Report of the Working Group on

Agricultural Research and Education

for the XII Five Year Plan: 2012-17

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PREFACE

Agricultural research and education has played key role in economic development of the country. This began with seeds of high-yield varieties, fertilizer and associated crop management practices. Wide adoption of these technologies contributed to quantum jump in foodgrain production, popularly known as the 'Green Revolution.' Advancement in hybrid development, improvement of varieties for horticultural crops and technologies for higher milk, meat, egg and fish production contributed to the diversified and accelerated growth. Of course, policy and public investment were useful ally to achieve the growth. However, the slowdown after the mid-nineties was a great concern and therefore, concerted efforts were made to raise public investment and disseminate technology to the farmers. This strategy paid dividends in terms of achieving a growth of 3.3 per cent per annum in XI Plan.

The growth during XI Plan is quite appreciable but short of the target growth of 4 percent. This needs accelerated technology development and information flow to farmers coupled with greater access to inputs, services, and product markets. This report mainly focuses on agricultural research and education so as to make the system demand-driven, enhance technology flow to farmers and bring transformational changes in Indian agriculture. The report gives key objectives, strategy for technology development, their integration and transfer to farmers and major thrust areas. There is exclusive discussion on basic and strategic research and human resource development through education programmes. We hope that the recommendations made here will be useful for increasing the role of the Indian Council of Agricultural Research and State Agricultural Universities in promoting the knowledge-intensive agriculture that will result in the inclusive growth.

We are grateful to all the members of the Working Group and the Sub-groups for providing invaluable insights. Thanks are also due to the Planning Commission and the Indian Council of Agricultural Research for providing necessary support. Special thanks are due to staff of IARI, particularly Dr Suresh Pal, Head, Division of Agricultural Economics for help in preparation of the report.

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1. EXECUTIVE SUMMARY AND RECOMMENDATIONS

Indian agriculture is a success story of application of science & technology that helped in attaining and maintaining food security of the second most populous country on the earth. This accomplishment was realized through concerted efforts of the policy makers, scientists and farming community. **The country registered 3.3 percent growth in agriculture sector during XI Five Year Plan, which is much higher than that achieved during the last two plan periods**. The growth was largely driven by the increase in resource use efficiency, consolidation of past yield gains and generation as well as application of new technology. Now with the advancement in science, institutional change and human capacity, innovations in the creation and application of new knowledge have to play a much greater role in sustaining and further accelerating agricultural growth. Therefore, the focus in XII Plan should be on *innovations for promoting knowledge-intensive agriculture, conserving the natural resource-base and building resilience*, so that malnutrition and hunger are reduced and poverty alleviated. This would entail the blending of modern science and indigenous knowledge. The recommendations of the Working Group are built to achieve this objective. The report specifically suggests options to make **agricultural research demand-driven.** Such research will facilitate the diversification of agriculture to meet changing food basket, conservation of natural resources, reduction in cost of cultivation, rise in farm income, improve livelihood security of the poor and promotion of inclusive growth. The research programs will be tailored not only to meet the growth target of 4%, but also to achieve higher growth in the leading high value sectors like horticulture, livestock and fisheries.

1.1 Research Strategy

The research strategy should entail the organization of the programs on four lines: (i) strengthening basic and strategic research to feed into applied research for accelerating technology flow and addressing anticipated challenges; (ii) major programs for research integration and acceleration of technology generation; (iii) up-scaling of technologies for their larger adoption, facilitating transformation of agriculture in partnership mode; and (iv) strengthening frontline extension and outreach programs of ICAR institutes and state agricultural universities (SAUs).

With the advancement in sciences, higher skills are required for using information-intensive technologies and, therefore, capacity building deserves high priority. For this, modernization of infrastructure in ICAR institutes and state agricultural universities (SAUs), development of human resources and improvement in knowledge and skill of farmers are critical. Also, high priority should be accorded to build core competence in cutting edge science and strategic research.

The strategy focuses on sustaining the productivity gains and increasing, wherever possible, in the irrigated agriculture. The major emphasis should, however, be on the development of rainfed agriculture, promotion of integrated farming, high value agriculture, secondary & specialty agriculture. Important research areas will be pursued through *inter-departmental platforms involving ICAR institutes, SAUs and other organizations.* Anticipatory and strategic research on genomics, climate change, diagnostics and vaccines, precision farming, conservation agriculture, dryland agriculture, seed, protected cultivation, farm mechanization, alternative sources of energy, bio-sensors, GM food, foods for health, feed and fodder and institutional change will be accorded high priority to address the present and future development needs.

1.2 Technology Integration for Transformation of Indian Agriculture

A number of technologies are available on the shelf for initial adoption by farmers. Efforts should, therefore, be made to integrate and improve these technologies for their rapid adoption and spread among the farmers. The Working Group recommends the following mega programs for this purpose:

1. *Hybrid development and evaluation:* Spread of promising hybrids in rice can contribute 5-10 million tons of additional rice. Other crops like maize, sunflower, pearl millet and cotton, having majority of their area under hybrids, can contribute to significant increase in production by improving access to quality seed. This needs location specific evaluation of hybrids and dissemination of information to farmers so as to avoid the selection of low-yielding hybrids by farmers.

2. *Funds for research partnership:* ICAR should strengthen its linkages with other research organizations and private sector, especially for showcasing their technologies and commercializing them. For this purpose, such funds as *Agri-Innovation Fund, Agri-Incubation Fund, and Farmer Innovation Fund should be established*. There should be specific focus on public-private partnership in ICAR and promotion of economy and market-led extension by establishing a research and venture capital fund or *public-private partnership fund*.

3. *Linkages for technology backstopping:* There are a number of technologies like hybrid rice, precision agriculture, improved varieties of pulses and oilseeds, natural resource conservation technologies like aerobic rice and pressurized irrigation, farm machinery, etc, which should be taken-up for their wider adoption. This can be done by *providing technical backstopping* to various government programmes like Rashtriya Krishi Vikas Yojana, National Horticulture Mission, National Rural Livelihood Project and many others. Similarly, technologies for the health and nutrition of livestock and fisheries should be taken to large scale with the support of the NARS. In this context, linkages, especially, of SAUs with the state line departments assume significance.

4. *Establishment of pilots for taking available technologies to the farmers and promoting integrated farming for achieving higher agricultural growth:* Whole farm integrated approach on a 40 ha basis should be started at district level as a pilot under partnership with line department, private companies, NGOs and farmers. Later this can be extended to block, and P*anchayat* levels. This pilot can be used for capacity building of farmers for promotion of integrated farming. This has the potential to increase the income multi-folds with stability and sustainability.

5. *Establishment of pilots for addressing the emerging problems*: The following pilots can be established in the target domain for acid soils, saline and alkaline soils, water logged

conditions, drought mechanisms, waste land development, agro-ecology, agro-tourism, organic farming, nutrient and water use efficiency on farmers fields, weed management, integrated pest & disease management, urban and peri-urban agriculture, GM crops, zero-tillage agriculture, river-basin management, carbon sequestration, breed and feed development in livestock and fisheries, protected cultivation, hydroponics and aeroponics, xerophytes for dryland, export oriented agriculture and horticulture.

6. *Establishment of multi-location testing centres with public-private-farmers partnership*: At least 500 centres in the country should be established to reduce the time in the development of varieties and hybrids, and technologies for production and protection of crops. In the next phase, based on initial experience, this approach could be extended to a cluster of villages or at Panchayat level. This platform can also be used for multiplying the planting material, animal and fish breeds, etc.

7. *Expanding land development:* Technology development and backstopping for expanding cultivable land by (a) development of waste and fallow land through soil & water conservation and promotion for horticulture, agro-forestry, fodder, energy, etc., and (b) reclamation of problem soils, salt-affected soils, water logged area, acidic soil, etc. should be given increased attention. This can bring up to 60 million ha area under cultivation, improving the livelihood of millions of people. Promoting demand-driven and technology supported cropping systems will generate additional income for farmers. These changes need the strengthening of the Zonal Stations established under the National Agricultural Research Project.

8. *Seed production and technology:* There should be special thrust on seed production and seed technology with an emphasis to improve the seed replacement rate to 50% in cross pollinated crops, 100% in hybrids and 35% in self pollinated crops. Also, procedures for variety identification, release and notification should be revisited to cover private and farmers' varieties and also to avoid bias for varieties evolved by the testing institutions.

9. *Promotion of integrated farming with the emphasis on dryland farming:* It should target development of an integrated system which can provide to farmers a monthly income of at least Rs 10,000/ per ha in dryland areas and Rs 25,000/- per ha in irrigated agriculture. The mass campaign model of pre-monsoon or season knowledge, input and scheme-based extension involving students, scientists, line departments and policy makers should be followed. Development of dryland farming will *increase production of pulses and oilseeds*, which are mainly grown in dry areas. This coupled with promotion of non-farm employment through services and agro-industries at village/block level will help reduce rural poverty.

10. *Special squads for pest management*: The special squads will be helpful for containing and managing nationally important pests, diseases and disasters and can provide solutions in a war-footing manner.

1.3 Initiatives for Enhancing Technology Development

11. *Inter-Departmental Platforms* should be established for greater interaction among different R&D organizations for pooling their expertise. These platforms will involve institutions beyond NARS, like CSIR, DBT, DST and others. ICAR should initiate *Inter-Departmental Platforms in high priority research areas*, viz., genomics, seed, dryland agriculture, GM food, health foods, climate change, conservation agriculture, feed, fodder and fibre, diagnostics and vaccines, farm mechanization, protected cultivation, precision farming, secondary agriculture, energy, and high value compounds.

12. *The platform on genomics and transgenic* research should focus on stress tolerance, gene pyramiding, allele mining and microbial genomics in an inter-institutional and inter-disciplinary mode. Marker assisted transfer of multiple traits into regional varieties and hybrids should be expedited. Both molecular markers and transgenic technologies need to be given equal and high importance. Considering the high potential of transgenic research, certification standards and procedure for GM seed should be worked out. ICAR should establish a multi-disciplinary cell including social scientists to popularize GM crops/foods and create scientific awareness.

13. *Conservation agriculture (CA) which includes minimum soil disturbance, retention of crop residues, and appropriate crop rotations* is being promoted for enhancing input use efficiency and sustaining environmental quality. Research priorities in CA include unraveling of the role played by plant-rhizospheric interactions in modifying water and nutrient availability, carbon sequestration for mitigating climate change, and improving soil productivity, particularly of degraded soils, increasing water use efficiency and groundwater management.

14. *Climate resilient agriculture* through experimental and modeling approaches, assessment and mapping of geographical shifts of crop and horticultural regions and impact on livestock due to climate change need to be studied. Mapping of disaster prone areas, and pest and disease hot spots by using GIS and remote sensing technologies needs to be taken up. There is an urgent need to establish a wide interlinked network of automatic weather stations with real time data dissemination across the country. Necessary linkages with the Department of Earth Science may be strengthened.

15. *Capacity building efforts will be intensified* through externally-funded projects like the National Education Project, and National Entrepreneurship Project, and development of regional instrumentation facilities. A few ICAR institutes should be strengthened to increase the role of ICAR in international agricultural research, and resources for overseas fellowship will be enhanced.

16. *Strengthening the management of intellectual property and transfer of technology through creation of AGRINDIA* within ICAR with a budgetary support to the tune of Rs. 300 crore should be taken up. This scheme should develop an institutional mechanism for IP management with the required expertise (in-house and outsourced), manage overseas operations and eventually become self-sustaining over a period of time. Also, agricultural technology and food parks should be established on the campuses of SAUs and on farmers' fields for making technology available at the nearest possible place.

17. *Allocation of about Rs 1000/- crore of Plan funds for extra mural funding* to address the newly emerging challenges and to promote need-based collaborative research should be provided. This will also empower young scientists and help them train as science leaders. This fund will be managed by ICAR through expert groups of different SMDs. Also there should be special contingency funds with the Director General, ICAR for use in unforeseen situations.

1.4 Research Thrusts and Priorities

Indian agriculture is poised for rapid strides which can be realized through research support and technology generation. However, the thrust areas and priority sectors need to be identified carefully so that the objectives of XII Plan remain undiluted. In view of this, research thrusts in various sectors have been identified as presented below:

Crop Science

18. Crop improvement programs should focus on judiciously integrating conventional plant breeding with molecular biology and bioinformatics for accelerating the development of high yielding, nutrient-rich varieties and hybrids with biotic and abiotic stress resistance/tolerance. These varieties and hybrids must have large recommendation domains so that multiplicity of varieties can be checked.

19. Conservation and characterization of plant genetic resources, pre-breeding for stress tolerance and development of varieties for conservation agriculture should be accorded high priority. Gene complexes from wild relatives of crop plants should be introduced in the cultivated varieties to increase biomass for efficient partitioning coupled with enhancement in resistance/tolerance to biotic/abiotic stresses.

20. Intensify the use of molecular biology tools by introducing biotic and abiotic stress tolerance and incorporating organoleptic attributes in food crops. Adequate emphasis should be laid on development of **borer resistant chickpea, pigeon pea, rice and maize.**

21. Accelerate the development of hybrids in wheat, rice, maize, pigeon pea, cotton, pearl millet and mustard for breaking the yield barriers and spread the existing hybrids to newer areas for enhancing productivity should be pursued simultaneously.

22. Search of novel molecules including bromolectide for pest management with environmental safety should be emphasized. These molecules should have adequate shelf life and should not cause any damage to human health. Also, IPM modules should be improved by developing more effective and user friendly technology and practices like improving effect of NPV in pest control.

23. Genomics of agriculturally important pests, rapid and reliable diagnosis for on-site detection, assessment of pest risk analysis (PRA), prioritization of endemic and exotic pests, insect and nematode control, and development of transgenics using siRNA technology should be accorded high priority.

24. There is a need to strengthen studies on the understanding of vector relationship and its biology, with emphasis on thrips, bugs and mites for their role and biological association in viral transmission. Insects and disease surveillance and management methods in the context of climate change and food and environmental safety standards should be emphasized.

Horticulture

25. Horticulture is a sunrise sector of the country's economy. Demand for horticultural crops is rising in domestic as well as overseas markets. Therefore, development of better hybrids, rejuvenation of old orchards, pest and nutrient management, post-harvest management and protected cultivation should be accorded high priority for increasing crop yields.

26. Off-season crop production under protected conditions can be taken up as the best alternative to land use systems and also for the use of resources more efficiently. Multi-location evaluation and development of package of practices for different varieties of vegetables and flowers under protected cultivation should be undertaken. Low cost structures for protected cultivation for various locations should also be evaluated.

27. Urban and peri-urban horticulture with focus on aeroponics and hydroponics, efficient pollinizers and landscape for better carbon sequestration are new areas of research. There is a need to promote horticulture in the north-east region which has rich germplasm and suitable agro-climatic conditions.

28. Identification of new genes and their utilization for development of cultivars/hybrids by the use of new tools and techniques, and genomic studies of indigenous fruit and vegetable crops should be strengthened.

29. Production system management for enhancing the productivity of water and nutrients through plant architectural engineering and rootstock work should be accorded high priority.

30. There should be focused research programme on the secondary horticulture, foods for health and high value compounds like medicinal and aromatic products.

Natural Resource Management

31. Natural resources play a vital role in harnessing the potential of improved varieties/hybrids of all the food, feed and horticultural crops. Therefore, conservation and optimum utilization of natural resources should be the major focus. In addition, the problem of declining soil health and water quality should be addressed on priority.

32. Development of appropriate methodologies employing GIS and remote sensing for detailed soil resource mapping and land use planning at watershed level is needed. ICAR and SAUs should help develop an *information system on natural resources, including soil, and water* and disseminate information on weather and pest forecasting, and crop management practices to manage risks.

33. Abysmally low water and nutrient use efficiencies continue to multiply farmers' miseries and cause environmental degradation. Precision agriculture optimizing the use of water and nutrients involving pressurized irrigation techniques, site-specific and integrated nutrient management strategies; smart nutrient delivery system developed through nano-technological interventions; and development of customized and designer fertilizers are researchable issues. The popularization of bio-fertilizers and bio-pesticides should be taken up for their wider adoption.

34. Agro-forestry, green manuring, plant residues, composting and vermi-composting, biogas and liquid liquid organic manuring to reduce the cost of production and build strong sustenance should be taken as an important and integral component of agriculture.

35. Risk assessment of metal contaminated soils through case studies and modeling integrating metal levels in soils, transference to food chain and health hazards to animals and human beings should be taken up by ICAR and SAUs with active involvement of ICMR.

36. There is a need to identify alternative cropping systems with higher and stable yields and/or profit in different agro-ecological regions. Integrated farming systems internalizing synergies of different components for enhanced resource utilization, income and livelihood generation and minimizing environmental loading need to be developed for different agro-ecologies.

Animal Science

37. Productivity enhancement and management of animal genetic resources through development of methods and technologies for conservation and improvement of indigenous livestock and poultry breeds for high yield of milk and meat, improving the fertility by the use of newer embryo biotechnological tools, marker assisted selection to improve disease (small ruminants– parasitic diseases) resistance & fertility and buffalo genomics are priority areas for research.

