42nd FOUNDATION DAY LECTURE

FORAGE RESEARCH – NEW DIMENSIONS

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I feel great pleasure in delivering this lecture on the occasion of 42nd foundation day of Indian Grassland and Fodder Research Institute (IGFRI), Jhansi). The institute (established in November 1962), only of its own kind in whole of Asia, has achieved excellence in the field of research on improvement of forage crops, range management and aspects related to forage conservation and utilization. However, in the fast changing agricultural scenario the forage research also need newer and more innovative approaches for desired outputs.

Indian agriculture and animal husbandry are integrated to each other and this scenario is expected to continue in the foreseeable future. Perhaps nowhere in the world do man and animal come together in such a rich and diversified cultural environment as in India and unlike in the west where the livestock are viewed purely on economic considerations.

Deficiency in feed and fodder is identified as one of the major constraints in achieving desired level of livestock productivity. While there is some debate on the exact size of the current deficit, there is general agreement that the volume and quality of future feed and fodder supplies will be of vital importance in sustaining the growth of animal husbandry sector. According to an estimate the shortages in dry fodder, green fodder and concentrates are 40.4 per cent, 24.7 per cent and 47.1 per cent against the requirements of 650.7, 761.5 and 79.4 million tones for the current livestock population, respectively. The pattern of deficit varies in different parts of the country. For instance, the green fodder availability in Western Himalayan, Upper Gangetic Plains and Eastern Plateau and Hilly Zones is more than 60 per cent of the actual requirement. In Trans Gangetic Plains the feed availability is between 40-60 per cent of the requirement and in the remaining zones the figure is below 40 per cent. In case of dry fodder, availability is over 60 per cent in the Eastern Himalayan, Middle Gangetic Plains, Upper Gangetic Plains, East Coast Plains and Hills Zones. In Trans Gangetic Plains, Eastern Plateau and Hills and Central Plateau and Hills the availability is in the range of 40-60 per cent, while in the remaining zones of the country the availability is below 40 per cent.

Bridging this gap between demand and supply is indeed a matter of great concern. This is more so in view of limited area under forage crops and the practical difficulties in expanding this area and also deteriorated condition of natural grazing areas both in terms of its extent and quality. The scenario of forage crops is different when compared to other crops in respect of multiplicity, regional specificity and seasonality. Also, due to non-commercial, the farmers are generally not attracted towards these crops and in most of the situations forage cultivation is practiced even on degraded and marginal lands with very less inputs, realizing only low production.

Biodiversity in Forage Resources

Indian sub-continent is one of the world's mega centers of crop origins and crop plant diversity as it presents a wide spectrum of eco-climate ranging from humid tropical to semi-arid, temperate to alpine.

India's diverse agro-climatic and regional topography and the preponderance of indigenous tribal population and their ethnic groups have largely contributed to the agro-biodiversity. The country has 141 endemic genera belonging to 47 families of higher plants. Of the 4200 endemic species, Himalaya accounts for 2532 species, followed by peninsular region (1788 species) and Andaman and Nicobar Islands (185 species). It has 166 species of agri-horticultural crops and 324 species of wild relatives. Concentration of genetic diversity comprising native species and land-races occurs more in Western Ghats, Deccan Plateau, Central India, North Western Himalayas and North Eastern Hills. The richness of plant diversity is largely due to ecological diversity superimposed with tribal and ethnic diversification, plant usages and religious rituals. Equally rich are the livestock resources of the country having 81,000 animal species, 26 breeds of cattle, 40 breeds of sheep, 20 breeds of goats, 18 types of poultry and all the 8 breeds of buffaloes.

The Indian gene center possesses a rich genetic diversity in native grasses and legumes. There are reports of 245 genera and 1256 species of Gramineae, of which about 21 genera and 139 species are endemic. One third of Indian grasses are considered to have fodder value. Most of the grasses belong to the tribes Andropogoneae (30 %), Paniceae (15 %), and Eragrosteae (9 %). Similarly, out of about 400 species of 60 genera of leguminosae, 21 genera are reported to be useful as forage. The main centers of genetic diversity are peninsular India (for tropical types) and North-Eastern Region (for sub-tropical types) besides some micro-centers for certain species.

