान संबंधी मुद्दे तथा कार्यनीतिक फ्रेमवर्क काफी उपयोगी साबित होंगे।

(राधा मोहन सिंह)

केन्द्रीय कृषि मंत्री, भारत सरकार

Foreword

Indian Council of Agricultural Research, since inception in the year 1929, is spearheading national programmes on agricultural research, higher education and frontline extension through a network of Research Institutes, Agricultural Universities, All India Coordinated Research Projects and Krishi Vigyan Kendras to develop and demonstrate new technologies, as also to develop competent human resource for strengthening agriculture in all its dimensions, in the country. The science and technology-led development in agriculture has resulted in manifold enhancement in productivity and production of different crops and commodities to match the pace of growth in food demand.

Agricultural production environment, being a dynamic entity, has kept evolving continuously. The present phase of changes being encountered by the agricultural sector, such as reducing availability of quality water, nutrient deficiency in soils, climate change, farm energy availability, loss of biodiversity, emergence of new pest and diseases, fragmentation of farms, rural-urban migration, coupled with new IPRs and trade regulations, are some of the new challenges.

These changes impacting agriculture call for a paradigm shift in our research approach. We have to harness the potential of modern science, encourage innovations in technology generation, and provide for an enabling policy and investment support. Some of the critical areas as genomics, molecular breeding, diagnostics and vaccines, nanotechnology, secondary agriculture, farm mechanization, energy, and technology dissemination need to be given priority. Multi-disciplinary and multi-institutional research will be of paramount importance, given the fact that technology generation is increasingly getting knowledge and capital intensive. Our institutions of agricultural research and education must attain highest levels of excellence in development of technologies and competent human resource to effectively deal with the changing scenario.

Vision-2050 document of ICAR-National Research Centre on Yak (NRCY), Dirang, Arunachal Pradesh has been prepared, based on a comprehensive assessment of past and present trends in factors that impact agriculture, to visualise scenario 35 years hence, towards science-led sustainable development of agriculture.

We are hopeful that in the years ahead, Vision-2050 would prove to be valuable in guiding our efforts in agricultural R&D and also for the young scientists who would shoulder the responsibility to generate farm technologies in future for food, nutrition, livelihood and environmental security of the billion plus population of the country, for all times to come.

(S. AYYAPPAN)
Secretary, Department of Agricultural Research & Education (DARE)
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Preface

Yak is a remarkable bovine species of socio-economic importance in high hill and snow bound areas in India, Bhutan, China, Mongolia, Nepal and other parts of central Asia. It is a multipurpose animal, reared on pastoral system on alpine pastures. Yaks provide milk, meat, fibre, hide and dung at locations where other agricultural activities, including livestock husbandry, are not available. The yak is used as a pack animal for the transportation of household goods and is the backbone of the livelihood support of the tribal population of yak rearers in India. In spite of such usefulness of yak, due attention was not paid in the past. However, its importance was recognized and the "National Research Centre on Yak" has been established by ICAR in Arunachal Pradesh for the improvement of this species through scientific breeding, feeding and management.

At present, yak husbandry is being confronted with so many issues like indiscriminate breeding, degradation of highland pasture, prevalence of diseases, unscientific management practices and global warming. The climate change has special impact on emergence and new transmission modalities of trans-boundary diseases, vector borne diseases and macro-parasites of yaks. Therefore, great challenge is left in future with the institute to make the yak husbandry system more remunerative by improving germplasm, addressing feed crisis especially during winter, adopting scientific management practices, value addition and improving quality of yak products, networking of stakeholders to address problems on a platform and finally more income to yak rearers.

The Vision-2050 has been prepared incorporating novel thought and ideas based on rising global demands for land, water food, animal feed, fibre, energy and raw materials which will be helpful to develop sustainable yak farming practices by 2050. ICAR-NRCY will be mission oriented research institute which will address core development issues from the local to the international level. New vision of ICAR-NRCY also encrypts high rates of return and long term benefits through scientific yak rearing amidst the challenges of surging food demand, stressed surroundings and struggling supply of inputs which will close the global gap.