38. Basic research on animal genomics, stem cell research, cloning and marker aided selection, use biotechnology for higher yield, and nano-technology for drug delivery should be intensified by allocation of more resources.

39. Molecular diagnostics, vaccine development and transgenics for pharmaceuticals should be emphasized for better animal health and productivity. Similarly, genotypes with tolerance to abiotic and biotic stresses, and mitigation strategies for reducing methanogenesis in livestock should be accorded high priority.

40. Studies on manipulation of rumen ecosystem for improving the digestibility of low quality roughages, isolation of cellulose gene, rumen fungi and fungi from wild animals, bioavailability of nutrients and micronutrients, improvement and utilization of local feed and fodder resources should be strengthened. *Bio-village concept* involving agro-forestry, grasslands and fodder as base for enhanced productivity of animals and sustainability of production systems should be promoted.

Fisheries

41. Fishery sector has great potential of growth and both coastal and inland fisheries provide employment and livelihoods to millions of families; therefore, the thrust on enhancing fish production and productivity should be to achieve sustainability and optimum utilization of the resources in marine and coastal fisheries and aquaculture.

42. Research on marine biodiversity and conservation of resources, ornamental fisheries, and neutraceutical fisheries; development of resource specific fishing techniques; post-harvest and product development using unconventional fish species; research on reducing post-harvest losses and development of technologies for mass culturing of fish feed organisms as complement of aquaculture to generate additional income for women should be strengthened.

43. Breed improvement, water management, feed formulation and health management are directly related with fish productivity. These areas along with bio-security and quarantine, processing and quality assurance should be strengthened.

44. Management of inland open water fishery resources and standardization of management protocols for production enhancement through management models for culture based fisheries, pan & cage culture technologies should be accorded priority.

Agricultural Engineering

45. Farm mechanization is capable of improving the efficiency of Indian agriculture on one hand and reducing the drudgery of small and marginal farmers on the other. Therefore, agricultural engineering/technology interventions should aim at achieving sustainable growth in land, livestock and fisheries productivity, reducing production and processing cost and post-harvest losses, enhancing value addition and developing technologies for economic utilization of the main products and processing of byproducts and waste.

46. Important research issues include development of customized farm implements, increasing energy use efficiency, development of health and nutrition food by using extrusion technology, and utilization of natural fibres, resins and gums.

47. Ergonomics for increasing the safety and comfort of workers, particularly of women, should receive proper consideration in the design and development of hardware and processing farm mechanization and postharvest processing.

48. Precision farming, conservation agriculture, protected cultivation, cold chains, pressurized irrigation and use of byproducts need specialized machines which should be developed, tested and commercialized. Mechanization needs of small farmers should be given due attention.

Agricultural Education

49. Education is the most important sector that provides quality human resources to the country's agriculture in general and agricultural research in particular. Therefore, the funding support for agricultural education in ICAR-SAU System should continue to promote those initiatives taken in the preceding five year plans having relevance in the present context. In XII Plan, the focus should be on *faculty & institution development, reforms in governance, curriculum*

and instructional material development, which will go a long way in harmonizing agricultural education with excellence in science and technology output for livelihood security and sustainable development.

50. Most of the SAUs are operating with less than 50% of the sanctioned faculty strength mainly on account of financial crunch. To address this issue, Planning Commission should provide 10-15% of agricultural budget of the states to SAUs directly, and SAUs autonomy to fill the sanctioned faculty strength be restored. Also, an increasing share of SAUs budget should be channeled through ICAR for direct availability to SAUs.

51. The faculty strength of ICAR Deemed Universities decreased substantially leading to serious gap in quality assurance at international level. The cadre strength of DUs should be restored to 1985 level and position filled expeditiously.

52. The Vice-Chancellors of SAUs expressed the desire to *provide a separate budget line in the state budget for SAUs,* which are in very bad shape with poor financial health and dwindling faculty strength. In order to strengthen infrastructural facilities in SAUs, a one-time catch-up grant of Rs 100 crore should be provided to SAUs. Subsequently, Rs 25 crore must flow to SAUs annually through ICAR.

53. There is a need for more para-agricultural professionals and therefore capacity building, and education programs should meet this requirement. *SAUs can initiate bachelor's degree or diploma programs to meet this requirement of trained manpower or para-agricultural workers*.

Frontline Extension

54. Enhance the capacity of *Krishi Vigyan Kendras* (KVKs) by full e-connectivity, increasing staff strength to 20 and also provide platform for interdepartmental initiatives. Greater emphasis should be placed on dissemination of non-product technologies. KVKs should act like knowledge hubs and centres for capacity building for farmers. Seed production of local varieties, bio-products and mainstreaming of ITK should be undertaken by KVKs.

55. *Directorates of extension in SAUs should be strengthened by providing additional manpower and resources*. These Directorates should work closely with the state line department, ATMA and KVKs. The Directorates and KVKs can also build capacity of ATMA and other line department personnel and work for promoting demand-driven extension and help link farmers with markets.

56. The research in extension education is the weakest link in the growth of transfer of technology. Recent advances in the field of communication and information technology, behavioral sciences including management have great implications for improving research in extension education as well as development of models for technology generation, assessment and refinement.

Agricultural Economics and Policy

57. Appropriate strengthening of departments of agricultural economics in SAUs and ICAR institutes should be done to improve the education and research in agricultural economics to provide well trained manpower and research output. Greater emphasis should be placed on (a) assessment of ecosystem services, (b) accelerating agricultural growth for poverty reduction, (c) options to increase resource use efficiency, including energy and access to markets with focus on small farmers, and (d) research policy in the context of changing international and national economic environment. Research on statistical methods for assessing the reliability of agro-biological experiments, socio-economic changes in agriculture and forecasting methods should be given priority.

1.5 Expected outcomes

The proposed recommendations would help achieve the growth target of four percent per annum. However, this realization will need close collaboration with the Department of Agriculture, civil society organizations and other development agencies. The sector-wise expected outcomes in terms of contribution to higher production and income *vis-a-vis* growth targets are given below:

Commodity	*Current production (million tonnes)*	*Target production (million tonnes)*	*Technological interventions*	*Production contributions*
Cereals	223.0	251	Expansion of hybrid area under paddy, increasing seed replacement rate, balanced nutrient, single cross hybrids of maize, conservation agriculture, input use efficiency	Rice 13, Others 15-20 million tonnes
Pulses	18.1	22	Cultivation on rice fallows, development of pod borer resistance varieties and hybrids, introduction of pulses in rice-wheat system	5-10 million tonnes
Oilseeds	31.1	39	Higher yield of dryland agriculture, hybrids for mustard, seed replacement,	10 million tonnes
Fruits & vegetables	205.2	308	Development of fallow land for horticulture, reduction of post-harvest losses, secondary agriculture, nutrient management, diagnostics, plant health, nutrition and canopy management, protected cultivation	Doubling farm income and 10-30 mill ha more area under cultivation
Milk	112.5	151	Development of fallow and waste land for pasture and fodder, animal health (diagnostics and vaccines), fodder and nutrition management, enhancing reproductive efficiency	Doubling farm income and higher milk production by 30-40 million tonnes
Fisheries	7.6	10	Wasteland and watershed for aquaculture, post-harvest technology, health and nutrition, mariculture, ornamental fisheries, hatcheries	Doubling farm income and production

1.6 Finance and Resources

Public investment in agricultural research and education should be increased to one percent of AgGDP. However, in XII Plan, an amount of Rs 55,000/- crore for ICAR should be allocated.

58. The break-up of the proposed Plan allocations in XII Plan along with actual allocations in XI Plan is given below.

	Subject Matter Divisions/Programs of ICAR	XII Plan proposals (Rs. crores)
1.	Crop Science, including plant protection and seed*	10,000
2.	Horticulture	4,000
3.	Natural Resource Management	3,500
4.	Agricultural Engineering	1,500
5.	Animal Sciences	3,500
6.	Fisheries	1,000
7.	Agricultural Education	10,000
8.	Agricultural Extension	9,000
9.	Agricultural Economics, Marketing & Statistics	100
10.	ICAR/DARE Headquarters, CAU	1,000
11.	Structure, Modification of ICAR, IPR etc.	300
12.	Externally Aided (NAIP, Indo-US, National Fund, NAEP, etc.)	1,500
13.	Extra-mural funding	1,000
14.	Farmer Innovation, Agril. Entrepreneurship, National Innovation, public-Private Partnership, Agril. India Funds	1,100
15	Inter-Departmental Platforms	7,500
16.	Total	55,000

Notes:

1. The proposed allocation in crop science also includes seed program with Rs 2,000/ crore
2. 25% budget of Crop Science and NRM may be earmarked for climate change research and 10% in other SMDs.
3. A separate budget line for the State Agricultural Universities may be provided with an additional outlay of Rs 10,000/- crore.
4. List of potential platforms: Genomics, seed, dryland agriculture, GM food, health foods, climate change, nanotechnology, conservation agriculture, water, feed, fodder and fibre, diagnostics and vaccines, farm mechanization, protected cultivation, precision farming, energy, and high value compounds.

1.7 Policy Recommendations for Government of India, ICAR, State Agricultural Universities, and State Line Department for Implementation

1. Irrigation water use potential is very low and not on scientific lines. Necessary measures need to be taken at every step right from desiltation in dam area, repair of main canal, distributaries, sub-distributaries and field channels, and changes in cropping pattern and irrigation methods. ICAR and SAUs involving irrigation and agricultural department can take one sub-distributary covering 40 ha in each command area and establish a permanent demonstration unit. Water release, control and regulation may be on the model of Israel.
2. Water use efficiency measures like sprinkler and drip irrigation is spreading at a slow pace. Increase the speed to cover large area in short time. During drought period arrangement of diesel pumpsets and pipes can immediately save the crop in the drought prone areas.
3. In rainfed/ dryland areas, water table improvement, rainwater harvesting, soil and moisture conservation, mulching, use of green manure, crop residue and organic matter play a vital role. Policies should be developed to achieve greater potential of dryland incorporating above technologies for harnessing on a sustainable basis. ICAR and SAUs involving line department can establish such demonstrations on minimum of 40 ha in each district.
4. Fertilizer shortage is going to continue and the Government may evolve policy to support animal husbandry (dairy) and poultry activities, fodder promotion, green manuring, and bio-fertilizers in a very big way and encourage farmers by incentives. ICAR and SAUs involving line department can demonstrate through pilots of 40 ha size.
5. Seed, planting material, breeds, and fingerlings play major roles. This aspect requires altogether a different approach. These should be made available at village level.
6. 60 million ha waste/wasted/ not-used/fallow land has to have a policy as how to improve the soil and create agro-forestry, agro-silvi-forestry and agro-silvi-horti-forestry models. In later years it will become a boon to the country. ICAR-SAUs system along with stakeholders to have demonstration on a minimum area of 40 ha in each of the above areas on a zonal basis.
7. The losses during harvesting, transport and storage are too high in our country and require policy interventions.
8. For anything to happen at a larger scale in the areas like plant protection, tillage operations, harvesting and processing operations, small farmers aggregation/federation/groups are a must. The Government may evolve simple guidelines to achieve it at the national level. The policy of subsidy for farm machinery at farmers to the group level.
9. Increased impetus to be given to livestock, poultry and other birds, sericulture, horticulture and secondary agriculture with a changed credit policy for doubling the size of activity horizontally and vertically.
10. Creation of non-farm jobs at village level for rural youth (men and women) through processing, value addition, packaging and exports targeting and marketing to medium and high income level consumers should be encouraged through policy interventions.

Governance Issues

11. Bureaucratic procedures to be reduced for grant release, sanction and implementation. More authority and responsibility to be given to technical partners, i.e. Vice-Chancellors, Directors etc.
12. The Government, ICAR, DBT, CSIR, other S&T organizations and other concerned departments to have interactive video facility any time to review and guide the plan programmes at least on bi-monthly to achieve the targets.
13. Similarly, at state level, principal secretaries of inter-ministerial department, Vice-Chancellors, Commissioners and Directors of line Departments should have ICT communication on regular basis and should review, monitor and guide on bi-monthly to achieve the plan targets.
14. Human resource is a major problem in the program implementation by all the agencies. The Government should direct states putting rider for release of grants that block-wise in the line department and scientists and extension workers in the universities, including remote areas, should be filled, failing which 25% grant will not be released.
15. The Government and universities to change the set up of their institutions to produce graduates who can be job providers and entrepreneurs and able to become practical and field oriented to produce para-professionals and technicians who can provide service at the field level in villages and build the capacity of farmers to achieve self-confidence in evolving their own integrated farming system. This will enable a shift from the subsidy to solution approach in agriculture.
16. Universities apart from shortage of staff, are suffering from lack of infrastructure, poor maintenance of laboratories and equipment for want of funds. One time catch-up grant and regular budget may be provided with a separate budget line in the state budget. If the agricultural universities are not provided with the budget mentioned in the plan, the government should not release second quarter grant.
17. Linkages at state level principal secretaries of inter-ministerial department, Vice-Chancellors, Commissioners, Directors of line Departments and ICAR institutes should interact for two days on a quarterly basis:
    - First quarter in January for annual/budget plan
    - Second quarter in April for *kharif* programme
    - Third quarter in July for *rabi* planning
    - Fourth quarter in October for programme implementation

    The above procedure can be followed by at district and block level by respective cadre people to accomplish the plan proposals and achieve the targets on annual basis and apply corrective measures for XII Plan. ICAR and SAUs can also work on similar lines.
18. There is a demand from coffee growers to conduct research in public sector on a regular basis. Therefore, ICAR may think of taking coffee, tea, rubber and sericulture etc in its agenda for conducting research on these commodities.
19. Agro-climatic research in the context of climate change needs to be revived by strengthening of the zonal research stations with adequate manpower and infrastructure facilities.

2. Composition of the Working Group

No.M-12-43/03/2011-Agri.
Planning Commission
(Agriculture Division)
Yojana Bhavan, Sansad Marg
New Delhi-110001
Dated March 8, 2011

Sub: Constitution of the Working Group of "Agricultural Research & Education" for the Twelfth Five Year Plan (2012-17).

In order to formulate the Twelfth Five Year Plan (2012-17) Document, it has been decided to constitute a Working Group on 'Agricultural Research & Education' with the following Composition and Terms of Reference:

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2.1 Terms of Reference

Specific

1. To assess the extent by which the research projects drawn up during XI Plan have been able to meet the objectives in addressing the problems of agriculture.
2. To suggest modifications/improvements in the on-going projects for enhancing their effectiveness in terms of impact and accountability, and also recommend winding-up schemes that could not deliver expected outcome made significant impact so far.
3. To suggest high priority research areas and mechanisms for their effective redressal in a given time frame.
4. To identify relevant and time tested ITKs and recommend measures to put them into practice by integrating with technology recommendations.
5. To review the outreach programmes of SAUs and ICAR Institutes and suggest modalities for their effective linkages with development departments.
6. To enlist technologies having commercial potential and suggest modalities for their promotion, in a time-bound manner, through private players/industries.
7. To recommend short-term and long-term remedial measures for solving critical problems being faced by small and marginal farmers.
8. To recommend measures to synergise the efforts of SAUs and ICAR in order to avoid duplication of research.
9. To review climate mitigation and adaptation strategies in agriculture and allied sectors, and suggest new facets if any, in this critical area.
10. To review higher education system so as to meet the current and emerging challenges.
11. To recommend measures to strengthen the financial viability of SAUs.
12. To study the present level of private investment in agricultural research and education, and suggest modalities for up-scaling the same through PPP mode in specific areas of animal health, agriculture entrepreneurship and agriculture education and fisheries.

General

1. The Chairman of the Working Group may co-opt any other official/non-official expert/representative of any organization as a member(s), if required.
2. The Working Group may examine and address any other issues which are important though not specifically spelt out in the TOR. The Working Group may devise its own procedures for conducting its business/meetings/field visits/consultation of Sub-Groups etc.
3. The expenditure on the members on TA/DA in connection with the meetings of the Working Group of any work incidental to the functions of the Working Group/Sub Group will be borne by the parent Department/Ministry/Organization/State Government for official members, and by the Planning Commission for non-official members as admissible to Class-Aa Officers of the Government of India.
4. The Working Group will submit its Draft Report to the Planning Commission by June 2011 and final one by Sept., 2011.

Dr. (Mrs.) Vandana Dwivedi, Joint Adviser (Agriculture), Planning Commission, Room No. 230, Yojana Bhawan, New Delhi-110001, Telefax No.011-23096730, E-mail dwivediv@nic.in

and Fax No.011-23327703 will be the nodal officer of this group and any further query/correspondence in this regard made with her and also with Member Secretary of the Working Group. The Indian Agricultural Research Institute (IARI) will extendt the requisite secretariat assistance in the preparation of the report and bring out copies (100) of the same.

Sd/-
(G. Rajeev)
Under Secretary to the Government of India

Copy forwarded to the Chairman and Members of Working Group.