Since ancient times, Indians have practiced mixed farming where livestock formed an integral part of agriculture. Rich genetic diversity exists for cultivated and rangeland species including tree, browse species, and herbaceous grasses and legumes. Major forage genera exhibiting forage biodiversity includes legumes like *Desmodium, Lablab, Stylosanthes, Vigna, Macroptelium, Centrosema* etc.; grasses like *Bothriochloa, Dichanthium, Cynodon, Panicum, Pennisetum, Cenchrus, Lasiurus, etc*; browse plants such as *Leucaena, Sesbania, Albizia, Bauhinia, Cassia, Grewia* etc. These genera besides many others form an integral part of feed and fodder resources of the country. The country is further endowed with the rich heritage of traditional know-how of raising, maintaining and utilizing forage, feed and livestock resources.

Forage Crop Breeding: Problems and Strategies

Forage crop improvement requires a long term and multidisciplinary approach involving several disciplines, *viz*., plant breeding, genetics, agronomy, pathology, nematology, entomology, physiology, biotechnology and animal nutrition etc. A thorough understanding of species relationships, chromosomal constitution, genome structure, putative parentage and extent of possible gene exchange/recombination and nature of polyploidy is also required for the breeding program. The strategy for various crops varies as per the problems encountered in that species.

For instance, tropical forage grasses are mostly apomictic and tetraploid and are thus difficult to breed. The conventional methods of hybridization and mutation have almost failed in incorporating desirable changes in the plant types. Hence, direct introduction of adaptable high yielding biotypes is considered as one of the efficient methods. Breaking of the apomixis by induction of sexuality to allow free gene exchange and development of new recombinants is a potential possibility for range grass breeding. The production period of the tropical grasses is from July to October that also happens to be a favorable season for many insect pests and other pathogens due to high humidity and high temperature. In order to save the damages on this account, attention is also required towards breeding of disease and pest resistant lines. Use of biotechnological tools *viz*., somatic cell hybridization, somaclonal variations, genetic transformations are also very important in the otherwise difficult grasses for inducing variability. Many grasses flower for quite long period and lack synchrony in flowering leading to difficult and costly seed harvest. Development of synchronous flowering plant types for increasing seed yield need due attention.

Leguminous species such as berseem, lucerne, cowpea, *Dolichos* and stylos are very good forages and attention is required for developing suitable lines with efficient nitrogen fixing ability, having high phosphate response resulting in high dry matter besides high protein content, wide tolerance for different soil conditions and diseases and pest.

There are several antiquality factors that affect the large-scale acceptance of many important and high yielding fodder crops such as oxalates in N-B hybrids, HCN in sorghum, mimosine in *Leucaena*, etc. These problems need to be dealt with by using suitable breeding techniques like selection, mutation etc. Biotechnological tools such as site directed mutagenesis, anti-sense RNA techniques may also provide answer to such problems.

In forage crops, most of the losses due to pests and diseases go unnoticed because of insidious nature and also coupled with the general lack of awareness. According to an estimate pests including pathogens, insects and nematodes incur yield losses up to 20-30 per cent in major forage crops. More work is required on identification of important pests, their biology and management. Since the chemical control of diseases may have adverse implications from the viewpoint of environment, emphasis is required on breeding/ developing forage crop varieties having tolerant/resistant genes for important pests and diseases. Transfer of desirable genes through successive backcrossing and/or evaluation of progenies/germplasm under epiphytotic condition could result in development of tolerant/resistant lines. Gene transfer from wild taxa through biotechnological tools/molecular gene manipulations may also help to solve some specific problems.

Biotechnological Approaches

Tremendous technological development in recent past has equipped the plant scientists with enormous options to tailor the plants according to need. The improvement of forage crops through biotechnological approach has started in late eighties but at global level it has made remarkable headway. The various biotechnological tools include molecular techniques for understanding the genetic structure of the plants, inserting foreign genes directly into the plant genome, *in-vitro* regeneration of plants from any plant part.