I wish to take the opportunity to put on record our gratitude to

Dr. S. Ayyappan, Secretary DARE and Director General ICAR, Dr. K. M. L. Pathak, Deputy Director General (AS), and Dr. B. S. Prakash, Assistant Director General (AN&P) of ICAR for their constant help, guidance and support in preparing this document. Thanks are also due to Dr. Rajan Gupta and Dr. Vineet Bhasin, Pr. Scientists for their help and encouragement.

I thankfully acknowledge the efforts made by scientists of this institute for preparing of Vision-2050 document. I hope it would be helpful for all and provide a specific direction for achieving sustainable yak production in the country.

S.M. Deb
Director
ICAR-National Research Centre on Yak

Contents

Context

Future yak husbandry will be depend on growth of human population, distribution of power, economic development, climate change, availability of natural resources, development and dissemination of new technologies, and demand of yak meat for human consumption. The aim of the vision document is to present a number of possible and conflicting future scenarios to stimulate new thoughts and ideas on future challenges, to identify research gaps and also shortcomings in knowledge, and broad ranging research issues for betterment of yak husbandry in India.

Since its inception from 1989, ICAR-NRCY is undertaking comprehensive research activities on breeding, nutrition, reproduction, physiology, health management, product technologies and extension activities to cater the needs related to improved yak productivity. The salient achievements and related concerns on yak husbandry are presented below:

Protecting Pastoral Community Livelihood Assets of NEH Region

Yak husbandry is facing the challenges due to transhumance system (migratory/pastoral) of farming on alpine pasture, paying grazing tax to community leader and degradation of the natural grasslands. To mitigate the issue and to enhance production potential of temperate grasses and legumes, seed production has been initiated at institute farm (Fig 1).

The pasture development initiatives have been continued through multicentre studies in Sikkim and Arunachal Pradesh and further research on efficient grazing management are required.

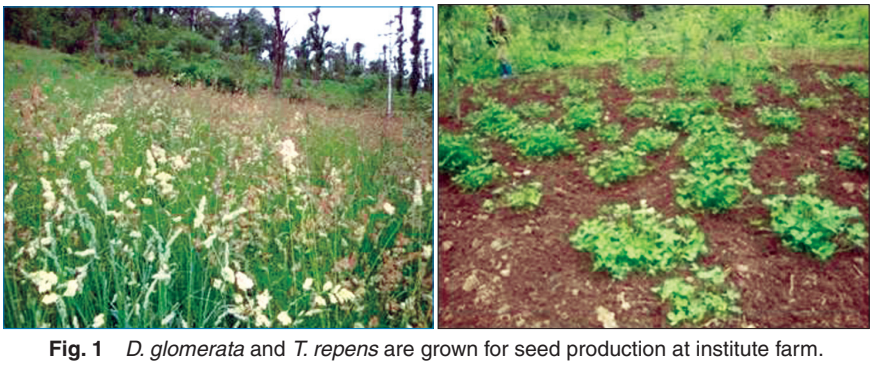


Fig. 1 *D. glomerata* and *T. repens* are grown for seed production at institute farm.

Nutritional Intervention in Winter Feed Crisis

During hot season yaks migrate to the high altitude (8,500-14,000 ft above msl or even to the 16,000 ft above msl). In winter, yak herders stay in the village at lower altitude because of heavy snow fall and graze the yaks in adjoining pasture lands, simultaneously grazed by sheep, cattle and ponies. These over grazing resulted in the deterioration of pasture land and yaks suffer severe starvation and nutritional deficiency. During this period yaks lose 25-30% of their body weight. To overcome inadequate fodder resources during winter, different complete feed block (CFB) technologies are prepared by ICAR-NRCY utilizing locally available crop residues viz. corn stover, finger millet straw along with edible tree leaves, concentrate mixture and molasses (Fig 2). Similar types of more interventions are required in future.

Fig. 2 The CFB prepared by ICAR-NRCY using locally available resources.

Conservation of Superior Yak Germplasm

To address the issue of conservation and multiplication of superior germplasm of yak, embryo transfer technology (ETT) and *in vitro* fertilization (IVF) techniques have been standardized. Yak calves were born for the first time through ETT (MISMO) in 2005 and through IVF (NORGYAL) in 2013 at institute farm (Fig 3).