Copy also forwarded to:

1. P.S. to Deputy Chairman, Planning Commission
2. P.S. to MOS, Planning Commission
3. P.S. to Member (AS), Planning Commission
4. P.S. to Member (KK), Plnning Commission
5. Sr. PPS to Member Secretary, Planning Commission
6. P.S. to Sr. Consultant (Agri.). Planning Commission
7. P.S. to Adviser (Agri.), Planning Commission
8. P.S. to Adviser (PC), Planning Commission
9. Adviser (SS)/Director (DSA)/Jointy Adviser (Agri.)
10. Dy. Adviser (Agri.), Dy. Adviser (Animal Husbandry)/SRO (AS)/RO (DM)/Consultant (Fisheries) in the Agricultural Division.
11. Pr. Advisers/Advisers of all Divisions
12. Account-1 Section, Planning Commission
13. S.O. (Agriculture) Division, Planning Commission.

Sd/-
(G. Rajeev)
Under Secretary to the Government of India

3. INTRODUCTION

Accelerating and sustaining agricultural growth, which is necessary for inclusiveness in the economy, is the key priority of the Government in India. Although agriculture contributes less than 15 percent to the national gross domestic product, its importance in the economic, social and political fabric of the country is much larger than what is indicated by its economic importance. Growing urbanization coupled with higher purchasing power demands not just higher production levels, but a wider range of quality attributes of agricultural products along with food safety standards. Hence, the agriculture sector in the new millennium must respond to multiple challenges which go beyond the historical objective of higher productivity, and the sector should now pay increasing focus on meeting diversified consumption needs along with addressing concerns of environmental security and improving livelihood of the millions of rural poor. This needs mobilization of traditional sources of agricultural growth like use of natural resources (land and water), inputs and capital in a more efficient way. Technological change has also been the main source of growth, which now should interface more closely with newer sources of growth like institutional change, human capital, and innovations in the creation and application of new knowledge. Therefore, the focus in XII Plan should be on innovations for transformation of Indian agriculture to knowledge-intensive sector, conserving natural resource base of land and water, and building resilience to climate change, whilst promoting the inclusive and diversified growth.

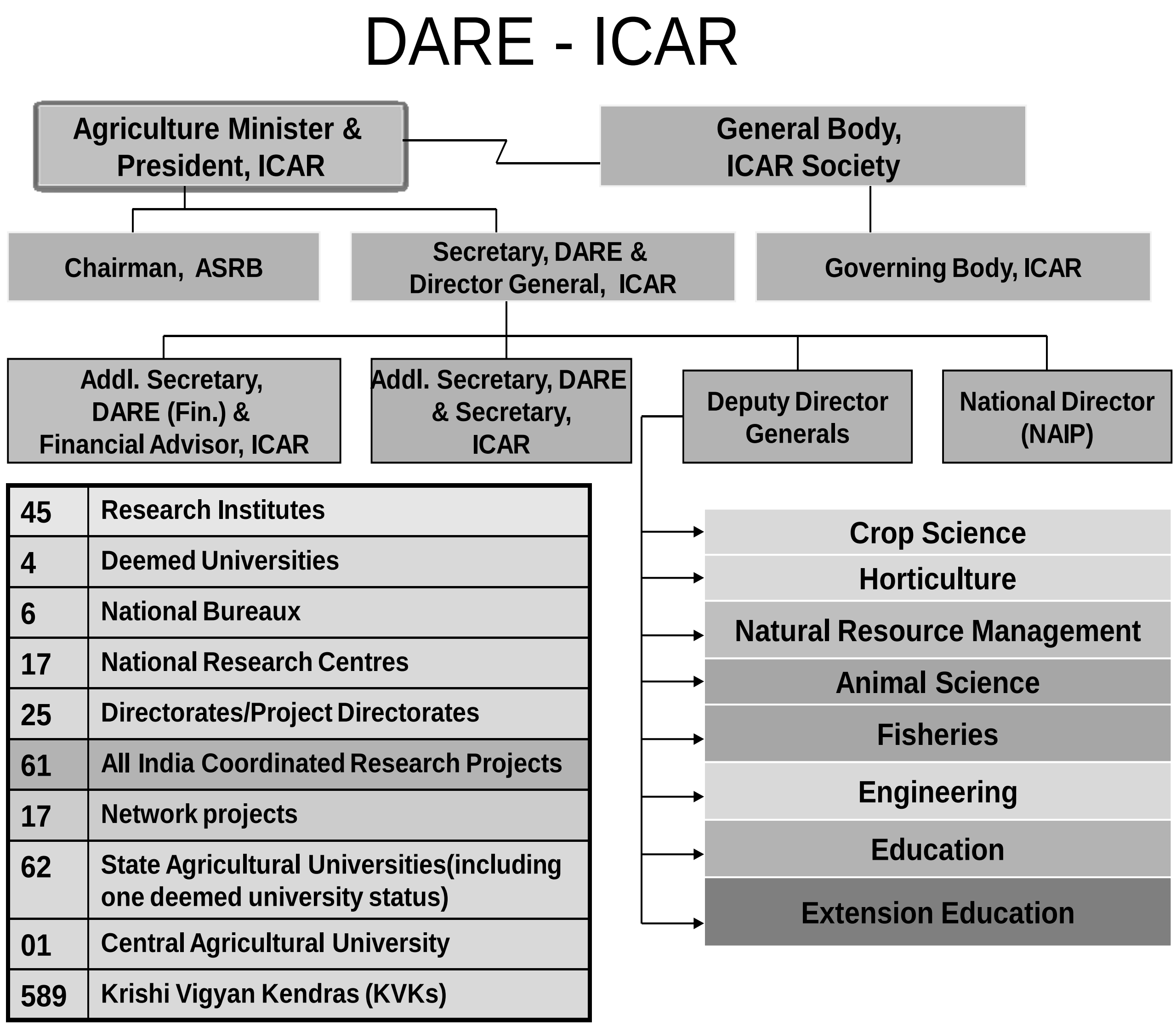
It is important to underscore here that technology alone is not the panacea for agricultural growth as its interface with policy and infrastructure and delivery of public services has become stronger in recent times. Some of these non-technological factors of growth are inadequate, especially in less endowed areas. More importantly, harnessing potential of technology in an inclusive manner is largely influenced by the factors such as its affordability to the farmers and farm support systems, including those dealing with input, markets, credit and technology transfer system. Therefore, the government should increase public investment to develop key infrastructure for agriculture and also create conducive environment to attract private investment through innovative policies and support.

Since science and technology will continue to be the main drivers for transformation of Indian agriculture, strengthening the existing research institutions and up-gradation of the infrastructure and creating new institutions to meet the changing technological needs is urgently required. The agricultural R&D expenditure is a good indicator of the capacity, but it continued to be low despite persistence increase overtime. The government expenditure on agricultural research and education at current prices has increased from Rs 12 billion in the mid-nineties to Rs 63 billion by the end of this decade, giving an expenditure intensity of 0.58 percent. At the same time, there has been rapid expansion of R&D institutions and programmes in the country. Therefore, research resources are thinly spread over a large number of institutions.

The ICAR-SAU system and the Vision: The national agricultural research system (NARS) comprising more than one hundred schemes or institutions of the Indian Council of Agricultural Research (ICAR), see Fig 1, and sixty two State Agricultural Universities (SAUs) are working for achieving technology-led agricultural growth with inclusion of all sections of the society.

The system has envisioned for *harnessing science to ensure comprehensive and sustained physical, economic, and ecological access to food and livelihood security to all Indians through generation, assessment, refinement and adoption of appropriate technologies*. In order to realize this vision, the system's aims to promote sustainable and inclusive agricultural growth and development in the country by interfacing education, research and extension initiatives complemented with efficient and effective institutional, infrastructure and policy support for ensuring livelihood and environmental security.

Fig 1. ICAR-SAU system



The important schemes of the NARS, comprising ICAR institutes and SAUs, are organized as (a) deemed and central universities of ICAR for conducting basic and strategic research and imparting higher education, (b) national institutes and research centres for upstream research, (c) bureaux for collection, conservation, evaluation, classification and documentation of natural resources and strategic research support for their management and effective utilization, (d) SAUs for imparting education and catering to location-specific research needs, and (e) centres for frontline extension. The complete list of ICAR institutes and SAUs are given in the Annexure I.

The main policy and strategy of the ICAR-SAU system target building capacity to accelerate agricultural innovations in a sustainable manner. Inter-institutional and inter-disciplinary linkages and close partnership with farmers, private organizations and other stakeholders are key elements of the strategy. This strategy is operationalised through investment in scientific infrastructure and human capital, identification of research priorities in a consultative mode, and partnership in development and commercialization of technology to address current and emerging agricultural R&D needs of the country. This emphasis is reflected in allocation of the plan funds and identification of thrust areas, targeting inclusive and sustainable agricultural growth. The investment priorities are backed with the strategy of coordinated research programmes in a partnership mode with SAUs, private R&D organizations and international agricultural research institutions, mainly centres of the Consultative Group on International Agricultural Research. The partnership with various R&D organizations is also encouraged through the management of intellectual property with the following main features: (a) use of intellectual property rights for sustainable agricultural development, and (b) share the benefits with the scientist innovator. Efforts are also made to pursue these elements of the strategy and accelerate transfer of technology to farmers.

This strategy has paid rich dividends in terms of economic and other impacts of agricultural research. Efforts are being made to sustain these impacts by further fostering partnership with various stakeholders and revising research priorities in subsequent plan periods. This is done in the context of likely impacts of major driving forces like globalization, changing demand patterns, climate change, concerns for product quality and environment, and international agreements. The thrust under XII Five Year Plan should be to sustain past research accomplishments and their impact and accelerate wherever possible. In addition, mega programmes should be initiated for (a) transformation of Indian agriculture through application of technologies in an integrated manner, (b) greater focus on inter-Departmental programmes or Platforms to accelerate technology generation in a demand-driven mode, and (c) anticipatory and basic research to make Indian agriculture resilient to climate change and other external shocks. Also, programmes are needed for effective translation of plan outlays into research outcomes like immediate use of research products by clients and eventually their impact in terms of higher productivity and income, resource conservation, poverty reduction etc. This can be done by fostering linkages with stakeholders, especially line departments, strengthening frontline extension system, private sector etc. Therefore, it is utmost important that due attention is paid to all those processes and mechanisms which affect transfer and uptake of new knowledge and technologies. Some of these processes and organizations are beyond the control of ICAR-SAU system, but proactive role in guiding the government programs and technology transfer efforts in a partnership mode with farmers will go a long way in transforming Indian agriculture into a knowledge-based sector.

4. SIGNIFICANT ACHIEVEMENTS IN XI FIVE YEAR PLAN

4.1 Initiatives Of ICAR Under XI Plan

1. Established the National Institute of Abiotic Stress Management in Maharashtra to address issues such as drought, temperature extremes, floods, salinity, nutrient deficiency and other abiotic stresses affecting agriculture production.
2. The Planning Commission has given in-principle approval for establishment of the National Institute of Biotic Stress Management for addressing the plant protection issues, policy support research for biotic stress management, human resource development etc. Further process of seeking the final approval is in progress.
3. The Planning Commission has also given in-principle approval for the establishment of of the Indian Institute of Agricultural Biotechnology to serve as a national centre of excellence for undertaking cutting-edge research, excellence in education and training in agricultural biotechnology. The process of seeking the final approval is in progress.
4. The ICAR/DARE has upgraded the earlier IPR component to Intellectual Property Management and Transfer/Commercialization of Agricultural Technologies (IPMT/CAT) to set in place an institutional mechanism to protect/manage Intellectual Property (IP) generated within the ICAR system.
5. Establishment 50 more KVKs in larger districts has been approved by the Government of India, in addition to the 569 KVKs already established in the rural districts of the country.
6. The Department has reoriented the functioning of 13 National Research Centres and one All India Coordinated Research Project to work in Directorate mode of operation. Similarly, the Project Directorate of Biological Control has been upgraded as National Bureau of Agriculturally Important Insects (NBAII) and its programmes have been reoriented. These steps contribute towards widening of the mandate of the institutes, and strengthening the programmes and technology delivery.

4.2 Aggregate Research Impacts

ICAR in partnership with SAUs has developed number of technologies which are being used by farmers on a large scale. Important among these are doubling yield of basmati rice with reduction in crop maturity period. These varieties occupy nearly two million ha area in the north-west plain zone. **Rice varieties in Basmati quality have contributed to approximately Rs 6,000 crores of additional annual income due to improved varieties like Pusa Basmati 1121 to the farmers of Punjab and Haryana, an almost 50% gain in income over 2 million hectares.** The similar increased income in the southern and north eastern plains due to improved varieties has been to the tune of **Rs 20,000-25,000** crores annually. Improved varieties have contributed importantly to more than 2.5 million tonnes that directly went into the public distribution system during 2010 from higher productivity in Punjab, Haryana and Western UP.

Improved wheat varieties resistant to rust, including race ug99, have been developed and these are spreading fast in the rice-wheat system. Improved varieties of crop plants such as wheat, maize, pearl millet, mustard, chickpea etc., which cover nearly 40% of the cropped area of the country have impacted most in the improved production and productivity. ***For example, the improved wheat varieties over the last five years have increased yield to the tune of 6.6–48% in different zones.*** In north-west the improved productivity has been 8.5%, in the north east, 26.5%; in the central zone, 12.6% and in the peninsular zone 48.2% yield enhancement over the existing technologies. The overall impact in terms of increased returns to farmers purely due to the additional yield will amount to an estimated Rs 4,600 crores at an average of Rs 4,600/ha in the north-western plains over an approximated 10 million hectares. The increased income due the additional gains in the north-east is about Rs 8,200 crores at an average of Rs 8,900/ha. ***Overall, the increased productivity gains in wheat crop alone accrue to nearly Rs 15,000 crores annually in India***.

Soybean and Bengal gram of JNKVV (MP) have covered 90 per cent (8 M ha) and 40 per cent area (4 M ha) respectively of the country with an increased yield of 20 per cent, generating an additional annually income of Rs 6,000 crores.

Similarly**,** the varieties of mustard which have recorded an average yield improvement by 1.2 quintals/ha to 4.5 quintals/ha in the central-western and north-western parts of the country over the existing varietal technologies have added an additional average income of Rs 3,500 to Rs 12,000 per hectare, respectively. These raises are due to varietal improvement and their spread have increased the overall production by 2 million tonnes in the oilseeds. In the pulses, the chickpea varietal contribution to Andhra Pradesh which witnessed unprecedented productivity increments has contributed to about 1.5 million tons at the national level.

In addition, QPM and single cross hybrid maize have made significant contributions for raising the yields. Bt cotton hybrids which are mostly based on public material has created fibre revolution in the country by at least doubling the yield. In natural resource management, resource conservation technologies like micro-irrigation, aerobic rice, zero/reduced tillage have been popularized. The spread of zero-tillage wheat is about three million ha and the estimated annual returns of Rs 530 crores. In fruits and vegetables, better varieties and hybrids, disease management and multiplication of planting material has contributed to higher growth. In livestock and fisheries, disease management technologies (vaccines and diagnostics), feed and fodder management, improving reproductive health, and production of fisheries seed have been notable contributions.

Efforts continued to improve conservation of water and improve the use efficiency of irrigation water. Modifications were proposed in the existing ridge and furrow systems for *in situ* rain-water harvesting which helped to increase harvested water from 1 per cent to 10 per cent of the rain. These modifications helped to improve water productivity and increase castor yield by 30 per cent. Individual farmer-based technologies focusing on groundwater recharge, integrated farming and laser levelling/improved irrigation developed for the northwest states, helped to improve rice and wheat yield by 8-12 per cent while saving irrigation water to the extent of 18-21per cent.

Work on the conservation and genetic improvement of livestock continued with focus on improving milk yields, and length of the lactation period. Analysis of the crossbred cattle strain Frieswal, revealed that the overall mean of milk yield in 300 days was 3,308.65 kg with an average peak yield of 15.04 kg. Milk yield improved over the lactations, reaching 3,543 kg in the fourth lactation. Significant improvements were also achieved in other parameters like the average lactation length and age of delivery of first calf. In case of buffaloes, elite herds of Nili-Ravi, Jaffarabadi, Surti, Bhadawari, Pandharpuri and Swamp buffaloes have been established at different centres in different parts of the country. In the case of sheep and goats, significant improvements have been achieved in wool production, body weight and in mortality reduction through processes of selective breeding and better flock management. Successful introduction of prolific gene *FecB* from Garole into Malpura and backcrossing of GM with Malpura for mutton production, substantially increased body weights of Garole × Malpura, Malpura, GMM lambs at different ages. Moreover GMM ewes produced 40 per cent twins in the flock.

For poultry meat production, synthetic broiler strains, like PB-1, PB-2, SDL, CSML and CSFL, were improved through intra-population selection for body weight at 5 weeks of age. The body weight at 5 weeks of age increased by 155 g and 237 g in PB-2 and PB-1 populations, respectively, over previous generations. Intra population selection for improvement of six pure line White Leghorn poultry breed resulted in an increase of 16.5 to 18.9 eggs in different line in the hen house egg production up to 40 weeks of age.