A number of techniques such as embryo rescue, micro-propagation, andogenic haploid plant production and creation of novel variations simply help at one or more steps involved in conventional breeding methods. These techniques save time and energy required for conventional methods. Further, the plants developed through these techniques do not attract those who are against the genetically modified organisms. Embryo rescue has well been exploited in *Lolium/Festuca* complex for production of hybrids. *Lolium/Dactylis* hybrids have also been developed by this method and so is many interspecific hybrids in *Trifolium*. Progress in developing interspecific hybrids of berseem at IGFRI has also been made. Regeneration of the plantlets from reproductive parts such as anther results in haploid plant production. Hence, the process is very effective in developing plants with double set of genome in the otherwise tetraploid tropical grasses.

Biotechnological approach offers opportunities for creation of novel variations in forages which as such not possible through conventional methods. The various means of creating variation in forage grasses and achievement are somaclonal variation, somatic hybridization, genetic transformation etc. Artificial introduction of some foreign gene in the plant genome is genetic transformation. Insertions of genes may be by chemical, electrical, physical or micro-projectile transfer. In grasses it has been only limited success so far. To date successful transformation has been reported in some perennial grasses *viz*., *Lolium sp., Festuca sp. Agrostis sp., Dactylis, Paspalum* and *Dichanthium.*

There are several molecular techniques *viz*., RFLP, AFLP, RAPD and isozymes that may be used from time to time for characterization of germplasm, cultivar identification, detection of hybrids and genetic mapping and gene tagging. The molecular characterization of agriculturally important plants is equally important to that of many grasses and weeds because through the transformation techniques genes identified from any plant or living organism can be transferred to the target species on account of similarity in DNA sequence across various species and genera. Characterization of germplasm is one of the most important aspects, especially in the context of the changing scenario with regard to Plant Biodiversity Act. Presently, forage germplasm characterization is mainly on isozyme basis. There is a need to classify forage germplasm for the two objectives - firstly for developing DNA fingerprints and secondly for identifying the duplicates in the germplasm.

It is desirable that the forage varieties are also subjected to molecular characterization in order to avoid any dispute regarding use of germplasm in coming years. The major problem encountered with these molecular markers of the forage species is that most of the cultivars are synthetic populations and variability exists within the population. However, the efforts have been made for characterizing the varieties based on RAPD, RFLP markers and discrimination between the varieties can be based on gene frequencies.

Genetic mapping and gene tagging in forage species has not been attempted much. For single gene control traits gene tagging is important but in case of forages most of the desirable agronomic traits are multi-genic and hence are difficult to tag.

There are also opportunities for improving the amino acid balance of the plants used in intensive feeding production systems. At CSIRO Australia, incorporation of gene normally expressed in sunflower for sulfur amino acid to lupin (deficient in sulfur amino acid) increased sulfur amino acid content of transgenic lupin grain, resulting into higher animal productivity through usage of lupin meal.

Another important area need attention of biotechnologist is stress tolerance, biotic and abiotic, in forage crops and range species. Encouraging results have been obtained in different crops in identifying the genes and regulatory elements. Selection of germplasm for salinity tolerance is very important utilization of such lands. Germplasm can be screened *in vitro* at two levels: (i) seedling level and (ii) tissue or cell level. *In vitro* studies have shown significant interspecific and intraspecific variation among legume and clover species for salt tolerance. Intracultivar variation has been identified in lucerne and *T. repens*. In case of post fertilization incompatibility barriers, embryo rescue is most effective and successful technique.

Identification of genes controlling apomixis is an area that can pay good dividends in grass breeding. Identification and cloning of these genes can well be patented and can also be used in transferring in other cross pollinated crops for fixing heterosis and thus save on the account of producing hybrid seeds every year. Although, this aspect is receiving global attention, success has been little till date. Another aspect on these lines is identification of sexual lines in grasses. There is need to develop reliable molecular technique for screening of the grass species for existence of sexuality as it would accelerate the breeding process in such grasses as many of these plants could be used in crossing. The plants with better agronomic traits and apomixis can be selected and advanced for developing varieties.