Approaching Soil Web System for Integrated Parasite Management

Parasites, a major problem, developing resistance to dewormers, alternative strategy using nematophagous fungus will be eco friendly

Fig. 3 MISMO and NORGYAL with their respective surrogate mothers at institute farm.

approach for managing parasite population in refugia. Scientific pasture management are also done to contain this menace.

Molecular Dissection of Yak Genome

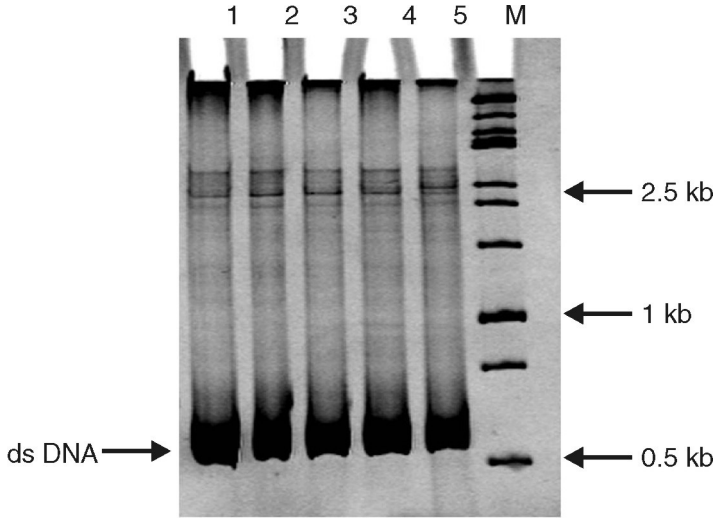


Fig. 4 SSCP of TLR2 gene of yak
[Lane 1-4: Common SSCP; Lane 5: SSCP observed 2%].

As yaks having unique physiological features on respiration, digestion and immunity, molecular dissection of their genome will be remunerative research activity in future. Describing genetic variation in those loci related to these features will be useful in selection of yaks for higher productivity, superior adaptability under climatic fluctuations and disease resistance.

Further identification of molecular variability in genome is required for marker assisted selection (MAS) for higher production. Presence of polymorphism in TLR2 gene, conferring adaptive immune response, located at relatively conserved domains of genome is significant because earlier studies revealed that Indian yaks showed considerable monomorphism in several candidate gene loci (Fig 4).

Molecular Identification of Infectious Agents

Virulent genes of enteric pathogens isolated from yak have been identified using molecular techniques and has been compared with the other organisms already reported in centralized repositories of public database.

Molecular signature of cutaneous papillomatosis of yaks has been done for the first time in the world. These works have to be continued in future for easy and accurate diagnosis of pathogens/parasites for better health management and thereby reducing economic losses to farmers.

Toxicant and Eco-toxicology

Pyrexia of unknown origin (PUO) in yaks followed by sub normal temperature during April to August was a disturbing health problem of yak. Alkaloid containing poisonous plant like *Senecio crysanthomoides* was identified having fatal effect on yak was responsible for this menace. The pathway of senecio poisoning was explored through pro-inflammatory, oxidative and pro-apoptotic signalling methods. Such types of works are required to be continued in future.

Technology Developed and Refined

Technologies have been developed for yak production and health and also for meeting the nutritional requirements of resource poor farmers of yak rearing states by the institute. Yak production has been improved by CFB. Intervention of pink eye disease of yak has been accomplished by in house development of herbal drugs (Fig 5).

The ICAR-NRCY has developed some milk/meat products having good market opportunities (Fig 6) and such research works needs to be continued as market demands, as well as to earn more revenue for the yak rearers.

Importance of the livestock products are increasing globally due to consumer demand which will increase many fold due to increase in global population by 2050. Modern technologies used elsewhere viz. landscape genomics, silicogenomics, nutrigenomics, high throughput sequencing of rumen metagenome along with yet to be developed

(A) (B)

Fig. 5 Showing pink eye of yak (A) and aetiological agent (B) of the disease.

(A) (B) (C)

Fig. 6 Yak Milk product (A= Functional paneer packed in LDPE bags) and Yak meat products (B= Meat pickle, C= Momo).

technologies will be used for this purpose. Ecotourism, value addition, smart marketing strategies of yak products as well as development of commercial stock of yaks using cloning, ETT, transgenesis will help flourishing of yak husbandry and the institute will act as catalyst and will provide research back up.