A protocol for fullsib and halfsib family production of *Macrobrachium rosenbergii* was developed and standardized. In a study, first of its kind, chitosan (CN) and gold-based salmon LHRHa (S LHRHa) hormonal nanoparticles were formulated for effective delivery of the hormone for spawning of a cyprinid fish (common carp), which can serve as an alternative for the commercially available inducing agents. *Cobia (Rachycentron canadum),* a marine fish, was successfully induced bred in captivity for the first time.

A technology package for nursery rearing and grow-out culture of hatchery produced megalopa larva of *Scylla tranquebarica*, a crab was standardized. Better growth and higher survival was achieved by rearing in soil-based open ponds with natural hideouts. Also, artificial hideouts were found to be more practical and viable choice in comparison to natural sea weed, without compromising on survival and growth. The grow-out culture trials yielded an average production of 1.12 tonnes/ha in West Bengal and a production of 1.3 to 2.8 tonnes/ha in a culture period of 4 months in Tamil Nadu.

Using improved technologies under various government programmes, the country is able to achieve a record 241 million tonnes of food grain production. It is estimated that research has been a major source of growth in total factor productivity of agriculture, and in some crops its contribution to output growth has been 70 percent. *The estimated rates of return are more than 46 percent in the recent period.* The Division-wise significant research achievements are given below.

4.3 Crop Science

The Crop Science Division of ICAR made pioneering contributions in developing improved crop varieties for various crops, suitable for cultivation in different production systems of India. More than 500 crop varieties have been developed, identified and released. The Council’s efforts have also led to the conservation of over 346,000 germplasm accessions of crops and their wild relatives, 2517 microbe cultures and 175,000 insect species, which are invaluable genetic resources for the present and future agricultural research and development.

Noteworthy achievements have been made during the last few years in crop improvement, especially in rice, wheat and maize, including breeding for early maturing varieties, aromatic rice, and molecular market-assisted breeding for biotic and abiotic stress tolerance (e.g. bacterial blight in rice; rust resistance in wheat; downy mildew and turcicum leaf blight resistance in maize and nutritional quality (e.g. QPM). For instance, the duration of aromatic rice has been reduced from 160 days to 110 days and yields increased from less than 2.5 t/ha to more than 7.0 t/ha. Shortening the crop cycle has not only saved water and labour, but also permits forays into new combinations of crops in rotations, such as rice-mustard-wheat-vegetable instead of rice-wheat only. Such outputs have immense practical value, as applied successfully in Punjab, Haryana, Maharashtra.

- 50 rice varieties (30 STMS), 50 Trigonella (25 ISSR), core collection of pigeonpea (3 AFLP primer pairs), Allium sp. (30 RAPD), 20 Giloe (15 RAPD), 25 Kalmegh (10 RAPD and 10 ISSR) and 6 cotton (27 STMS) sample were fingerprinted.
- Super absorbent hydrogels with water absorption potential of 500 times of its weight were developed. The hydogels are effective in significant improvement in germination of various crops and it is estimated that nearly 4,000 acres is covered under the technology.
- 3124 in bred lines of Maize were evaluated and 400 desirable lines selected. These included 82 normal, 34 QPM, 7 Sweet corn, 16 pop corn and 13 High oil lines. Out of 296 single crosses that were evaluated 21 were selected.
- Out of nine lines of *Brassica juncea* var. Varuna transgenics having NPR1, four lines showed over expression of NPR1 mRNA as confirmed bt RTPCR.
- Lycopene β-cyclase promoter fully characterised in transgenic tomato.
- Developed Bt Bikaneri Narma (Bt BN) cotton variety and NHH4 4 Bt cotton hybrid.
- A total of 17 hybrids including 12 hybrids from CRRI were evaluated in Shallow lowland hybrid trial. The hybrids CRHR 41, 33, 46, 37 and 43 showed an yield advantage of up to 34% over hybrid check and 26% over the best inbred check. Another hybrid rice trial consisting of 19 released hybrids (MLT) was also conducted during Kharif-08.
- The Studies on insecticide resistance in Brown Plant hopper (BPH) populations from different region in the country indicated moderate to high degree of resistance to imidacloprid (RR of 35.13), thiamethoxam (10.78) and clothianidin (4.95). There was no cross resistance to fipronil (RR of 0.92) and ethiprole (0.62).
- Wheat germplasm and breeding materials have been screened in Kenya and Ethiopia for resistance to Ug99 wheat Black rust race. Resistance to this new race of Black (Stem) rust is incorporated in PWB 343. The performance of newly released wheat variety DBW 17 and PBW 550 was higher over the existing varieties. Wheat varieties, viz., PBW 590, tolerant to terminal heat tolerance suitable for late-sown irrigated conditions, Raj 4120 tolerant to leaf rust and karnal bunt, superior in resistance to Ug 99 race of Stem rust disease and Durum variety, UAS 415 having superior Patties-making quality.
- Advance breeding genotypes viz., VL 7849, VL 7853, VL 7876, VL 30758, VL 31283, VL 31289 and VL 31291 were evaluated and found resistant to leaf and neck blast disease.
- Rapeseed-Mustard: Two hybrids of Indian mustard namely NRCHB 506 of Directorate of Rapeseed Mustard Bharatpur and DMH-1 sponsored by Dhara vegetable Oil and Food Co Ltd., Anand has been identified for release.
- Two superior medium staple cultures of *G. arboreum* namely CINA 363 (26.7 mm) and CINA 369 (27.3 mm) were deployed and identified for evaluation. Attempted crosses using wild species as female viz. *G. anomalum*-32, *G. trilobum* -26 with diploid cultivars for diversification of male sterility system.

- Biological control of the sugarcane woolly aphids, mealy bug management, rice pest management was taken up in communities through *Panchayat* based people's movement and adjoining *Panchayats* in Thrissur district, Kerala.

4.4 Horticulture

Emphasis on horticultural development has been focused through various programmes, including National Horticulture Mission, Technology Mission for Integrated Development of Horticulture in northern hilly states, and the State Horticulture Missions. These programmes have contributed significantly to the production and dissemination of seed and planting materials. Technologies developed by ICAR provided strength to these Missions.

- Tomato IIHR-2101; Chilli hybrids Arka Swetha, Arka Meghana and Arka Harita; Watermelon hybrids WH-24 and WH-35; French bean variety Arka Anoop, Carnation Hybrids IIHR-C-1, IIHR-IS-1, IIHR-IS-2, rose variety Arka Parimala, crossandra hybrids Arka Kanaka and arka Ambar, Gerbera selections Arka Krishika and Chrysanthemum selection IIHR-1 are recommended for notification.
- 269 varieties of mango finger printed using STMS markers. Sex linked makers have been validated in papaya.
- Transgenic plants containing the replicase transgene resistant to TLCV in Tomato Arka Saurabh and Arka Meghali developed and a transgenic brinjal Arka Keshav using Cry2A against *Leucinodes arbonalis* were developed
- Foliar spraying (0.1%) Propiconazole/ Companion/ Carbendazim at 20 days intervals gave good control of Sigatoka leaf sport disease in both Robusta and Nendran) with increased yield.
- Site specific nutrient management in sweet orange increased productivity by 65% over farmers practices. By rainwater harvesting productivity increased by 74% over conventional practices.
- Development high & medium density orcharding system in apple, almond & apricot, & Standardized drip irrigation & mulching in almond & apple. Rejuvenation apple orchards through pruning, nutrient & pest management.
- Standardized technology, for polyhouse cultivation of strawberry and gladiolus. Identified promising varieties & hybrids in apple (23), almond (7), Apricot (3), walnut (5), pomegranate (3), strawberry (05), saffron (03), onion (02), chilli (05), tomato (05) and gladiolus (10).
- High yielding improved varieties of coconut viz., Kalpa Dhenu, Kalpa Mitra, Kalpa Pratibha and one variety viz., Kalparaksha with higher field resistance to coconut root wilt were released.
- Six high yielding varieties of potato and two varieties for processing industry were developed. Combined resistance to late blight and potato virus Y developed. Use of tissue culture raised nucleus stock for production of breeders' seed developed.
- ELISA and PCR based diagnostics for viruses in black pepper and vanilla developed. Metalaxy1-mancozeb (44.5%) followed by copper oxychloride (36.5%) controlled the rhizome rot of turmeric.

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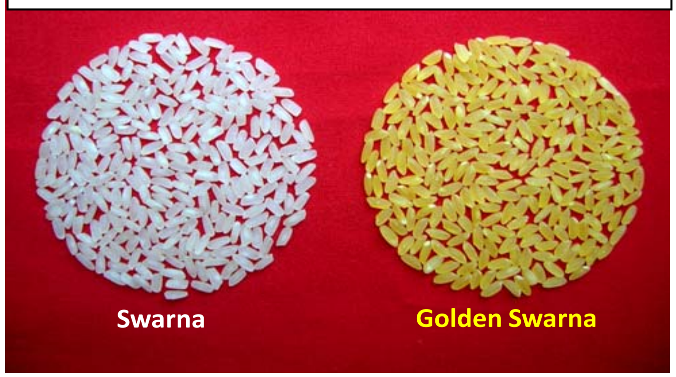

Participatory seed production of Pusa Basmati 1121 – A profitable venture

4.5 Natural Resource Management

The Government of India has laid strong emphasis on watershed projects to improve rainfed farming and for which ample budgetary support has been provided to the concerned Departments. The Government has also established National Rainfed Area Authority (NRAA) to address the problems of rainfed agriculture. In this programme, ICAR/DARE has a very critical role to play in developing location-specific models and solving other technological issues.

- Generated one soil fertility map and six soil maps & area delineated for nutrient deficiency.
- 14 Integrated Water Management package developed for increasing water productivity,
- 11 number of integrated farming system developed involving Agroforestry, Fisheries and Livestock components.
- Standardized multi-spectral remote sensing technique for assessing and mapping soil erosion with an accuracy of over 80%.
- A salt tolerant wheat genotype (KRL 119) with resistance to rust and other disease identified.
- For effective utilization of drainage waterways, technology was devised by growing crops (rice bean & millet in Kharif, brassica & lentil in rabi and Panicum maximum as perennial grass) along with lemon on side slope.
- Benefits of micro-tubewell (limiting depth to 10-12m and diameter to 5-7.5 cm) demonstrated in drawing non-saline fresh water for irrigation of rabi crops in coastal saline area of Orissa.
- Developed liquid biofertilizer formulations for *Rhizobium, Azospirillum* and *P-solubilising Bacillus megaterium* with enhanced shelf life upto one year.

4.6 Animal Sciences

Management of animal genetic resources is a major concern because many indigenous breeds are not economically sustainable today. Priority is given to *in vitro* conservation (oocytes semen, embryo, somatic cells and DNA) for such genotypes so that these are available for future use.

Identification and localization of Quantitative Trait Loci (QTL) for fertility, production and disease resistance traits and their fine dissection to identify the Quantitative Trait Nucleotide (QTN) in the candidate genes offers good prospects of increasing rate of genetic improvement. Work on improvement of indigenous and newly developed breeds in various species is going on using conventional selection and breeding systems.

High milk producing animals are highly susceptibility to production/metabolic disorders like Milk fever, Ketosis etc. The research efforts are strengthened to study their pathophysiology and effect on health, production and reproduction to develop diets and dietary regimens suitable for high producing animals.

A number of technologies have been generated. For example (i) Urea treatment of straws, engineering input for bailing and compacting would be essential. (ii) Treatment of agro-industrial by-products for their detoxification e.g. neem seed cake, castor bean cake, mahua seed cake, karanj cake etc. (iii) Probiotics and (iv) Area specific minerals mixtures and many others. Now their refinement and commercialization is emphasized so that these can be made available to the farmers in next 2-3 years. Appropriate partnership with industry for their purpose is being developed.

- Breed Registration Authority designated, documented indigenous breeds of livestock and poultry registered and Accession numbers assigned. Breed descriptors developed.
- First cloned buffalo calf born at NDRI, Karnal through hand guided technique.
- Mozzarella cheese (Pizza Cheese) using skim milk, vegetables oils/fat replacers developed. Number of indigenous milk products like Channa, Basundi, Mango Lassi, Herbal Ghee, Kunda, Peda, and Dietetic Burfi have been developed.
- Rapid test for detection of adulteration due to oil, soymilk and detergent in milk developed.
- Improved strains of sheep for fine wool, carpet wool and meat developed.
- Elite germplasm of Broiler and Angora rabbits made available for breed improvement programme at farmers level.
- Jamunapari, Barbari, sirohi, malabari, beetal breeds improved through selective breeding.
- Biochemical markers developed for assessing micronutrient status in livestock.
- A new fungus genus Cyllamyces icaris.sp with better fibre degrading ability identified for the first time in the rumen of Indian cattle and buffaloe.
- Hormonal modulation protocols developed in poultry for increased egg production.
- Draughtability parameters in 3 Camel breeds assessed and value addition to camel milk done by preparing paneer, different flavours of kulfi and sugar free kulfi.
- Kits for differential diagnosis of FMD serotypes developed and state of the art international diagnostic facility for FMD launched.
- Improved poultry strain laying 300 egg per annum developed and four strains of poultry developed for backyard system suited for different agro-climate regions.
- Vrindavani cattle developed with production potential of 3500 kg per lactation.
- A device-crystoscope developed to detect accurate time for insemination.
- Diagnostic kit for swine fever, chicken infectious anemia, tuberculosis, Johne's disease trypanosome & Babesia developed and being validated while validation of diagnostic kits for PPR, CCPP, Thileriosis, B.T., Brucellosis and IBR have been completed and transferred for commercialization.
- A low passage homologous cell culture vaccine developed for swine fever. Pentavalent vaccine for blue tongue disease developed. Developed killed vaccine against avian influenza using indigenous strains. Developed serum bank facility, having more than 170000 serum samples.
- High security Animal Disease laboratory, Bhopal conferred recognition OIE for AI testing. Data base on animal disease trends, disease prevalence, meteorological data, land use data, animal and human demography, soil pattern and crop production data developed for disease forecasting and monitoring.

4.7 Fisheries

- Fish landing estimates of all maritime estates have been finalized. Software like MFDRS & GEARBASE updated. Broodstock development and breeding of sapphire devil damselfish *Chrysiptera cyanea* was achieved.
- A total of 70 species of marine fishes belonging to 19 families were recorded in the coral reef ecosystem using underwater visual census technique of belt-transect. The technology for the production of a highly valued marine ornamental fish *Amphiprion ocellaris* has been commercialized.

- Information on water quality parameters, pollutants and assessment of fish health at molecular, proteomics and community level is generated for the river Damodar for health monitoring.
- A 6.4 m length plank built canoe for gill net fishing was constructed using coconut wood in place of the costly Aini wood. Design and fabrication of a new shrimp trawl with short body and cut away belly, low vertical opening and large horizontal spread appropriate for selective shrimp trawling has been completed for field evaluation.
- International award winning Juvenile Fish Excluder-cum-Shrimp Sorting device (JFE-SSD) has been demonstrated at Ratnagiri coast in collaboration with the College of Fisheries, Ratnagiri and Cameroon International for commercialization.
- Indigenously developed High Impact poly propylene (HIPP) trays were found suitable for packing frozen value added fish proudcts like Battered and breaded products.
- Fish sandwich paste was fortified with EPA & DHA.
- Gene encoding capsid protein of MrNV (1.14 kb) was PCR amplified clone and sequenced.
- The existing database on fish genetic resources of India has been modified, restructured and updated by adding more information to the designated fields. 40 catfish species belonging to 10 families were added to the checklist alongwith images of 23 species. Now the database has having 2279 fin fishes of India.
- Protocols for induced maturation & breeding have been standardized for advancement of breeding in rohu & catla. Successful breeding of two indigenous ornamental fish species, Puntius fasciatus (Melon barb) & Brachydanio frankei (Leopard danio) achieved.
- Breeding and hatchery management protocol was standardized for Puntius sarana Total 11.25 lakh of *P. sarana*. 14.5 lakh of *Labeo fimbriatus* and 4.3 lakh of *L. gonius* spawn were produced. Further 1.6 of catfish fry, 4.2 lakh PL of freshwater prawn and 0.78 lakh of ornamental fish seed were produced beside production of 520 lakh of carp spawn.
- A growth experiment of tiger shrimp under probiotic based zero water exchange system was successfully carried out. Shrimp stock @ 13 numbers/sq.m. showed better growth performance with a production of 2660 kg/ha.
- A sensitive and accurate molecular dtol (KIT) has been developed and revalidated for the detection of chemoautotrophic ammonia oxidizing bacteria (AOB) associated with aquatic and agricultural environment and commercially available bioaugmentors.