Forage Production on Arable Lands

Wherever there are opportunities to produce fodder on arable lands, intensive forage production system may be practiced, aiming at achieving maximum sustainable harvest of nutritive herbage per unit area and time. In multiple cropping systems, 3 or 4 high yielding forage crops are grown on a particular piece of land in a calendar year. The crop sequences are tailored with an objective of achieving high yields of green nutritious forage and at the same maintaining the soil fertility. The system assures regular supply of green forage when staggered sowing and harvesting schedules are followed. Under assured irrigation multiple crop sequences like MP Chari - turnip, Berseem + mustard - maize + cowpea - MP Chari + cowpea and Berseem + mustard - MP Chari + cowpea has been found better. These systems are better suited to well-managed mechanized farms.

The concept of overlapping cropping systems may also be practiced. In this, sowing of succeeding crop in done while the preceding crop is still in the field. This practice reduces or even avoids the slack period of forage availability. The system involves growing of combination of appropriate perennial and annual forage species that are not competitive and ensure regular supply of green forage throughout the year to meet the requirement of large dairy farms and also of small farmers having limited land holding to grow food as well as forages.

The fertilizers management strategies in fodder crops aim at increasing the herbage production per unit area and time along with improvement in forage quality parameters and maintenance of soil health. The requirement of fodder crops for nutrients particularly nitrogen is comparatively higher. Chemical fertilizers have played a significant role in increasing crop productivity. But, for sustainable production from arable lands it is important to prepare a balance sheet of nutrients depleted and nutrients supplemented. Majority of the soils at present are rich in potassium but continuous cropping without K application over the years may turn to be deficient.

Bio-fertilizers, the products containing living cells of different types of micro-organisms, play important role in enhancing fodder production and also cutting down the usage of chemical fertilizers. Studies have shown that a saving of 20 kg N/ha may be achieved with application of *Azotobacter*/*Azospirillum* in cereal fodder crops. Similarly, increase in forage yield due to *Rhizobium* inoculation to legume forages ranged between 14-46 per cent. Seed inoculation of berseem with phosphate solubilizer significantly increased the green fodder (103.6 t/ha), dry matter (16.19 t/ha) and crude protein (3.20 t/ha) yields over the control. Integrated use of organic, inorganic and bio-fertilizer sources of nitrogen in sorghum + cowpea–berseem cropping system led to over 25 per cent saving in N through use of *Rhizobium* and/or *Azotobacter*. However, a reliable system of quality control and efficient system of storage, transportation and management of bio-fertilizers is required for its wider applicability.

Organic manure-induced improvement in soil physical, chemical and biological properties is well established. Build up of secondary and micronutrients, counteracting deleterious effects of soil acidity, salinity and alkalinity and sustenance of soil health are the key beneficial effects associated with organic manure application. Use efficiency of N fertilizers is improved in the presence of FYM.

Integrated pest management is emphasized these days in order to reduce the use of chemicals. The population of the three major pests namely leaf hoppers, lucerne weevil and aphids can be managed effectively by growing of least susceptible variety, IGFRI-450 in first week of July with fertilizer application of 30 kg N, 100 kg P_2O_5, 80 kg K_2O per hectare and if required application of endosulfan @ 0.08% or berliner @ 0.84 kg/ha may be done. In cowpea, the damage due to major pests like, leafhoppers, semilooper, tobacco caterpillar and grasshopper can be managed without using insecticides by planting the least susceptible variety in the first week of July, using an optimal fertilizer combination of 30 kg N, 100 kg P_2O_5, 40 kg K_2O per hectare with two weeding at 15 and 30 days old crop.

Successful integration of forage crops in the existing cropping systems (rice-wheat or jowar/bajra/maize-wheat) may be profitable also good from the viewpoint of soil health. There are reports of more profitable forage crop sequences *viz*., rice-berseem and cowpea-wheat when compared to rice-wheat and jowar-wheat systems, respectively. Similarly, integration of *Sesbania* on bunds (accounting 5-7 % of field area) may provide nutritious forage during summers.

Scientific management of water is crucial for year round supply of green fodder from an intensive fodder production system. It aims to provide ideal moisture regime to the crops for realizing their yield potential commensurate with the maximum economy in irrigation water and maintenance of soil productivity.