Keeping in view the nutritional hardship yaks faced in general and farmers face in particular, the institute envisions less number of yaks with higher productivity, designer yak population and smart marketing of yak products in accordance to the dynamic demand of the society. ❑

Challenges

The ICAR-NRCY is the unique institute in the country engaged on improvement of yaks and nowhere research activity on yaks are carried over in India. Thus, exclusive responsibility lies with this institute for development in yak husbandry in the country. The vision of the institute is improvement and conservation of yak germplasm for higher productivity and profitability through innovative research.

Yak husbandry is facing lots of limiting issues relating to population dynamics, nutrition, genetics, health and value addition of products which are proposed to be addressed scientifically by this institute in collaboration with line departments. However, huge opportunities exist for improvement of this species. Yaks are traditionally reared on organic method, therefore, their products may fetch premium price. Moreover, due to its importance on livelihood and socio-economic issues of yaks, this species has earned several names like the Bison of Tibet, Ship of the Plateau, Coconut of Animals or simply Gold of Tibetans.

To increase the population size of yaks, its husbandry has to be profitable employing available and upcoming technologies emerging out of research activities in dynamic mode. The yak germplasm has lots of unexploited potentials viz. cold tolerance, conversion of coarse roughages, sustenance on limited fodder, good markets for milk/meat products, packability on high and difficult hilly terrain and finally intimacy with the socio-cultural milieu and livelihood of the tribal yak rearers of the region. For higher productivity and profitability from sustainable yak production system, the institute proposes to engage with the following strategies:

Germplasm Characterization, Conservation and Efficient Utilization

Yaks are unique genetic resources which can sustain on limited grass available in highlands and can tolerate severe cold. A lot of phenotypic variations exist in yak population along with underlying unexplored genetic variability. Distribution and migratory pattern of yaks in relation to pasture can be tracked through GPS system. Landscape genomic approach will be employed to understand how geography and environment affect the genetic structure, including variability of yak population. Molecular characterization of phenogroups and understanding of genetic variations (different alleles at gene loci) will

be studied employing silicogenomics, nutrigenomics and functional genomics for exploiting molecular variability related to production e.g. growth rate, feed conversion efficiency, cold tolerance, disease resistance etc.

The sincere endeavour of the institute will be to identify a group of yaks having superior attributes (genes/alleles) for the desired economic traits and those selected animals will be multiplied through conventional as well as modern reproductive methods like cloning, IVF, MOET, ETT etc. This will culminate to a base population having maximum variability and a production population having more homozygosity for desirable alleles. Production of broiler yak could be one of such situation. Economic traits being polygenic inheritance, Quantitative Trait Loci (QTL) approach for identification of haplotypes may be used for this purpose.

Approach of Sedenterization

In winter months when alpine pasture is covered with heavy snow, yak herders stay in the village and allow the yaks to graze in the adjoining pasture lands, simultaneously grazed by sheep, cattle and ponies. Over grazing causes deterioration of pasture land. This is followed by an increase in the weed population, which are occasionally poisonous to yaks. Due to scarcity of fodder during winter, yaks lose 25-30% of their body weight. To solve the problem research works on scientific management system including nutritional and housing strategies need to be undertaken.

Nutritional Intervention

In traditional yak husbandry system transhumance form of management predominates. The yaks lose their body weight during winter due to inadequate fodders. However, during summer months, while they are in alpine pasture with available fodder in pasture, compensatory growth occurs. Thus, the traditional way of maintaining the animals is to allow them to put on weight as much as possible in summer, and utilize the body fat as an energy reserve for survival in winter months, when there is scarcity of feed and fodder.

To overcome loss of body weight and low milk production during winter the future challenges with the scientists include development of low cost promising feed technologies to raise productivity of yaks thorough out the year, irrespective of seasons. Additionally, identification and encouragement of superior fibre degrading organism in rumen for enhanced Feed Conversion Efficiency and growth rate by sequencing

of rumen metagenome will be carried out to effectively utilize limited available fodder during winter.