4.8 Agricultural Engineering

- Designed and developed a number of machines, namely, single row manual and two row animal drawn planter, rotary slit drill, seed cum fertilizer drill attachment for rotavator four row vegetable transplanter, orchard sprayer, manure spreader, self propelled riding type interculture cum spraying equipment, planting unit for planting on plastic mulch under raised bed condition, reaping attachment to tractor mounted baler, pedal operated bud chopping machine for sugarcane, poultry litter based biogas plant, solar cocoon dryer, ethanol production unit with paddy straw and maize stalk, 10m fixed dome solid state biogas plant, equipment for collecting root zone soil water under drip irrigation, software for surface drip irrigation system, mole drain etc.
- Developed process technology for fruits and vegetable based bar and pilot plant, starch extraction from mango kernel using enzyme technique, ready-to-eat snack (chakli) extruder, thermal disinfestations equipment for selected pulses, drier for curry leaf and medicinal crops, steam blancher for selected vegetables, use of soy meal and okara in idli and dhokla,

soy-pearl millet based conventional type extruded products. Enhancing shelf life of soy millet based extruded, baked and traditional snack; enhanced shelf life of sprouted full fat soy flour, vinegar production from soy whey and extending shelf lie of tofu.

- Six women friendly equipment developed and ergonomically evaluated for use by farm women. Designed and developed animal drawn equipment namely, puddler, zero till drill, inter row seeder for rice and sesbania, inclined plate planter, improved bullock and donkey cart, tool carrier, and biasi cultivator, draftability studies of animals, rotary mode of power generation and improved donkey drawn equipment.
- Carried out evaportatively cooled structure, basket centrifuge, castor decorticator, aonla pricking machine, sunflower decorticator, roasting and popping units for makhana, banana comb cutter, coriander splitter, pomegranate aril extractor, blade tenderizer.
- Standardised strawberry cultivation in low cost polyhouse with drip irrigation and plastic mulch.
- Developed lab model cyclone system, labeling software, testing of cotton fibre samples, lap preparation machine, nano studies on cotton fabrics, HPTLC pattern as a marker, cotton stalk supply chain, cotton pre-cleaner, instrument for measuring electrical properties of textile materials, equipment for extracting fibre from banana pseudo stem etc.
- Demonstrated use of jute for decorative, upholsteries and handicrafts. Developed geotextiles for soil stabilization, particle board and composite and moulded products by mechanical pulping/bio-pulping of jute, jute briquetting and gasfication.
- Two collection of rangeeni lac insects multiplied and 34 host plant collections added to gene bank. Developed Seed Lac Dryer and Shellac based dental plates, Pilot of lac dye and Bleached installed.

4.9 Agricultural Extension

- 1671 technologies were assessed and 165 technologies were refined on farmers' fields. More than 1.5 lakh frontline demonstrations were conducted on oilseeds, pulses, cotton, vegetables and fruits in an area of 56627 ha to demonstrate the production potential of improved technologies on farmers' fields in different farming systems. 34 percent increase in yield was recorded in oilseeds and 38 percent increase was recorded in pulses in FLDs at farmers' fields.
- 95059 training programmes were conducted which benefitted nearly 25 lakh farmers and farmwomen. The trainings were organized to orient the farmers on various vocations including orchard management, production of inputs at site, economic empowerment of women, livestock production and management, value addition, fisheries and commercial horticulture.
- More than three lakh quintal seeds of cereals, oilseeds, pulses, vegetables, species, fodder crops and others were produced at KVK farms. In addition, production of planting material included 224 lakh saplings/seedlings of fruits, vegetables, spices, medicinal plants and ornamental plants which were made available to the farmers. Similarly, 21 lakh kg bio-products, 100 lakh fingerlings and other livestock/poultry strains were produced.
- More than seven thousand trainings were organized for extension functionaries working at Govt. And Non-governmental Organizations to upgrade their knowledge and skills in frontier areas of agriculture technologies which benefitted 1.7 lakh extension personnel. 582810 extension activities were organized which include advisory services, diagnostic visits, field days, kisan goshties, kisan melas, scientists visit to farmers' fields. Plants/animal health

camps were organized which benefitted 130.32 lakh farmers and extension personnel. In addition, 2.63 lakh soil and water samples were tested in KVK's labs.

4.10 Agricultural Education

- 6 AUs accredited, National talent scholarship awarded to UG students, 400 scientists attended refresher courses and 35 trainings/faculty development conducted through CAS.
- Infrastructure facilities and Human Resource Development in Agril. Universities (AUs) supported both professionally and financially.
- A mega-initiative taken to support modernization of AUs farms and 28 Niche Areas of Excellence supported in AUs.
- Revised ICAR Model Act for Agricultural Universities in India communicated to all AUs for adoption.
- New initiatives namely, development of museum and sports complex, and guest and adjunct faculty, faculty exchange, personality development and counselling of UG students supported.
- 1620 students were admitted in UG programmes through AIEEA-UG-2009 & National Talent Scholarship awarded to all the eligible candidates; 2010 students were admitted in *PG* programmes through AIEEA-PG-2009; 472 ICAR-JRF awarded to meritorious students for pursuing Masters degree programmes.
- 171 candidates were awarded ICAR-SRF for pursuing Ph.D. at agricultural universities and 436 candidates qualified for Ph.D. admission.

4.11 Intellectual Property Resources

- 83 patent applications including 4 International patents (2 in USA and 1 each in EU/France and Japan) have been filed and 27 patents have been granted in various fields of agricultural technology.
- 639 applications were filed for protection of plant varieties (567 extant and 72 new) of the notified crops. 66 titles for extant varieties have been granted.

and

5. RESEARCH PROGRAMS IN XII PLAN

5.1 Basic and Strategic Research

Agriculture is well established as a vital sector for feeding the burgeoning populations. The growth of Indian agriculture during the past 100 years is closely linked with the development of high yielding varieties of all major crops, including cereals, pulses, vegetables, fruits and flowers, generated through an eclectic mix of traditional and molecular breeding, The application of the tools and techniques of modern biology in agriculture is essential for revitalization of our current needs to ensure food and nutritional security of India. Basic and strategic research is fundamental to innovations and discoveries, which lead to the development of new technologies that can be applied for the advancement of agriculture. In this context, the role of basic and strategic research assumes vital importance in the XII Plan.

Modern biology that blossomed during 1970s has made spectacular strides and successes as applicable to agriculture. Advances in the area of genetic transformation, genomics, metabolomics and metagenomics need to be integrated in crop and animal breeding programs The tools of molecular biology and biotechnology hold great promise for both crop and animal genetics and diagnostics. Transgenic crops are now grown in about 148 million hectares in 29 countries with significant social, economic and environmental benefits to the farmers, especially in developing countries. Marker assisted selection mediated crop breeding has provided novel genotypes with traits of disease resistance, abiotic stress tolerance and quality protein. Another promising area of research is related to stem cell research, cloning, vaccines and diagnostics for the common diseases of domestic animals which is increasingly becoming essential for improving their productivity and developing useful germplasm. In the XII Plan, there is a need to focus on fulfilling these objectives through a synergistic combination of conventional breeding, marker assisted breeding and transgenic technologies.

The challenges of malnutrition, enhanced productivity and crop diversification can only be met by improved resource management, through breeding approaches and generating more nutritious and at the same time less resource input demanding crops. This challenge calls for harnessing the powerful tools of modern biology in agriculture. Several of the XI Plan initiatives such as molecular crop breeding, genomics, transgenics and cloning in animals already started giving rich dividends. Novel vaccines against important animal and poultry diseases were developed. The achievements will be consolidated in XII Plan. There is a definite need to strengthen new initiatives in agricultural biotechnology, such as ICAR network Project on Transgenics in crops by making it more focused vis-à-vis number of crops and traits. Programs on Gene Pyramiding for disease resistance genes in crops, and molecular breeding in crops need to be resurrected.

Despite the several gains made through these approaches, there are several constraints. The lack of high throughput transformation facilities and expansive temperature controlled transgenic glass house facilities, especially for investigations of plant-pathogen interactions in ICAR institutes and SAUs have severely limited the development and commercialization of transgenics in pulse, cereal and oilseed crops. Non-availability of suitable bioinformatics platforms with adequate hardware capacity and critical manpower is huge block to our progress. We do not have a genomics institute where all these high level facilities can be setup and used for decoding the genomes of important agricultural crops. Keeping the research gaps and the need for innovative research in the future, the following recommendations can be prioritized.

Marker assisted election (MAS) is a powerful approach that has already given rich dividends. Traits that are difficult to manage by transgenic approach such as disease resistance and for which resistance sources are available in the crop germplasm are amenable to MAS. There is a need to provide infrastructural and financial support to at least 10 institutions/SAUs**.** Additionally, genotyping and phenomic facilities should be developed in four major zones of India, keeping in view, the climatic conditions, crops grown and access to modern facilities. Rainout shelters need to be an integral part of most of the major ICAR institutes/SAUs. The crops that need our major attention include- Chickpea, Pigeonpea, Rice, Wheat, Maize, Groundnut, Mustard and Tomato.

Another important area of immense significance is the sequencing of agriculturally important organisms and functional genomics which needs to be strengthened in selected NARS Institutions, agricultural universities, general universities etc. with a focus on native crops such as wild rice, brinjal, coconut, mango, ragi, jute and pigeonpea, besides beneficial and pathogenic microorganisms. Bioinformatics is a growing area which is essential for complementing research output. Setting up Bioinformatic Centres in selected institutions can go a long way in enriching the data generated.

An area of immediate concern is the adverse impact of changing climate on crops which needs to be managed in an effective manner by exploiting the abundant microbial resources (extremophiles), which are adapted to extreme environments over millions of years and native crop species. Bioprospecting of genes and organisms from extremophilic conditions, and setting up national network projects in collaboration with CSIR, DRDO and private sector can be a fruitful endeavour**.**

Enhancing the general awareness of public towards transgenics and climate change is of vital significance. Bio-safety testing capabilities for toxicity and allergenicity assessment of novel and GM foods should be enhanced to instill public confidence in the transgenic technology. The ICAR should authorize a Committee with the mandate of bio-safety and field-testing of transgenic crops, so that the public feels confident about the transgenic material developed both in the public and private sector. To further strengthen this aspect, an Institute for Food and Feed Safety should be established and farmer-scientists interactions encouraged.

With the increasing industrialization and lab-to-land approaches becoming a major priority area, public-private partnerships in technology needs to be encouraged. Product development should be given particular emphasis. Both the sectors should play a pro-active role in communication, outreach, public awareness and education of the modern biology. This can help in improving the visibility of research output. Two-way transfer of technologies, incubator facilities and commercialization can be rewarding for empowering agriculture and realizing rich dividends. Private industries may be requested to fund endowments/scholarships to meritorious scientists/ students, and encourage young researchers. A paradigm shift is needed in the way research work is undertaken. Contract research and focused programs which result in products and technologies should be introduced, which can permit interactions of scientists with their counterparts in the industry. The ICAR-Consultation on Biotechnology has thrown up novel ideas such as establishment of Biotech Hubs for MAS, Phenomics, Genomics and Bioinformatics in ICAR Institutes and SAUs. Such facilities can provide an economically feasible mechanism, in terms of concentration of infrastructure, equipment, expertise, and human resources at central hubs to avoid duplication of projects and programmes.

Basic and strategic research in animal sciences has made substantial contributions during XI Plan. Cloning of buffalo, buffalo genome sequencing, transgenic chicken, stem cells etc are important areas. However, much more need to be accomplished during XII Plan. Some priority areas of basic and strategic research in animal sciences include marker assisted selection for higher production of indigenous cattle and buffaloes, identification of unique traits in Indian livestock species for climate resilience, improving genetics and reproductive efficiency of cattle and buffalo. Additionally, disease surveillance and preventive animal health programs, stem cell research, embryo transfer technology, designing diagnostics and new generation vaccines for major diseases of cattle, poultry and other domesticated animals deserve high priority**.**

Transgenics in animals (poultry and livestock) on an experimental basis need to be generated. In order to utilize the modern tools of genomics, phenomics and functional genomics, trained manpower through human resource development in animal and fish genomics, proteomics, animal disease diagnostics, weather-disease interaction and animal disease modeling are required. Development of a school/centre of excellence for research in genome/proteome research for animals and fisheries sciences can provide foundation for animal science researchers.

Biotechnology tools may also be used to improve our indigenous breeds using transgenic and stem cell technology. Bone marrow stem cells to treat structural and functional disorders in sick animals in various clinical situations like healing of wounds, cartilage and bone defects, tendon and spinal injuries etc. Generation of stem cell lines from different sources and development of the nano-molecules for propagation and delivery of stem cell might be helpful in improving livestock productivity, therefore, need special attention. Spermatogonial stem cell research to salvage poor fertility in breeding sires, sexing of semen, fertility markers for bull selection and improving freezability of spermatozoa are likely to have far-reaching consequences on the improvement of livestock fertility and productivity.

Nanotechnology is now emerging as rapidly evolving field, with a potential to revolutionize agriculture and food systems. Although it is projected to have the potential to provide rich dividends to emerging agriculture centred economies like India, it is essential to use the well established technology platforms in the country by creating its own nanotechnology based solutions and industries in the rural sectors. Innovations in nanotechnology are also critical to ensure that NARS remains globally competitive.

Nanoparticles can be synthesized by various physical and chemical processes; however, most chemical methods cannot avoid the use of toxic chemicals in the synthesis process. Recently, there has been tremendous excitement in the study of nanoparticles synthesis using biological systems. Such smart sensors and smart delivery systems will help the agricultural industry combat viruses and other crop pathogens, besides having multitude uses in diverse areas. There is a need to identify nano research and agri-food thematic areas. In the present scenario, emphasis needs to be placed on developing a framework and methodology for integrating nanotechnology into agriculture, not only at the laboratory or farm level, but encompassing all the links across the entire agricultural value chain, right from laboratory level synthesis, farm production systems, postharvest management, processing and value addition, and finally to markets and consumers. In this context, ICAR needs to encourage public-private partnerships, and initiate network projects, as has been done in the Nanotechnology Missions initiated by DBT and DST.

Although a large number of universities and colleges have come up in India offering degrees in modern Biology and Biotechnology, the quality of output is severely deficient. In particular, the hands-on training facilities are lacking in most institutions. Therefore, agri-biotechnology teaching and training should be supported and nurtured in SAUs to ensure a steady supply of quality human resource for the future. Refresher courses in modern tools, improving communication skills, enhancing the number of sabbatical programs, international /national training programs needs a re-look, so that students are encouraged to pursue agriculture as their profession. International collaborations need to be encouraged, which can not only provide inflow of money, but also provide a platform for researchers from NARS to present their work and enrich their skills. Brainstorming sessions can be arranged to take a fresh look at these issues to make agriculture a promising avenue for the coming generations.

6. Research Platforms and Mega Research Programmes

Recent advancements in science have brought research organizations closer and there is greater degree of inter-dependence for generating usuable technologies. This is through resource, material, expertise and knowledge linkages. Cross flow of technologies and intellectual property is quite common for realizing higher impacts. This particularly true for agriculture where a number of technologies converse. Therefore, it is suggested that ICAR should initiate Inter-Departmental Platforms in high priority areas, so that technology needed to accelerate the pace of agricultural transformation area available in time. These Platforms should pool expertise within and outside NARS (CSIR, DBT, DST, general universities and international agricultural organizations like CGIAR, FAO, private foundations, international universities in the US, Europe and Australia). Research partnership with other economies in transition like China, Brazil, Russia, South Africa, etc will help address the common research challenges and make agriculture more competitive globally. Research objectives, activity milestones and expected outputs and outcomes should be clearly identified for each platform. Research areas for potential platforms are given below.

6.1 Enhancing Resilience of Indian Agriculture to Climate Change

Climatic risks are common in Indian agriculture, which is highly vulnerable to drought because $2/3^{rd}$ agricultural land is rainfed and even irrigated system is monsoon-dependent. Floods do occur frequently in many parts, especially in eastern India. Frost in north-western India, heat waves in central and northern parts and cyclone in eastern coast also play havoc quite frequently. Climate change, caused by emission greenhouse gases (GHGs), further aggravates the challenges of agriculture. Agriculture contributes to the greenhouse effect primarily through the emission and consumption of GHGs such as methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2). It may considerably affect the food security through direct and indirect effects on crops, soils, livestock, fisheries and pests. Building climate resilience, therefore, is critical for achieving 4% growth in Indian agriculture in view of its high dependence on monsoon and seasonal variability in rainfall/occurrence of extreme weather events.

The strategies for mitigating methane emission from rice cultivation could be altering water management, particularly promoting mid-season aeration by short-term drainage; improving organic matter management by promoting aerobic degradation through composting or incorporating it into soil during off-season drained period; use of rice cultivars with few unproductive tillers, high root oxidative activity and high harvest index; and application of fermented manure like biogas slurry in place of unfermented farmyard manure. Methane emission from ruminants can be reduced by altering the feed composition, either to reduce the percentage which is converted into methane or to improve the milk and meat yield. The management practices to reduce nitrous oxide emission are site-specific nutrient management and use of nitrification inhibitors. Mitigation of CO_2 emission from agriculture can be achieved by increasing carbon sequestration in soil through manipulation of soil moisture and temperature, setting aside surplus agriculture land, and restoration of soil carbon on degraded land. Soil management practices such as reduced tillage, manuring, residue incorporation, improving soil biodiversity, micro aggregation, and mulching can play important roles in sequestering carbon in soil.