Management of Grazing Resources

Indian subcontinent is characterized by tropical monsoon climate, active growth of grazing land occurring only during monsoon months. Since ancient times cattle breeding and milk production has been the second most important profession in India after agriculture. Free grazing was practiced and became a way of life. Presently also, livestock production is primarily based on rangeland grazing. The grazing activity is mainly dependent on the availability of the grazing resources from pastures and other grazing lands *viz*. forests, miscellaneous tree crops and groves, cultivable wastelands and fallow land. Such lands are about 40 per cent of the total geographical area of the country. The grazing intensity in the country is as high as 12.6 ACU/ha as against 0.8 ACU/ha in developed countries. Therefore, our task is two fold *viz*. improvement of pasture and judicious implementation of grazing management.

There is a lot of difference in the extent of grazing lands in various states. In some states *viz.* Himachal Pradesh, Jammu & Kashmir, Meghalaya, Nagaland and Arunachal Pradesh the grazing land availability is as high as 70 per cent. Pasturelands constitute the main grazing resources of the country, available over an area of 12 m ha (3.94 % of the geographical area). The distribution of pasture lands are mostly noticed in the state like Himachal Pradesh (36.44 %), Sikkim (13.31 %), Karnataka (6.54 %), Madhya Pradesh (6.35 %), Rajasthan (5.39 %), Maharashtra (5.11 %) and Gujarat (4.49 %). The northern region has pasturelands in Jammu & Kashmir, Himachal Pradesh and Uttaranchal. This region has a potential resource in the form of green meadows and pasture, which at some places are mixed with the forests. The alpine meadow has an important economic value, providing pasture for the sheep and goats. The western India includes the pasturelands of Rajasthan and Gujarat. In Rajasthan the available grazing land is over 40 per cent and in Gujarat the area is about 30 per cent. The land under permanent pasture is about 5.4 per cent in Rajasthan and 3.5 per cent in Gujarat, providing good quality fodder for livestock.

Nearly 30 pastoral communities in northern and western parts of the country depend on grazing based livestock production. Based on the practice followed by these pastoral communities in various regions, the grazing systems may be categorized either on the basis of methods of grazing or patterns of migration. Considering methods of grazing the pastoral communities change the site of grazing after its utilization. The example of such type of grazing system is *Kharak* in Uttaranchal and *Goals* in the desert area of Rajasthan. Based on migratory habits the nomadic tribes are classified in 4 groups *viz*. (i) total nomadism; (ii) semi nomadism; (iii) transhumance; (iv) partial nomadism.

The success behind any grazing management practice depends on the accurate stocking rates considering the condition of the range. Moderate and conservative stocking rates sustain returns on a long-term basis when compared to heavy stocking rate.

Under different pasture utilization systems *viz*. rotational, deferred rotational, continuous and cut & carry; highest run-off and soil loss was recorded in continuous system while minimum run-off was recorded in rotational system. However, minimum soil loss was recorded in cut & carry system. The observations showed that improved practices of pasture establishment, contour bunding, grazing management reduced soil loss, made more water available and improved soil conditions. Out of the 4 systems of grazing management, relatively higher values of organic carbon and available nutrients (N, P & K) and lower average loss of nutrients were observed in deferred rotational system, indicating its superiority over other pasture utilization systems.

The results indicate that for improvement of the existing rangelands techniques like bush cleaning, application of fertilizers, controlled burning coupled with proper grazing management should be employed.

Alternate Land Use System: Agroforestry

Considering the continuous pressure on cultivable lands and deterioration already set in on the grazing lands, it is imperative to look for alternate land use systems that integrate the concerns for productivity, conservation of resources and environment and profitability. Agroforestry technologies such as silvopasture, hortipasture etc. hold promise not only for bioremediation of degraded habitats but also forage production.

Silvopastures integrate pasture and/or animals with trees. Woody perennials, preferably of fodder value, are introduced deliberately and systematically and managed scientifically. Under poor soil, water and nutrient situations where cropping is not possible such systems can serve the twin purposes of forage and firewood production and ecosystem conservation. It has been possible to increase land productivity from 0.5-1.5 t/ha/year to > 10 t/ha/yr (10-year rotation) by developing silvopastures. Now, concept of hortipasture is also finding applicability with the farmers for utilizing their degraded lands. The additional forage availability through such systems is likely to reduce grazing pressure and thus have important environmental implications. Efforts to design silvopasture systems to produce > 15 t/ha/year through species introduction, planting geometry, canopy manipulation and sustainable management through *in situ* grazing or cut and carry system are continuing.