Yak Production Under Climate Change

Climate change is one of the biggest environmental threats in the globe. This has been already predicted that, average temperature will increase by 1.8 to 4 degrees Celsius by 2100. It would result in reduced crop yield by 20-40% in most of the Asian countries. Moreover, 20-30% of species will be at risk of extinction. Due to climate change there will be emergence of trans-boundary and vector borne diseases and host-pathogen interaction will augment the emergence of unexpected events, including the emergence of new diseases and pests. The climate change may also affect the biomass availability and quality of high land pastures grazed by the yak.

It is well established that yaks sustain very cold and camels sustain very hot temperature. Being mammals, both have same sets of genes wherein alleles may vary. Combining these alleles may help the transgenic yaks to sustain both hot and cold climate. The Pharmaceutical Farming is other such prospective area. Similarly, molecular intervention of rumen microbes may help yaks to effectively utilize limited feed and fodder under climate change situations. The strategy of the institute will be the development of yaks which are heat tolerant, disease resistant, efficiently utilize coarse feed and fodder and release less methane to the environment. Simultaneously, epidemiological studies and newer diagnostic and vaccine production strategies have to be developed dynamically as situation demands.

Packability and Ethological Studies on Yak

Yaks can carry up to 100 kg loads and move on high hills with stiff and hostile terrains and climate at ease which has certain strategic advantages. Locals use yaks for riding purposes also. To enhance the economic returns from the yak farming, yak tourism and use of yak as pack animals could be other alternatives. Presently, yaks are not trained for such activities on commercial basis because relationship of yak with handler is trainer specific. It is proposed to initiate research activities to understand work physiology and ethology (behaviour studies) for development of package & practices for these purposes.

Value Addition of Yak Products and Transfer of Technology

A good market for yak products exist in the yak rearing states. As modern marketing demands value addition based on market demand,

brand name, good packaging and advertisements for the finished products the institute proposes research and dissemination of technologies on these issues for motivating the farmers to achieve better returns from yaks.

The end users of most of the technologies related to yaks, developed and to be developed, will be the farmers. Being research organization, the institute proposes to mobilize line departments for propagation of those technologies to the farmers. Simultaneously, a few villages, having substantial population in yak rearing states, will be adopted for demonstration of technologies and their assessment in terms of their economic impact and improvement of livelihood of farmers.

❑

Operating Environment

Yak is the most ecologically sustainable genetic resource of the Himalayas which provides livelihood support and nutritional security for highlanders; especially, the poor tribal farmers on remote hills. They are reared on pastoral system by the tribal people on high hills where no other livestock husbandry or crop production is possible. The yaks can sustain severe cold (up to –50°C) and can travel comfortably on snow bound steep hills and hypoxic conditions. They are multipurpose animal which provide milk, meat, fibre, dung and are also useful for transportation of household goods. Thus, livelihoods of rearers are solely dependent on yaks. Traditionally, the yaks are reared under free-ranged system in the high hills where the air, water, and pasture are free from any pollution, and their products are organic and just natural. Thus, yak husbandry has lots of untapped opportunities and can be improved by collective efforts for scientific intervention, developmental activities of line departments and business entrepreneurs having immense role to play to uplift the economy of yak herdsmen in our country. Unfortunately, Indian yak owners do not get good return from yak husbandry. For example tail hair (Chammer), bones, skull and horns are important products of yak – which may be a potential source of income. Presently, the items are utilised either in crude form or converted as waste. If these products are processed finely and brought in modern market, it will surely fetch higher prices than what has been obtained presently by the yak herdsmen. As an example, Chinese are drawing four times higher prices of "fly-whisker" (Chawer) than that of the crude form. The initiative will be taken by the institute to improve the marketability of different yak products in local, national and international arenas. The majority of human population in yak rearing states eat meat and also appreciate different meat/milk products which indicate that huge potential of local market for those products.

The use of yak as pack animals in higher altitudes by the defence establishments might have many fold advantages in addition to the conservation of yak viz. yaks are sure footed animal and can climb stiff terrain with ease, suffer less diseases, comfortable in chilling cold weather and have military advantage of being native to the border areas. This institute plans to study the physiology and ethology of yaks when used

as pack animals to develop modules for their use in tourism and pack animals in different establishments.