Potential adaptation strategies to deal with the impact of climate change are developing cultivars tolerant to heat, moisture and salinity stresses, modifying crop management practices, improving water management, adopting new farm techniques such as resource conserving technologies (RCTs), crop diversification, improving pest management, better weather forecasts and crop insurance and harnessing the indigenous technical knowledge of farmers.

6.2 Liberating stagnant productivity of major crops through hybrid technologies

The public-bred hybrids have reached the farmers of India only in sorghum, maize and pearl millet and a marginal extent in rice. While heterosis has been identified in wheat and rice, two most land occupying crops of India, there has been limited success in rice and no success in wheat over the last decade. The varieties of Green Revolution seem to have reached their maximum potential and stagnating production in these crops is resulting in reduced buffer stocks. Therefore is to take up this enormous problem and solve it through perfecting the hybrid wheat and rice technologies on priority. The imminent consequence is productivity increase provided there is replacement of the existing varieties with the hybrids. It is this area where public sector based research institutions are ineffective because, together, these two crops occupy about 70 million hectares in India and therefore under fast information exchange, the potential yield increment is likely to generate demand for hybrid seed far beyond their capacity. The only means to realize this vision is on a Public-Private partnership mode can easily do the same. Within two years of release, the PPP can effect 50% seed replacement to make India produce nearly 250 million tonnes of wheat and rice alone.

At the same time, the potential of hybrids in mustard, pigeon pea and soybean is equally sound where ample research scope exists in perfecting the technology. Both oilseed and pulses sector together will get a boost hybrid technology adoption by farmers. While the hybrids may not be the best option for Indian conditions due to the need for seed replacement by 100%, these are the only technologies which have been dutifully replaced year after year by the farmers. A mega programme involving large scale heterotic pool development and large sized F1 hybrid evaluation over multilocations has tremendous scope of application and success with public private partnership in product development and commercialization of the hybrids.

6.3 Harnessing QTLs into varieties for climate resilience

Ability of plant genotype (variety or hybrid) to adapt to climate change that reflects in the form of a range of abiotic stresses is governed generally by large number of genes each of which have small effects making the expression quantitative, rather than qualitative. These gene complexes are cumulatively named as quantitative trait loci (QTLs). Till the middle period of the first decade of the 21st century, the depth of understanding on the QTLs in terms of their mode of action and interactions among themselves or with the environment was functionally grey. However, the recent innovations in the marker technologies and their applications have enabled not only a better directed understanding of these evasive QTLs but also enabled their cloning. A network needs to be developed crop-wise to detect the QTLs responsible for the adaptive capacity of the crop to the subtle but definite progressive changes such as temperature, moisture and epidemiological adaptations by pests and pathogens which are bound to happen in the targeted environment. The largish crop zone needs to be broken down into cropping system based sub-divisions for each network to target accumulation of the desirable QTLs into agronomically suitable genotype. This has to be developed for mega crops such as rice, wheat, maize, pearl millet, chick pea, mustard, soybean, pigeon pea, groundnut and cotton.

6.4 Genome sequencing and functional analyses of genes

Genomic investigations are required to have a knowledge of plant evolution and comparative genomics, understanding population structure, and genetic responses to selection, and to identify and maintain reservoirs of genetic variability for future mining of beneficial alleles. Knowledge of genetic relationships among germplasm sources will guide choice of parents for production of hybrids or improved populations.

The genomic information followed by functional annotation enables development of perfect marker for the specific allele, which in turn allows for the utilization of the specific allele across regions and populations wherever the same exists, along with expected trait value. These genomic applications will be highly successful in characterizing existing genetic variation within species which has not been accomplished. The provision of this research facilitation allows for keeping the national leadership on the crop including owning genes and sequences of importance through protection under IPR. There is possibility of acquiring genes from existing genomes spanning all kingdoms of life, or designed and assembled *de novo* in the laboratory.

Genomics for new trait associated genes in minor crops. While globalized genomic information services and material acquisition options are available for mega crops, for a largely agrarian and diverse agricultural system like India, there are multiple genome resource platforms required to be established. This needs to be done in two tiers, **a)**. Genome resource center for informatics and sequence generation and **b)**. Genome resource for functional analyses and genetic enhancement. The focused crops should be minor crops such as ragi, rice bean, moth bean, kodo, etc. for traits that enhance their productivity, value and adaptation.

6.5 Crop genomics for harnessing QTLs into varieties for abiotic stresses:

Ability of plant genotype (variety or hybrid) to adapt to climate change that reflects in the form of a range of abiotic stresses is governed generally by large number of genes each of which have small effects making the expression quantitative, rather than qualitative. These gene complexes are cumulatively named as quantitative trait loci (QTLs). Till the middle period of the first decade of the 21st century, the depth of understanding on the QTLs in terms of their mode of action and interactions among themselves or with the environment was functionally grey. However, the recent innovations in the marker technologies and their applications have enabled not only a better directed understanding of these evasive QTLs but also enabled their cloning. ***Indian research gains and expertise in this area are globally comparable with the best, unlike many other areas!*** A network needs to be developed crop-wise to detect the QTLs responsible for the adaptive capacity of the crop to the subtle but definite progressive changes such as temperature, moisture and epidemiological adaptations by pests and pathogens which are bound to happen in the targeted environment. The largish crop zone needs to be broken down into cropping system based sub-divisions for each network to target accumulation of the desirable QTLs into agronomically suitable genotype. This has to be developed for mega crops such as rice, wheat, maize, pearl millet, chick pea, mustard, soybean, pigeon pea, groundnut and cotton.

6.6 Diagnostics

Viruses, bacteria and fungal pathogens have emerged as a serious constraint in the production and quality of Industrial crops such as sugarcane; fruit crops such as banana, citrus and watermelon; spice crops such as cardamom, garlic and chilli; vegetable crops such as bean, cowpea, potato, tomato and bhendi and ornamentals such as bulbous and orchids. Many of these crops are severely affected by multiple infections of pathogens. Emergence and spread of viruses include evolution of virus variants (Tomato leaf curl virus in Kolar, Karnataka), Changes in vector biology (Watermelon bud necrosis virus), Changes in the cropping systems (Potato apical leaf curl), introduction of new crops (Tobacco streak virus in Gherkin), the movement of infected planting materials (Grape vine stem pitting virus in Wine varieties of Grape), introduction of new crop species and new genotypes and introduction of host susceptibility genes (Cotton leaf curl virus in Cotton).

The detection of pathogens is a primary requirement for domestic and international quarantine programme. It is indispensible for certification programme for production and planting of healthy planting material of vegetatively propagated crops such as citrus, pomegranate, banana, grape, potato, garlic and ornamentals.

Many of the available detection assays such as biological indexing, colony morphology or microscopic examination are not only time consuming but also not very specific. Therefore, serological assays including ready to use pocket diagnostic kits, molecular detection assays such as PCR and high throughput detection system like DNA-chips need to be developed for quarantine, certification of vegetatively propagated planting material, resistance screening against pathogens for field crops such as soybean, mungbean, rice, groundnut, bean, cowpea, potato, tomato and bhendi. In recent times exotic viruses have become a threat to Indian agriculture and there will be an urgent need to develop diagnostic assays for such exotic viruses.

6.7 Integrated protected and urban/peri-urban agriculture

Successes in some of the satellite periurban regions such as Bangalore, Pune, Hyderabad have demonstrated value of intensified use of natural resources in multiplying the area of land usage vertically to harness six to ten times the normal field agriculture. This needs to be expanded to other cities and townships having more than 10 lakh population to facilitate larger number of smaller and even enterprising marginal farmers to adopt this agriculture. A major shortcoming in this sector is the non-availability of Indian seed material and that is fully suitable to adopt to Indian tropical system. The current successes are therefore limited to only those areas where temperate genotypes from Europe and Mediterranean are adapted. This needs to be taken up in a major drive in agri-horti crops to breed specifically for suitability to peri-urban agriculture. This would mean intensified multi-disciplinary approach to use urban wastes (both solid and liquid), renewable energy, harvested water, managed agronomy, protection from pests & diseases, infrastructural modification to enlarge growing period, etc., for breeding varieties that can adapt to this environment and produce quality products economically.

6.8 Transforming agricultural production systems through G M technologies

The value of transgenic technology in adding a missing trait or magnifying a cryptic trait in a genotype of crop without any additional efforts to be put in by the farmers is well established through the global success of BT cotton, BT maize, HT soybean, HT canola, etc. Without losing more time in having to perfect the protocols which are both standardized by many Indian research set ups and are available for use by licensing if not publically available, it is time ICAR went about setting a group of institutions with targeted crops and traits together on one platform. The platform would be a single all-purpose platform to support research with transgenic, field trials according to BRL I & BRL II, biosafety analyses and environmental safety assessment option for each GM material. Once the safety is established and the GM crop is approved for environmental release, the platform would support in converting the technology into a product. The common value addition would be in terms of resistance to pests, diseases and herbicides., nutritional improvement by biofortification., and tolerance to abiotic stresses such as drought, submergence, heat, salt and acid conditions. This would entail networking with nutritionists, environmentalists and health research institutions in the programme.

6.9 Health Foods

The last Plan has witnessed significant shift of the majority group of middle income earners to health supportive food options. This would mean development of marketable products that add value to healthier food of the same product than before and help improve health of the consumers. The option to be exercised by breeders and food scientists is to develop varieties of crops which can provide better nutrients which are bioavailable. A simple intervention of making wheat non-alergenic to children who suffer from “gluten-intolerance” or “cilliac” disease would go a long way in making the increasing number of children who are unable to assimilate nutrition because of their allergenicity to wheat. Similarly, each crop product can be improved for higher protein content, better balance of aminoacids like in “quality protein maize (QPM)” or better fatty acid composition like “Double Zero” mustard, etc. Even the GM options can be used specifically for this. Each crop network can have a dedicated group that can work towards naturally adding value to its targeted crop through this platform.

6.10 National Feed and Fodder crop platform though integrated approach

Indian livestock population that contains close to 20% of cattle, 55% of buffaloes, 16% of goats of the world would also therefore require feed and fodder most of which comes from agricultural crops. There is a 19% deficit in the needed feed and fodder and with increasing demand for producing more for human consumption, the requirement of the livestock has to be met without upsetting that balance. Therefore, a platform that puts both animal nutritionists and plant breeders to breed crop varieties whose byproducts such as silage and hay are useful for animals by adopting a "Dual Crop" selection strategy without compromising the quality and quantity of commercial grain product. There is enormous potential for enabling the silos for longer usage, better usage and nutritional enhancement through organic and microbial resources that has yet not been harnessed in India. In oilseeds, there is a need to better the quality of cakes produced for their suitability to be consumed by animals with better nutritional value. The platform would also consider facilitating best silo preparation by value addition of nutritional trait.

6.11 Converting crop residue, tree-products into fuel for energy generation

Unlike the developed world where crop is produced for biofuel conversion, India can take a major leap into biofuel production through a carefully managed and organized biomass exploitation without disturbing the balance of grain production, conserved environment and pollution. There are large areas which are non-productive or problem soils for cultivating crops economically which can be diverted to energy producing crops like Jatropha, Subabul and toxic mineral quenchers. These activities which have to be spread focused only in islands from different regions of agri-ecologies, have to be knitted together onto a platform so that an integrated approach to breed for energy producing sugars for conversion into alcohol, biodiesel, etc is enabled across crops. This platform would require a large network of biochemists, analytical chemists, agronomists and breeders.

6.12 Precision Farming

Indian agricultural production system is one of the most diverse systems when it comes to variability that exists in the soil and water resource. The variance can be significantly high even in two land units separated by 500 meters. With the advent of modern information generating tools which operate dynamically through satellite technologies and other GIS options, it is possible to map a projected geographic contig to detect its water and nutritional status supported by rapid testing facilities of soil sample analyses. In crops such as wheat, rice and maize which are grown in more than 10 million hectares in India, a precision farming system development is necessary and breeding varieties which are resilient to a given range of variability that may occur in the soil property become a daunting task. Location specific data-base supported breeding to develop varieties which show least instability to variation in the soil and water resources. The resilience through root adjustment for acquisition of water and nutrients become a major trait that is at the moment being best used only in Australia in breeding wheat. This platform would require breeders, agronomists, soil scientists, physiologists and water scientists.

6.13 Secondary agriculture and high value compounds

The secondary agriculture add value to primary agro-commodities, allow farmers to get higher returns from their produce and creating more rural employment. This will also help reduce post-harvest losses of production. This needs technological, institutional and infrastructural support. In particular, role of business sector in partnership with public R&D organizations assumes greater importance. Establishment of venture capital fund, human resource development, and special focus on bioprocessing are critical for development of the secondary agriculture. Much of the bioprocessing technologies are in private domain, including multinational companies, and therefore their partnership, or access to technology is essential. It may be noted that quality of value added products is influenced by characteristics of the produce and their R&D efforts to improve product quality should be intensified.

Plant and agricultural systems have a huge repertoire of compounds that have high market value in industry, health, cosmetics, condiments and environment. There has been an awareness of importance of these crops to a large extent, without however, converting the value from simple raw material marketability status to the compound producer status, at the farmer or local levels in the country. The platform proposed will explore these possibilities crop-wise in different regions in view of the compound the crop is capable of producing. The ICAR's strength in developing Zonal Technology Management Units **(ZTMU),** Business Development Units (**BDU**) and Institutional Technology Management Unit (**ITMU**) networks will be employed in exploring industry links and interests in organizing a first-time approach of initiating breeding programmes for industry products. Even the sole source of barley in malting and brewing industry is to yet to be bred with that aim only in India. More often than not, the breeders and the farmers are not able to trade their products based on the value adding compound in their product. This picture has to change again, if Indian agriculture has to get oriented to "***industry***" and farmer, an "***industrialist***".

6.14 Agricultural mechanization and energy management

India has made remarkable progress in the development of agricultural mechanization technology. It is well established that mechanization through the use of modern and traditional power sources and matching implements reduce drudgery, bring in added operational capacity, reduce undue dependence on labour, enhance timeliness in field operations so essential for optimal productivity, and achieve precision in metering and placement of inputs. These measures lead to conservation of inputs thereby reducing the unit cost of production, increased productivity, increasing profitability and thus sustainability of agriculture.

The availability of farm power per unit area (kW/ha) has been considered as one of the parameters for expressing the level of mechanization. It has been found that agricultural productivity has direct correlation with farm power availability. The present estimated total farm power availability of 1.7 kW/ha is still far less than which is needed to achieve desired levels of productivity. Agricultural mechanization has become a major driver for catalyzing agricultural growth especially in the context of scarcity of farm labour and adverse impact of climate change. It is, therefore, imperative to not only leverage farm mechanization for enhancing agricultural productivity, but also, to enhance energy use efficiency for production agriculture in view of rising energy costs.

7. Research Thrusts by Sector

7.1 Crop Science

Pre-breeding and broadening of genetic base

India has rich genetic diversity in crops like rice, *Vigna*, maize. However the pedigree and molecular analysis have revealed a narrow genetic base of cultivars of different crops. Utilizing the same elite genetic pool for development of new varieties coupled with this narrow genetic base has limited the per cent yield gains that can be obtained in different cycles of selection as well as made the varieties vulnerable to biotic and abiotic stresses.

There is an urgent need to collect/acquire, evaluate, maintain and utilize wild species as well as land races from their centres of origin. Development of core collection at the national level in different crops is essentially required and may follow a ***Focused Intensive Germplasm Screening*** (**FIGS**) approach to form a representative core collection. Introgression of targeted traits into few of those sets which do not have the obvious agronomic inconsistencies in the targeted area needs to be taken up as a major task as high in priority as the main breeding programme. This can also be part of the ACIP or molecular marker based programme for fast pacing large scale development of value added genetic stocks to be utilized in breeding programmes across the NARS. Such a strategy would help in development of elite lines with resistances to diseases, abiotic stresses, gene pyramiding for multiple stress resistance and quality parameters.

Utility of donors for various abiotic stresses like drought, heat, cold, salinity, water logging etc is only possible if the breeding methodologies and screening techniques are well designed. Feasibility for large scale screening, the role of genomics (**MAS** and transgenic) utility of Wild relatives/landraces through the approaches of **allele mining** and **Eco-TILLING (Targeting induced local lesions in genome)** approaches will greatly aid in this. Where natural variation is exhausted, creating the same and identifying variation through **TILLING** is now a well-accepted methodology to be followed.