The grasses have a lot of conservation benefits in reducing soil and water loss to a great extent. Average soil loss from deforested land is reported to be 12-43 t/ha in black soil and 4-10 t/ha in red soils whereas soil loss from natural grassland has been only 3.2 t/ha from a protected site. Silvopastures are still better for soil conservation, soil loss from these areas coming down to 0.9 t/ha. Grasses and legumes are primarily valued as forage and their value in checking soil erosion is often less viewed. There are specific recommendations for a particular type of soil and rainfall. For example, *Dichanthium annulatum* is best in reducing soil loss from 20.5 t/ha to 1.5 t/ha on sandy loam soil (2 % slope) in 790 mm rainfall situation.

Animal Husbandry Sector

Animal husbandry serves as a source of employment for large population (over 70 million rural families) of the country. Sometimes livestock is the only source of income for the family, particularly in the events of crop failure. The value of livestock output forms about 26 per cent from agriculture, accounting for 8 per cent of the GDP.

Although India possesses the largest population of livestock in the world and stand first in milk production besides being self sufficient in meat and poultry, the livestock productivity is low, providing limited resource returns. Further, the consumption of milk, meat and eggs on a per capita basis is still below the WHO recommendations. The availability of milk per head per day in the country in only 178 g against the norm of 250 g. Similarly, the consumption of eggs and meat is only 35 and 800 g per head per year against the norm of 180 eggs and 11 kg, respectively.

Thus besides such deficits in supply, it is not a happy situation for a country where majority of rural people derive their sustenance to a great extent from animal husbandry. The demand of the day is to make animal husbandry as an economically viable, environment friendly sustainable farming that can boost overall economy of our country. To achieve this target an improvement in nutrition of farm animals is essential, since in ruminants the feed cost alone represents 50-60 per cent or more of total recurring expenditure. Thus, it is imperative to supply nutritionally adequate diet and to prepare the diet in a manner that encourages consumption with minimum waste and allows high efficiency of feed utilization.

Management for Maintaining Lean Period Fodder Supplies

In fodder supplies, the paradoxical situation is that in many parts there is surplus fodder during monsoon and a deficit occurring during lean season. This is especially so in the far flung areas. Thus there is need to identify the crops that can be grown in between the two crop seasons. This would help to meet the forage requirements of the lean periods. Utilizing the leaf meal of the leguminous species (both woody perennials and herbaceous) such as lucerne, stylo, *Leucaena* hold promise to overcome the lean period fodder deficits. The post harvest technologies such as biomass processing, enrichment, densification etc. hold the key for better animal husbandry in the deficit zones.

India is a mosaic of agro-environments ranging from extremely humid to extremely arid tropical and temperate zone. Thus a different approach is required to feed the animals during lean period. The present practice depends largely on grains that is costly and also competes with the human requirement.

Forage Seed Availability

One of the main reasons for slow pick up of forage production technologies is unavailability of proper seeds of forage crops and range species. According to an estimate, hardly 20 per cent of forage seed requirement is met. With the development of a number of improved and high yielding varieties in forages, it has become important that quality seed is readily available for supply to the farmers. There is increasing demand of seeds of *Cenchrus ciliaris*, *Chrysopogon fulvus, Pennisetum pedicellatum, Panicum maximum*, cowpea, berseem, sorghum, and oat.

By and large forage crops are shy seed yielders. There are various causes of low seed yield in forage crops *viz*., indeterminate growth, uneven maturity, blank seed, seed dormancy, site effects etc. Also, the nature of forage seed production is much more complex and a number of environmental and physiological factors have a significant impact on seed production potential of a crop. In majority of forage crops, seed production depends on photoperiod, thermo period, humidity, soil texture, soil structure, soil reaction and moisture. Each forage crop is, therefore, suited to only specific area for forage and/or seed production such as berseem in the northern plains and lucerne in the northwest India. Similarly pasture grasses like *seven* is best adapted and productive under low rainfall situations of western Rajasthan whereas Congo Signal grass and guinea grass produce better seeds in the highly humid regions of Kerala.