By 2050, the institute wishes to see specialized yak populations with high growth rate, higher milk production, higher feed conversion efficiency, suffer less from diseases, comfortable in cold and hot weather and a base population of yaks having substantial variability for all economic traits and are linked with database of ICAR-NRCY through GPS and other modern communication devices. The institute will also plan for construction of yak gallery-cum- eco-parks in different altitudes of yak rearing pockets of India and each yak rearing states may have such parks. In these units, farmers will be provided with the facility of AI, vaccination, treatment of ailing yaks and awareness about new technologies on nominal fees. This service will be rendered by local unemployed youths of this area and this will help for close surveillance of yak tracts, employment generation of highlanders and ultimately socio-economic upliftment of yak rearers and highlanders in four yak rearing states of India.

Opportunities & Strengths

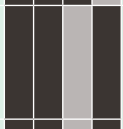
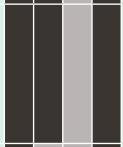
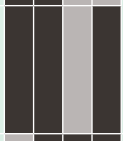
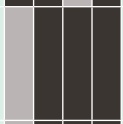
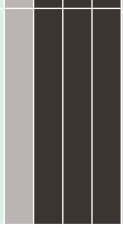
To conserve, improve and effectively use yak germplasm using frontier technologies, the institute will be vigilant to investigate production and adaptive processes of yak in a changing environment system. Use of latest molecular tools and techniques will be helpful to study Functional Genomics for understanding how these yaks are comfortable at a temperature as low as minus 50°C and what may happen when global temperature increases vis-a-vis their production and growth. Studies on Stress Physiology will substantiate better understanding of these processes. Studies on Reproductive Physiology will remain a necessity for enhancing conception rate, multiplication of superior germplasm at a faster rate and addressing emerging requirement of technologies like transgenic, cloning etc. Since yaks can sustain on coarse fodder and vegetation, also believed to survive on eating snow, studies on their Rumen Ecosystem and their Manipulation along with identifying Alternate Feeding Resources will address the basic issues of nutrition. Considering the facts that yaks are reared on migratory mode Epidemiological Studies on diseases (including parasitism) and development of diagnostic and preventive measures will help this husbandry, especially in a changing climatic scenario. Capacity Building of yak rearers, users and line department through training and demonstration will remain a continuous process. Development of Technologies for Value Addition, improved and designer yak products (milk, meat, hair, hide etc.) has to be carried out on the basis of dynamic market demand. Moreover, yak husbandry is by default organic in nature, providing proper marketing opportunities will be highly remunerative to the yak rearers.

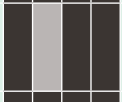
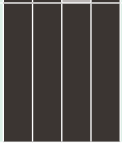
❑

Goals and Targets

As discussed earlier, there are lots of untapped opportunities in yak husbandry which is presently confronted with scientific and developmental in nature. The role of this institute during the next 35 years will remain focussed on understanding the population dynamics, stress physiology, functional genomics, landscape genomics, nutrigenomics, transgenesis, reactivity of yaks to climatic changes, enhancing income opportunities of yak rearers and finally towards value addition of yak products. Therefore, the targets and their expected outputs are presented below.

Goals/Targets	Activities	Timeframe (shaded area) 35 yrs	Output
Developing suitable breeding strategies and conservation of yak germplasm.	Selection of elite animals for higher growth, milk production and feed conversion efficiency.		Meat and milk productivity of farmer's herd will be enhanced up to 100%. Reduction of inbreeding depression to <5% and availability of superior sires to cater the need of the yak population.
	Establishment of nucleus herd and adoption of ONBS in different yak habitats in India and breed characterization of yak hitherto registration in NBAGR.		
	Crossbreeding with cattle for 5- fold higher milk production.		
Genomic studies for understanding economic and adaptive traits in yak.	Structural and functional genomics to identify genes of economic importance and their exploitations.		Identify model genotype for genetic improvement for growth, production and disease resistance. Mitigation strategy against impending climate change using genetic means of selection. Molecular characterization of phenogroups and identification of superior alleles and MAS.
	Bioinformatics tools for interpretation of molecular data for superior allele related to production and disease management.		
	Genetic dissection of cold and hypoxia tolerance traits in yak and their exploitation.		
	Whole genome selection based on SNP and transcriptome profiling for economic traits.		