Progressive Recombination Breeding Methodologies (PRBM)

Plant breeding methodologies adopted in general over the last decade need to be taken to the next plane where the emphasis is not just in limiting the methodology to creating the recombinants to be followed either through pedigree or bulk selection or bulk-pedigree options in self-pollinated crops and in inbred development in the cross pollinated crops. The last five years have been able to throw up several breeding method variants to reshuffle the alleles in a targeted manner among the polymorphic genotypes in a breeding population. PRBM allows multi-site and multi-number selections from each population.

Definition of the traits targeted such as productivity component traits, stresses or value addition traits in each crop supported by availability of easy and reliable phenotyping techniques for the traits is the key for successful adoption of the intensive reshuffling of genetic variability being captured in the recombinants of a breeding population. This will require development of phenotyping facilities such as "**phenomics**" where fine analysis of the phenotype is required or extensive "***screen houses***", "***greenhouses***" *or* "***rain-out shelters***" as common minimum facilities in institutions where breeding research is happening. *Investment in these field-research facilities is as essential for India as is the investment in developing communication, roads, rail tracks or airports for enhancing economic growth in a region.*

The new tools for enhancing and tapping new recombination spectrum in crops are, Marker Assisted Recurrent Selection (**MARS**), Multi Parent Advance Generation Inter Cross (**MAGIC**) Populations and Nested Association Mapping (**NAM**) Populations provide breeders with greater base material to carry out selections on.

Association Genetics and Search for New QTLs in Germplasm

Over the last five years, another genetic tool has emerged that enables identification and isolation of genes and QTLs responsible for trait variation of the well phenotyped trait in a crop species. The genetic stocks or germplasm that represents the variation in the species is to be assembled and phenotyped in multi locations and genotyped in one location. This will enable the breeder to identify the genes responsible for the trait as well as the markers associated with the trait. This approach minimizes the population development requirement and the time period for identification of QTLs. The crop institutions which already possess sufficient genetic resources only need to focus on proper phenotyping to look for new genes and QTLs which can be explored in breeding populations and recombinants. This activity would add tremendous value to the already valuable genetic resources and germplasm stocks. Once this is carried out, the national breeders elsewhere only need to use these along with their typed marker systems to select for the trait to improve the existing population in a crop species.

Development of hybrids in major crops

The improvement in production and productivity of rice, maize, pearl millet, sorghum and cotton in the past was greatly benefitted because of the development of hybrids. This needs to be consolidated in these crops further and extended to other crops. The revolution in rice took place in China and then has been steadily showing improvement in India only because of emphasis laid on working out the heterotic combinations to maximize the hybrid vigour. Multilocational testing was carried out to evaluate thousands of cross products. This needs to be replicated on similar network mode in other crops such as wheat, mustard, etc. However, even in the successful cases, there is narrow genetic base for the source of cytoplasmic male sterility (**CMS**) which needs to be enhanced for broadening the hybrid profile. Efforts are needed towards diversifying the cytoplasmic male sterility sources, identification of new sources of sterility, assembling and enriching breeding populations, superior and diverse inbred line development, assignment of inbreds to parental groups, hybrid development and refinement of seed production technology. Focus is required on the utilization of thermo genetic male sterility (TGMS) and photo genetic male sterility (PGMS) or apomixes for the exploitation of hybrid vigor in various crops. Development of double haploid technique to fix hetrozygosity in cross pollinated crops and use of tissue culture techniques would help fixing heterozygosity in clonally propagated crops.

Enhancing the productivity of mega crops like wheat and rice under medium and medium-low input conditions

Quantitative improvement of productivity of crop plants especially wheat and rice in the north eastern plains of India in the IGP and central Indian regions by targeting upwards of 20% yield increment, plant breeders would aim to provide the farming community a means to have a basic yield potential increase over the currently stagnating yields of these low-seed-replaced crops in about 17-18 million hectares of rice-wheat cropping system. This is planned by an accumulative approach of "**cumulative component breeding or CCB**" where the methodology would be to stack and pyramid the quantitative trait loci (QTLs) for component traits associated with yield. The components will not only be the direct yield component traits but also will include QTLs related to higher nutrient and water use efficiency. This is visualized as a realizable goal in three phases which involve the first five years of work to map and tag the QTLs on a network mode using multilocation based phenotyping of the reference mapping populations in different crops. The second phase would be dealing with the molecular marker assisted selection (MAS) where the markers identified in the first phase will be employed or accumulating the QTLs in desirable recombinants or genetic backgrounds. The next phase of five years will be aimed for bulking up homozygous materials, yield testing and product release.

Varietal development for conservation agriculture in IGP and Kaveri belt

Crop genetic response in terms of genotype X tillage or genotype X crop agronomy or genotype X cropping system integrated tillage was considered only as a stability trait in a variety. It is only in the last couple of years that it is coming to light that there are large number of biotic and abiotic factors in the crops growing micro-environment which influence the manner in which a crop genotype responds or manipulates to draw its nutrition or water from the soil. These are specific interactions with specific crop rotations and residue management. The development of varieties which carry QTLs and genes which increase the synergistic response of the current crop in a land by adapting to the residue complex left behind by the previous crop as a consequence of the tillage operation or the lack of it would be the most desirable and most environment friendly agricultural intervention that enhances productivity potential of a system in harmony with the type of tillage practiced in the current crop. This novel approach would be the most desirable plant breeding programme in all those crop sequences of IGP and Kaveri basin areas where crop rotations are adopted by farmers.

Breeding for Nutritionally Biofortified Crops

Targeted value addition to varieties of crops for nutrition improvement, biofortification and nutraceuticals would be the focus of the next two decades so that varieties are available for direct nutritive quality enhancement like the β carotene enrichment in rice, mustard oil or specialty starch enriched maize for industrial application. A nutraceutical crop is a food crop with medical-health benefits, including the prevention and treatment of disease. The available options are diversification of diet, intake of food supplements and bio-fortification. Among these, bio-fortification is a viable and sustainable option that can be put into practice through organized breeding for biofortification. This approach will have to be adopted for making farming a industry-driven and industry-supported activity. The varieties so developed will be packaged a minimum quantity of bioavailable or bioprocessable quantities of given nutrient or quality component. The varieties of crops like rice, wheat, maize and bajra will be picked up for improvement such that purchasing these would not be expensive for the below-poverty line and poor consumers. Towards this effect it would be released with a purpose of suitability to replace existing popular varieties with no additional input requirements in their cultivation and minimal post harvest processing to preserve their quality. The targeted traits for this purpose would be micronutrients and essential vitamins with high bioavailability.

Breeding crops for nutrient and water use efficiency

Both water and nutrients have been available in limited quantity in Indian agrarian system through history. There is however, a possibility of manipulating plant traits and organelles to be able to make best use of the moisture available and nutrients efficiently from a given environment. Increased crop productivity through identification and deployment of novel genes for nutrient efficiency, identification of genes for tolerance to metallic toxicity needs to be done for horizontal area expansion. Studies on understanding of the key steps of nutrient assimilation in different crop species through the use of combined approaches including physiology and molecular genetics is required. Genetics of symbiosis and nitrogen fixation needs to be explored, taking into account both the plant biological constraints and the species specificities.

Enhancing availability of quality seeds

Seed is the basic and most critical input for sustainable agriculture. The response of all other inputs depends on quality of seeds to a large extent. It is estimated that the direct contribution of quality seed alone to the total production is about 15 – 20% depending upon the crop and it can be further raised up to 45% with efficient management of other inputs.

The Indian Seed Improvement Programme is backed up by a strong crop improvement programme in both the public and private sectors. At the moment, the industry is highly vibrant and energetic and is well recognized in the international seed arena. Several developing and neighbouring countries have benefited from quality seed imports from India. India's Seed Programme has a strong seed production base in terms of diverse and ideal agro-climates spread through out the country for producing high quality seeds of several tropical, temperate and sub-tropical plant varieties in enough quantities at competitive prices. Over the years, several seed crop zones have evolved with extreme levels of specialization.

The following issues need to be addressed for improving availability of quality seed:

- A rolling seed plan for Breeder, Foundation and Certified seed for next five years must be prepared for all crops for all states. The seed plan shall consider seed multiplication ratio and 25 per cent buffer stock for each category of seed. This rolling seed plan shall serve as a guideline for all agencies indenting seed. The varieties to be included must be recent and provision should be made for new varieties also. This will require frequent interaction between researchers and different state departments indenting the seed.

- *Revival of Seed Village Concept to enhance quality seed availability.* To narrow down the mismatch between the demand and supply of seeds, the seed village concept shall be extended to all crop schemes. Cluster or seed villages should be formed and a cluster should comprise a number of "seed villages" where a group of farmers have to raise quality seeds under the supervision of seed personnel/researcher. Different farmers and villages should be trained during the successive phase of the programme. The programme should aim at (a) Organizing seed production in cluster (or) compact area (b) Replacing existing local varieties with new high yielding varieties (c) Increasing the seed production (d) To meet the local demand, timely supply and reasonable cost (e) Self sufficiency and self reliance of the village (f) Increasing the seed replacement rate.

- *Enhancing Seed Replacement Rate (SRR) in different crops.* SRR is poor in all the crops, especially those where hybrid is not the common seed system. There is an ever increasing gap between available technologies in the form of varieties and number of these cultivated by the farmers purely due to lack of a designed seed production, distribution and future planning. There is an absolute lack of an "**exit plan**" for a variety once its replacement is available, as a consequence of which even three decade old varieties continue to be indented even though each acre of their cultivation deprives the nation and the farmer financially as well as in productivity of the land. This requires improvement for enhancing the productivity. SRR can be enhanced by increasing the quality seed availability and educating the farmers and state government officials indenting for seed to DAC.

- *Efficient FLD of new varieties.* FLDs of new varieties should be planned to demonstrate their high yield potential. This will enhance requirement for quality seed of new varieties ultimately resulting in increased production.

- *Rationalization of breeder seed prices.* The prices of breeder seed should be rationalized. Subsidies can be given o seed price of pulses and oilseeds. The extent of wastage of the efforts put by breeders in producing the nucleus seed and seed scientists in converting it to breeders' seed in India is phenomenal and can be even termed "national wastage". For example, the breeders seed indents for rice and wheat if converted to foundation level 1 and certified seed would meet several times the need of the total seed requirements in the 45 and 29 million hectare land area annually. Yet the coverage with replaced seed is only 12-14%! This obviously indicates a huge gap between what is supplied to seed producers as breeders' seed and their converting it to certified seed that goes to farmers. This also means wasted time, land and other resources as well as wasteful diversion of research field for seed production that is non-productive to national needs. This can be curtailed to a large extent by rationalizing the seed cost of breeders seed to at least 10-15 times the cost of certified seed and an advance share in the benefit of the seed sold through seed producing agencies to the original breeding institutions. A seed money variety-wise needs to be therefore granted to the seed agencies to procure latest seed and build demand for its popularization and acceptance by farmers.

Crop Protection

Strategies for mitigating biotic stress in major field and horticultural crops

Biotic stress in crop plants is constant threat to agricultural productivity and nutrition security of the nation. Today's food security situation is being worsened by new strains of viruses, pathogens/pest/nematodes that are emerging more frequently and spreading much faster and to new areas than before due to fast mode of international trade. With the perceptible climate change across the globe and "high profit" oriented industrialized agricultural scenario, the challenge is multifaceted and needs scientific interventions at every stage of agricultural activity starting from seed to grain. New and exotic pest and diseases are fast emerging or re-emerging in almost every season in every crop. Among the pathogens, Oomycetes or Fungal diseases such as *Phytophthora* diseases in horticultural and plantation crops & rust in wheat, blast and sheath blight in rice, foliar diseases in cereals and vegetable, wilts in pulses, oil seed crops, fruit crops and vegetables; bacterial diseases such as bacterial wilt in solanaceaous and zingiberaceous crops & bacterial rot in vegetables, blight in rice and pomegranate, takes heavy toll of crop every year. Several hundred plant viruses are affecting nationally important crops and their association with succulent planting material is serious threat in horticultural & plantation industry. Post harvest losses due to pests, rodents and pathogens is one of the serious issues in developing country like India which is responsible for huge economic loss of food and fruits as well its cumulative production cost. Coupled with lack or poor infrastructure for long term storage at distribution point, the losses are enormous. *A prioritized and focused research along with infrastructure development, this avoidable loss can be minimized. Strategies to combat the post harvest losses in essential and perishable commodities can be a priority area in research programmes in future plan period in India.* Plant disease with complex etiology in mango malformation needs thorough investigation. *Insects such as white fly, hoppers, borers, thrips, grubs are not only a pest per se but can effectively vector several plant viral diseases and phytoplasmas for which no effective control measures are in place.* Nematodes are silent killers of the plants belong to all category which needs special mentions in the holistic crop protection. National and transnational pest and pathogen monitoring system which exploits genome information need to be prioritized. Furthermore, there is a need to study the dynamics of plant diseases under the climate change regime and developing forecasting models.

Recent advances in the genomics of biotic agents, quantum of useful data is already available publicly. Such a basic information on genome can be tapped for development of race specific markers for interception of invasive microorganisms and pests. For example, rust race Ug99, Race T of *Helminthosporium maydis*, Moko wilt pathogen-*Ralstonia solanacearum* Race 2, Bacterial wilt of groundnut caused by *Ralstonia solanacearum,* newly emerged *Xanthomonas* bacterial wilt (BXW) in banana caused by X*anthomonas campestris* pv. *musacearum,* downy mildew of soybean, cowpea mottle virus, sugar beet *Heterodera*, flat grain beetle in rice are non existence in India. The possibility of their unintentional introduction through trade route needs constant surveillance. Full genome information of these pathogens is already available in public domain. Therefore, identification of genome (and proteome/metabolome) targets generated from these genomes and the transcriptome upon their host interaction would be a fundamental to the development of race or strain specific probes and novel crop protection strategies. Furthermore, availability of full genome information of several thousand genome of microorganism can be exploited for microbial bioprospecting. Collectively these data sets can aid in the realization of potential of microbial wealth of a nation aimed at identification of useful biomolecules for target use in agriculture and medicine. Search for novel molecules in the microbial collection through genomic approach can be a focal point in future.

Crop improvement for biotic stress tolerance facilitated by modern biotechnology is one the most significant developments in plant biotechnology research and development. Developing country farmers who increasingly face pests and diseases, droughts and poor soils induced by climate change could benefit from genetic engineering. The success of GM crops in cash crops needs to be replicated in food crops in developing countries in order to sustain the acceleration of food production. Transgenic technology has the potential to reduce the quantum of toxic agrochemical from getting into environment. Based on these facts the following priority areas and the research strategies thereof are suggested for mitigating future challenges in crop protection.

Priority areas in crop protection and research strategies

Priority area	Research strategy
1. Development of Diagnostics & Molecular Barcoding of Pests/Pathogens/Nematodes and their National Database.	**National Select Agent Database or registry**: This will serve as a referral center for identification and authentication of Pests/Pathogens/ Nematodes. Couple with the database envisaged, the center would serve as a resource for information related to bio-security related issues. **Molecular Bar coding:** Electronically portable genome based codes for invasive pest/pathogen/nematode needs to developed with the help of genome databases
2. Development of pest and disease surveillance methodology, forecasting & prediction models and crop loss assessment system.	**Race / biotype monitoring:** Monitoring of exotic Pests/Pathogens/ Nematodes **Disease surveillance and prediction models**: Development of robust and accurate prediction and forecasting models for economically important pest and diseases. Pest and disease advisory and model based spray schedules would ensure cost reduction for disease management besides protecting the environment
3. Genomics and novel molecules	**Genomics of pest and pathogens**: Pathogenomics and identification of new genome targets for development of ultra sensitive diagnostics tools & high throughput race monitoring mechanism. Genome analysis of pathogenic species by high throughput bioinformatics programme for identification of multi spacer regions which can act as a genome target for diagnostics. This would complement presently available single gene based diagnostics. This would ensure high level of sensitivity for detection and the eventual diagnostics **Interactomics**: Interactive genomics and transcriptomic approaches to mine genome and transcriptome targets leading to development of resistant cultivars. Identification of Pathogen Associated Molecules and the virulence associated effector molecules in pathogen and their targets in host plant in order to exploit the universally occurring natural defense in plants. This would yield an array of molecules for future disease management strategies through conventional and unconventional methods. This is possible through a focused approach on transcriptomics and interactomics **Metabolomics**: Genome mining of beneficial microbes for natural products that are mutually complementing for sustainable disease management and productivity enhancement. Genome mining and genome wide identification of genes and their clusters in bacteria

	& fungi for natural products that is useful in productivity enhancement. This would yield novel molecules that can be exploited as new generation microbial origin biocides
4. Genetic improvement of crop plants through biotechnological approaches including molecular breeding for biotic stress management	**Transgenic crop plants**: Environmentally and socially acceptable transgenic crop plants can be developed to mitigate biotic stress. Ecologically safe transgenic plants which does not pollute the environment can be developed **Transgenic root stocks:** Use of transgenic root stocks for mitigating biotic stress especially viruses and soil borne bacterial diseases in high value horticultural crops **Non host resistances and Cisgenic plants:** Non host resistance must be explored to develop Cisgenic plants against major pest and diseases. The unexplored non host resistance can be exploited for identification of candidate genes for development of transgenic plants against major biotic stress

7.2 Horticulture

Horticultural crops are highly dynamic, especially the flowers, vegetables and many fruits wherein consumer preference determines the economics. Production of fruits, vegetables, flowers, spices and plantation crops has been a success story of the last decade, and to build on this success, sector has to address the new challenges. Therefore, there is a need to prioritize the action outlining the research, development and extension, to make this sector a key driver in rural, health and economic development. Strengthened research on impact assessment of climate change on horticultural crops using controlled environmental facilities and simulation models, analysis of past weather data and integration with productivity changes (including extreme events). Therefore, sustainability will depend upon improving competitiveness, reducing environment externalities, quality assurance and food safety and capability of communities engaged in this sector to manage the change.