Future Outlook

Time has come to take a stock of present situation and re-examine our research priorities to make them need based. The following points are suggested in this direction:

- The current emphasis on forages is to be focused on regional problems. Considering the continuous pressure on cultivable lands it is imperative to look for alternate forage production sites. The main emphasis should now be on degraded lands/problem soils where nothing can be grown and cost of chemical/physical amelioration is very high.

- The alarming situation of the fragile ecosystem of the desert and also in the alpine pastures and meadows on the high hills of the Great Himalayas require adequate attention. The lesson that “Forests precede civilization and deserts follow them” should always be kept in mind. Restoration of degraded rangelands and re-vegetation/ rehabilitation of wastelands must form a part of the overall development plans. Landscape be the unit of development and resource management.

- Inventory of degraded lands in all the agro-ecological regions of India should get a high priority. GIS should be effectively used for making an inventory of biophysical sources and monitoring of development systems.

- There is an urgent need to have a sincere effort to collect the genetic diversity of various plants from problem soils and their proper evaluation in both field and laboratory conditions in order to identify the suitable germplasm for a particular problem condition. Identification of the traits/genes will be the next step for genetic improvement programme. Identification of such genes/traits can then be attempted for transfer through conventional or biotechnological methods.

- Efforts should be made to develop crop based feeding system for different agricultural crops grown in different zones of the country. The regional deficits are more important than the national deficit, especially for forage as often is not economical to transport over long distances.

- Mixed farming system should be supported, as the economic contribution of animals becomes even more significant in the context of beneficial effects like a low input integrated and sustainable system, nutrient recycling, alleviation of rural poverty and improved food security besides positive effects on the environment.

- The improvement in fodder production on saline soils can be augmented by increasing salt tolerance through exploitation of natural variation in the germplasm or by creating novel variations.

- Genetic improvement for drought tolerance is an important component in stablizing fodder production in the country. *Kharif* crops (sorghum, millets, grasses and legumes) are sown at the onset of the rains. Probabilities of moisture deficit are highest at start and the ends of rains. Similarly for *Rabi* crops dry winter is followed by a hot spring and water deficits are common near flowering stage of the crop. The need is to accelerate the search for unique drought adoptive mechanisms using the full range of diversity available.

- Bloat causes farmers a lot of concern and results in significant losses in production. Bloat is due to feeding on rich legume forages, where plant lacks protein and precipitates tannin. The transgenic technology could relieve a lot of animal suffering and restore the grazing system to full productivity.

- Transgenic berseem and lucerne crop based around *Bacillus thuringiensis* gene giving protection against *Heliothis* damage, which is a principal seed crop pest in these crops.

- Identification/building of a resistant gene that provide stable resistance against stem and root rot complex of berseem.

- Improvement of the amino acid balance of the forage plant species used in intensive feeding and production systems.

- Improvement in the efficiency of uptake of essential nutrients such as nitrogen and phosphorus through understanding of molecular and cellular mechanism of uptake of nutrients by plant roots from the soil.

- Formalize the community gene bank existing at the village level.

- The appropriate sites for undertaking forage seed production may be identified apart from the traditional areas for growing these crops. Adequate emphasis is also required on seed processing and handling techniques for maintaining the quality of forage seeds. A concerted effort is the need so that available technology could be passed on to the forage and seed producing agencies and also to farmers for their eventual use in augmenting forage resources. Also, in order to meet the huge requirement of forage seeds, it is important to expand the programmes related to participatory forage seed production.

- Rumen manipulation to improve the utilization of low-grade forages (in the ruminants) is an area where a real breakthrough is yet to be achieved. It may be little difficult and time consuming, since the rumen ecosystem is strictly anaerobic.

- The concept of forage based livestock production that is coupled with aided environmental conservation is fast picking up in view of the changing socio-economic pattern. There is need for availability of adequate scientific and technical manpower for transmission of forage technologies suitable for farmers of all strata in different agro-ecological zones.

- The social issues are extremely important in adoption of forage production technologies as the benefits and costs involved in different technologies in various conditions and on farm types and identification of appropriate uptake pathways for effective dissemination of technologies vary.

- The research is to be tuned more with a participatory bias, whether it is crop breeding, designing of agroforerstry system, range management or seed production. Participation of clients and end users will definitely enhance the adoption of technology.