Understanding rumen ecosystem of yak and their manipulation for enhancing utilization of coarse fodder and lesser methane production.	Isolation and characterization of fibre degrading microbes from rumen fluids and faecal digestion in yak.		Addressing fodder scarcity and enhancing better conversion of roughages and production of lesser methane. Enhanced digestibility of non-conventional tree fodder. Feed and fodder crisis will be addressed in a wholesome manner.
	Identification & quantification of anti-nutritional factors of tree leaves preferred by yak.		
	In vitro studies on ruminal fermentation, methane production, enzyme and microbial profile in yak.		
Addressing constraints related to grazing, sedenterization during winter and study of grazing dynamics.	Development and management of pasture on high hills.		Development of suitable feeding schedule for yaks in winter months to compensate production loss. Improvement and better management of grazing pastures to address the nutritional requirements of yaks.
	Identification of non-conventional feed resources like tree leaves for their use as fodder.		
	Development of fodder preservation methods for locally available biomass.		
Studies on stress physiology and ethology for assessing carrying capacity of yaks at different climatic variables.	Study the level of thermal stress in yak during different seasons with different altitudes and their effect on production and reproduction.		Maintenance and improvement of productivity under changing climatic conditions. Assessment of load carrying capacity as a transport animal in difficult areas where other transport facility is not possible. Strategies for efficient use of yak as pack animal and encouraging tourism and develop package and practices.
	Heat shock protein profile in yak for different seasons and development of different stress ameliorative strategies with reference to cold and heat.		
	Training of yaks for transport with different climatic conditions and altitude.		
Assisted reproduction using modern technologies in yak for increasing productivity.	Frozen semen production and complete AI coverage of yak population in India.		One million doses of straw will be produced, complete AI coverage in the field, increase in embryo production and transfer. Improved reproductive efficiency, enhancing conception rate (>80%) and multiplication of superior germplasm.
	Improvement of protocol for embryo production, transfer and cryo-preservation to cater the needs of the Country.		
	Yak production through introgression of alleles (transgene) of heat tolerance genes from camel/Rathi cattle.		Addressing concerns of climatic changes on yak husbandry.
Development of technologies for value added yak products and by-products adhering to quality and safety parameters.	Mechanized processing and packaging technology for meat of yak.		Newer and designed products for higher economic return. Marketing strategies for milk and meat products.

	Exploring the potential use of yak and blended fibres for development of high end traditional and contemporary textiles.		
	Development of newer processing technology for milk and milk products and their viable marketing strategies.		
Epidemiological studies on diseases (including parasitism) and development of diagnostic and preventive measures.	Seroprevalence and molecular epidemiology of major bacterial and viral pathogens of yak.		Forecasting disease occurrence and preventive measures in a changing climatic scenario. Identification of immune-prophylactic antigens in its native form to confer prolonged immunity and development of newer vaccine and diagnostic kits. Package and practices for disease management of yak.
	Development of DNA chips based diagnostic tests for yak pathogens.		
	Development of chemotherapeutic agents and repellents to control parasites of yak.		
	Development of DNA vaccine of respiratory and abortifacient pathogens in Yak.		
Repository of all information on yaks.	Collection and updating of all information on research, development and allied activities on yaks at national and global level using suitable software and internet.		To act as single window service pertaining to yaks and to became world leader on yak husbandry.

Way Forward

To feed the world, production must double by 2050 and need more sustainable practices. Meeting the challenge of feeding the world of 2050 sustainability in any sector will require aligned contributions from stakeholders. A network of partnership is required to bring public involvement and acceptance of the paths for progress.

The ICAR-NRCY has been consistently working to develop the yak and the yak rearers through systematic research. Although modern developments viz. biotechnological, social, economic, industrial, informational are changing rapidly, this has little impact in changing scenario of yak rearing region. Most of such developments are controlled by complex interactions by many variables. The institute is mandated to conserve yak germplasm, improvement of nutritional status of yak for higher productivity, establishment of disease free zone and finally these actions will lead to socio-economic upliftment of poor yak farmers. Therefore, with continuous intervention and effort, ICAR-NRCY in future will be describing and analysing the problems of yak husbandry and will identify better outcomes for individuals and society by illuminating strategies of intervention.

To address complex problems of yak production, strategy have been planned on different perspectives. Therefore, research programmes of institute have not been proposed as a single programme rather it recommends collaboration to strengthen both individual projects and collective effort through interdisciplinary, multidisciplinary and inter-institutional programmes. Research targets, thus, must address the burning problems of yak husbandry viz. declining yak population, inferior germplasm, less understanding of physiology and production process, high cost of grazing, deterioration of pasture, poor marketing infrastructure, and lack of scientific package and practices of yak management. The framework has been aligned in such a way that, using scientific expertise and research resources, the institute can improve yak husbandry and can contribute significantly to alleviate the poverty of yak farmers of this region of the country by pursuing the following research themes.

1. Genetic improvement for higher production, reproduction and packability: Genetic evaluation of economic traits will be carried out for improvement in production and reproduction through application

of suitable breeding strategies. Development of suitable breeding programme for the yaks, reared under migratory mode using GPS and microchips, will be useful for sustainable management of this unique germplasm. Highly variable (heterogeneous) base population and homogeneous production population having superior alleles for the chosen economic traits.

2. Genomic studies for understanding economic and adaptive traits: Assessment of novel gene (s) which aid and assist in better production, cold adaptability and disease tolerance will be done. Characterization of genetic architecture and identification of molecular markers of important proteins in yak are to be undertaken. Landscape genomics, functional genomics, silicogenomics and nutrigenomics techniques will be used for this research works.
3. Development of feeding standards for different categories of yak in relation to the rumen ecology and highland grasses: Rumen ecology of yak will be studied for better understanding and its manipulation for efficient utilization of coarse fibre and lesser methane production using throughput sequencing of rumen metagenome. Development and evaluation of suitable winter feeding strategies for yaks will also be a priority area, after feeding new variety of product, pasture grass, and fodder trees suitable for yak rearing tract of India.
4. Controlling of disease by Genetic Engineering: Infectious diseases are still the main cause of illness and death of yak. In vision 2050 we visualize most of the infectious diseases of yak will be controlled by genetic manipulation of organism and host genome. Genetic engineering technology will be handy for development of polyvalent DNA vaccines. For controlling FMD in yak, research works in collaboration with PDFMD will be undertaken.
5. Nutrigenomical studies for better understanding of nutrition and production matrix: Yak genomics will be incorporated with nutritional factor targeting specific nutrients and deprivation which influence expression of certain genes. It also facilitates greater understanding of how nutrition affects on metabolic pathways and thereby developing custom made feeding module for higher production.
6. Studies on stress physiology and ethology related to packability: For encouraging yak tourism and packability, studies on stress physiology and ethology under different altitude and climatic conditions using scientific techniques will be undertaken.
7. Developing capacities and competitiveness to screen various infectious and parasitic diseases and to develop suitable control

measures: Suitable immune- and/or DNA-based diagnostic tests for infectious as well as parasitic diseases will be developed. DNA microchip will be developed for detection of yak pathogens. The abiotic stress like environmental pollutants and other stressors in yak will be identified and their effect on production and reproduction will be studied.

8. Assisted reproduction in yak for increasing productivity: Hormonal and non-hormonal manipulation will be done for improving fertility and productivity. Fine-tuning of artificial insemination, embryo transfer, somatic cell cloning and transgenic research will be undertaken for increasing productivity and faster multiplication of superior germplasm. ETT, AI and frozen semen technologies will be also considered as existing practices.
9. Development of technologies for value added yak products and by-products adhering to quality and safety parameters: To make yak husbandry more remunerative, the marketing of designer yak products will be the priority area. Modern packaging and fine tuning of processing will be worked out along with economic assessment of products and marketability will be undertaken.
10. Capacity building of yak farmers/other stakeholders: The activities include organization of training programmes and extension camps for brokpas (yak rearers) and other stake holders, impact analysis of developed technologies of yak husbandry by adopting villages in yak rearing regions for improving socio-economic status and livelihood of farmers.
11. Transforming Yak farming to Yak industry: The vision 2050 aims to transform traditional yak husbandry to modern and smart yak industry wherein a base population with high genetic variability, linked with database, will be maintained simultaneously with the population of homogenous yaks for designer production system like broiler yak, environmentally suitable yaks, disease resistant yak populations etc.

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