Major research priority areas

- Diversity analysis, identification of new genes and its utilization for development of cultivars/ hybrids using new tools & techniques.
- Genomic studies of indigenous and national fruit crop mango
- Production system management for enhancing productivity of water and nutrients, using plant architectural engineering and rootstock.
- Climate resilient horticulture.
- Plant health management, utilizing diagnosing, and bio-intensive management of pest and diseases. Production of nucleus seeds and planting materials.
- Protected cultivation, organic farming, urban and peri-urban horticulture.
- Post-harvest management, value addition and secondary horticulture.
- Human resource development of par excellence and capacity building of stakeholders.

Challenge Programmes for XII Plan

Harnessing potential of hybrids for enhancing production

In order to achieve the growing demand of the vegetables and flowers, superior hybrids will be developed. Exploitation of genetic male sterility, gynoeceous lines and tagging the responsible gene for development of hybrid would further pave the way to achieve high yield in cucumber and bitter gourd. Biotechnological tools, viz. marker assisted selection and QTLs, introgression of desirable gene responsible for different economically important traits and testing the genetic purity in flowers and some vegetables crops will also be under taken to enhance the productivity.

Crops for future- a strategy to harness potential of new crops

A number of fruit crop like jamun, custard apple, chironji, jackfruit, bael, avocado, macadamia nut, pomelo has conventionally being grown and consumed in a small scales in selected areas for specific medicinal/other purposes. Therefore these fruit crop need to be exploited and popularized for large scale cultivation. Hence, survey collection, evaluation, maintenance, propagation techniques, production technologies, reproductive phenology, canopy architecture and value addition and commercialization these unexploited fruit crop will be undertaken.

Root stock research

Use of appropriate rootstocks in different horticultural crops improves production by influencing canopy architecture, nutritional uptake, flowering, yield and fruit quality. Besides it can combat stresses such as soil pathogens, thermal stress, salinity and nutritional stress. Therefore, study on Standardization of rootstocks for variable needs in horticultural crops would be under taken.

Climate resilient horticulture

The increase in average global temperature and other unfavorable climatic conditions or under climate change conditions require urgent attention to assess the impacts of high temperature, periodic episodes of drought, floods, elevated CO_2 concentrations, and their interaction on growth, development, productivity and quality of horticultural crops. Assessment of the incidence of pests and diseases under climate change conditions in major horticultural crops and their growing regions is important. Evolving suitable adaption strategies for enhanced production under climate change conditions along with mitigation strategies by identifying eco-friendly and green technologies for production, protection and post-harvest management of horticultural crops are necessary.

Biosecurity and plant health management

Pest and pathogen surveillance at regional and national and global level, identification of causal pathogen(s) associated with newly emerging diseases and development of quick reliable, sensitive and robust diagnostics for pest and pathogens, pest risk analysis establishing quarantined periods for plants being introduced into new area alongwith capacity building of researchers would be the priority areas. Effective detection of pathogens in seed/planting materials is most important for realizing the high yield. To achieve this, a database of major pathogens including nematodes of different vegetatively propagated horticultural crops will be developed by using modern tools and techniques.

Nano-technology for enhancing input use efficiency

To develop nanodevices as smart delivery systems to target specific sites and nano carriers for controlled chemical release. Some nanotechnologies can improve the crop management techniques. Nanocapsules would help to avoid phytotoxicity in the crop by using systemic herbicides against parasitic weeds and the research objective will be identification of physiologically relevant compounds to pest, develop nanomatrix as delivery system for pheromone and kairamone, and to assess the field response of weevils to the pheromones loaded to the delivery system. Nanotechnology based diagnostics of phytoplasma and identification of lead compounds which are specifically inhibitory to the phytoplasmas are also of high priority.

Nutrient dynamics for balanced nutrition

Nutrient deficiency and unbalanced use of nutrients seem to be one of the major causes of low productivity. Therefore, understanding soil carbon and nutrient stocks and microbiota in different horticulture production systems, to measure nutrient flows in perennial crops as a means to describe current nutrient management, to identify the key factors influencing nutrient imbalances and nutrient disorders in horticultural crops and to develop remedial measures, to minimize environmental pollution and deterioration in soil health, and to produce high quality and nutrient dense horticultural produce are research priority area under this theme.

Canopy management and architectural engineering

Light interception in the tree canopy has major impact on yield potential of most of the fruit crops. Development of efficient plant architectural systems using different rootstocks and scions for harvesting is urgently essential. Utilization of maximum vertical space and energy, to maximize production and to improve color and quality of produce along with reduced incidence of pests and diseases and also to facilitate mechanized intensive orcharding are important priority areas.

Protected cultivation

Off-season crop production under protected conditions can be taken up as the best alternative of land use systems and also for the use of natural and other resources more efficiently. Moreover the producer can substantially increase their income by growing these crops in off seasons. Therefore, multi locations evaluation and development of package of practices of different varieties of vegetables and flowers under protected cultivation will be undertaken. Low cost structures for protected cultivation for various locations will also be evaluated.

7.3 Natural Resource Management

Soil Management

Current status of the country’s resources throws gigantic challenges. The per capita arable land is expected to shrink from 0.34 ha in 1950-51 to 0.08 ha in 2025. Since 1970, the net cultivated area has remained around 140±2 Mha and highly productive agricultural land has been lost to urbanization, industrialization and other developmental activities. It implies that out of total 140 Mha, more marginal and degraded lands are being progressively being brought under cultivation.

Green Revolution era with focus on enhancing productivity of selected food grain crops ensured food security to the teeming millions; with this emerged second generation problems of degradation of natural resources and decline in the total factor productivity under intensive cropping systems due to high nutrient turn over in soil-plant system coupled with low and imbalanced fertilizer use, emerging deficiencies of micro and secondary nutrients (S, Zn, B, Fe, Mn etc.), insufficient input of organic resources because of other competitive uses, and wide nutrient gap between nutrient demand and supply. Water tables declined in many agriculturally important regions resulting in escalated pumping costs, replacement of shallow gravity tube wells with submersible pumps at huge cost, adverse effects on water quality and overall ecology of the region. Declining soil carbon and fertility, shrinking soil biodiversity, need for increasing use of inputs to maintain yields all impacted the quality of produce and environment. Inefficient use of fertilizers and other agro-chemicals created scare of surface and groundwater with connected health hazards.

All India consumption of $N+P_2O_5+K_2O$ increased from 69,800 in 1950-51 to around 26.4 Mt in 2009-10 and was one of the major contributors to the increased food grain production. Fertilizer applications skewed largely in favour of nitrogen at the expense of P and almost neglect of K created nutrient imbalances. Use efficiencies of fertilizer nutrients have remained abysmally low at 30-50% for nitrogen, 15-25% for phosphorus, 50-60% for potassium, 8-12% for sulphur, and seldom exceeding 2% for zinc, iron, copper and manganese. Excessive and imbalanced application of major nutrients, particularly nitrogen, accentuated the occurrences of the deficiencies of secondary and micronutrients *e.g.* sulphur (41%), zinc (49%) and boron (33%). Deficiencies of other micronutrients like iron, copper, manganese, molybdenum in soils are on the rise. Implications of iron and zinc deficiencies in soil, plant and humans have led to a realization that agricultural technologies can contribute significantly in improving human and livestock health in a much more sustainable manner than therapeutic means, particularly for the rural population, which is largely malnourished.

Cold chain research for promoting bio-fertilizers: Use of bio-fertilizer in the INM is well documented. However, field scale adoption of bio-fertilizer is far from being adequate (except in soybean). To facilitate its wide scale adoption at the farmers level, intensive research and extension efforts is the need of the hour. Research efforts should be mounted to overcome the bottleneck of the cold chain in use of bio-fertilizers.

Water Resources and Management

Agriculture sector is the largest consumer of water (82.8%) but faces stiff competition from other sectors. In 2025, out of country's 1093 billion cubic meters (BCM) anticipated total demand for water, 910 BCM will be consumed by irrigation. The per capita per year water resource of the country has been continuously declining from 5176 m^3 in 1951 to 4732 m^3 in 1955, 200 m^3 in 1991, 1869 m^3 in 2001 and 1703 m^3 in 2007 and is likely to be less than 1500 m^3 by 2025 (less than the internationally prescribed level of 1700 m^3. With 58 Mha area under irrigation, India tops the world in terms of total irrigated areas but average crop yields of around 2.3 t ha^{-1} are pathetically low largely due to inefficient management of water and poor fertilizer use efficiency as well as low and imbalanced nutrient application. With proper input management, it could easily be raised to around 4 t ha^{-1}. Many farmers in Punjab are harvesting more than double that yield from one hectare of assured irrigated land.

Single intervention of proper land leveling through laser levelers increases the water application efficiency which results in higher yields and also increases water and nutrient use efficiency by 20-30% or more. A properly designed check basin or border strip can easily save 10-15% of water. Practice of alternate or skip furrow irrigation can save considerable quantity of water without significantly affecting yields. One of the resource conservation technologies (RCT) that has gained popularity during the last few years is the Raised Bed Planting system of crop cultivation which is essentially a modification of the furrow system. This method of crop establishment adds to the benefits of zero-till to bed planting and is a more sustainable system. This is gaining popularity as it opens up avenues to farmers for crop diversification and intensification in the Indo-Gangetic Plains. It is ideally suited for vegetables and can be adapted for many other crops successfully. Development of pressurized irrigation systems in the form of sprinkler and drip systems marked the era of precise water application in small quantities. To encourage adoption of these water efficient technologies, the Government has provided subsidy to popularize pressurized system of irrigation like sprinklers and drip (Trickle) which both together now occupy 2 Mha while the potential area identified in the country is 69.5 Mha**.** Applying fertilizers through irrigation water, particularly through the drip system, termed as fertigation, can result in savings to the tune of 40% of the fertilizer applied. In rice, years of research conducted on varying soils all over the country have conclusively established that irrigating rice only one to three days after disappearance of ponded water can save 20 to 30% of irrigation water applied without any significant effect on the yield. The saved irrigation water could be used to bring additional area under irrigation or diverted to dry and/or water scarce areas. System of Rice Intensification (SRI), aerobic rice cultivation *etc*. are some other options available as water-saving measures.

Bio-remediation of polluted water: In many parts of the country quality of surface and ground water used for irrigation has deteriorated over time. Besides low quality water such as industrial effluents, wastewater of the cooling towers and sewage water will be increasingly used for irrigation. This leads to entry of the toxic elements and pollutants in the food chain, thereby affecting the food bio safety. Research efforts are required for ascertaining the dynamics of the toxic elements in soil-crop system and developing appropriate mechanism for bio-remediation/phytoremediation for safe use of water.

Rainfed Agriculture

Eighty-plus Mha of net sown area in India is rainfed and contributes around 40% of food grain production and supports two-third of livestock population. Notwithstanding accelerated irrigation-potential development, 85% of the coarse cereals, 83% of pulses, 42% of rice, 70% of oilseeds, and 65% of cotton are still cultivated under rainfed conditions. Wide gap between attainable and farmers' yields is a worrisome concern. Self-sufficiency in pulse and oilseed production can only be realized through increasing productivity of dryland agriculture, largely through resource-centric interventions.

Small and marginal farmers who are backbones of rainfed farming are risk-poor and risk-averse. Rainfed agriculture is completely monsoon-dependent; rainfed soils are both hungry and thirsty. The existing productivity of arid (0.2 t ha^{-1}), semi-arid (0.6 t ha^{-1}) and sub-humid (1.0 t ha^{-1}) is 5, 3 and 3 times less of their potential productivities of 1.0, 1.9 and 3.0 t ha^{-1}, respectively. All management strategies in this zone are targeted on conserving the maximum amount of rainfall either *in situ* or *ex situ*. For example, off-season/summer tillage coinciding with pre-monsoon showers helps in increasing rainwater infiltration, moisture conservation and efficient weed control. Deep tillage of 20-30 cm layer is specifically applicable to soils having differentially textural profiles or hard pans in chronic drought prone arid regions. In case of black soils, tillage combined with compartmental bunding is most effective. Extensive tillage of sandy soils (common to desert areas) makes them more vulnerable to wind erosion and superficial scraping to eliminate weeds is adequate.

Conservation Agriculture (CA) vis-à-vis Conventional Agriculture

Conventional agricultural systems involve intensive tillage with heavy machinery. Essential fall-outs of these systems are decline in soil organic matter, soil fertility, biodiversity and accelerated soil erosion resulting from aggressive seed-bed preparation; burning of crop residues causes pollution, greenhouse gases emission and loss of valuable plant nutrients. Conservation agriculture (CA) on the other hand is a production system involving minimum soil disturbance, providing a soil cover through crop residues or other cover crops and crop rotations for achieving higher productivity. Key features of CA include: (i) minimum soil disturbance by adopting no tillage and minimum traffic for agricultural operations, (ii) leave and manage the crop residues on the soil surface, and (iii) adoption of spatial and temporal crop sequences / crop rotations to derive maximum benefits from inputs and environmental impacts. Crop residues retained on soil surface in combination with no tillage cause onset of processes leading to improved soil quality and overall resource enhancement. Thus the CA technologies may lead to sustainable improvements in the efficient use of water and nutrients by improving nutrient balances and availability; increasing infiltration and retention by soils reducing water losses due to evaporation; and improving the quality and availability of ground and surface water.

Adoption of CA in India is gaining ground after initial resistance as an estimated 3.4 Mha of land in India is under conservation agriculture as against 111 Mha in the world. Embracing no-till has been especially difficult in developing countries of Africa and Asia, because farmers often use the crop residues for fuel, animal feed and other purposes. Herbicides needed for weed control are not available or can be prohibitively expensive to farmers. New generation machines, viz. Happy seeder, turbo seeder, rotary seed drill etc - welcome development - are very efficient in sowing the crop even under high rate of residue application. The CA - an effective carbon sequestering strategy – needs quantification for its carbon sequestration potential *vis-a-vis* dynamics and quality of SOC. Scanty information is available on the nutrient and water management strategies based on nutrient-dynamics in soil and profile moisture status under CA.

Development of CA technologies is expected to (i) reduce cultivation costs, (ii) improve and sustain stable yields, (iii) ensure longer life and minimum repair of farm machinery, (iv) reduce soil degradation, (v) increase organic matter and biological activity, (vi) reduce pollution of surface and groundwater, (vii) reduce emission of greenhouse gases, (viii) effect savings in non-renewable energy source, and (ix) increase C retention / sequestration.

Resource Conserving Technologies

Resource conservation technologies have drawn the attention of agronomists and other crop production scientists to devise innovative tillage and crop establishment techniques for higher productivity. Experiences from several locations in Indo-Gangetic Plains show that with zero tillage technology, farmers are able to save about Rs. 2500/ha on land preparation and reduce diesel consumption by 50-60 litres per ha. Similarly, bed planting systems help more efficient use of water under both rainfed and irrigated systems. So far zero- till and bed planting technology have largely been evaluated in wheat under rice-wheat cropping system in the north-western plain zone. Greater emphasis has been laid on crop diversification due to growing concerns about the unsustainability of rice-wheat system in this region. Crops like maize, soybean, pigeonpea, groundnut etc. are suggested as possible alternatives for rice in *kharif* season; while in *rabi*, mustard and chickpea are required to be included in the cropping system due to their less water and nutrient requirements compared to wheat. Further, summer cropping with legumes such as greengram, cowpea and *dhaincha* (green manure), particularly in the cereal-dominating cropping sequences, is essential for conserving resources and improving productivity. Recycling of at least a part of the crop residues produced by different crops is essential for maintaining soil health and long-term sustainability of the system.

Carbon Sequestration and Global Warming

Intergovernmental Panel on Climate Change (IPCC) report predicts a temperature increase of 0.5–1.2 ˚C by 2020, 0.88–3.16 ˚C by 2050 and 1.56–5.44 ˚C by 2080 for the Indian region, depending on the scenario of future development due to enhanced emission of green house gases into the atmosphere with CO_2 being the most dominant. Antonym of CO_2 emission is carbon sequestration. The total C sequestration potential of restoring degraded soils, adopting intensified agricultural practices, erosion control, and formation of secondary carbonates in India is 7 to 10, 5.5 to 6.7, 4.8-7.2 and 21.8-25.6 Tg C/yr. Summed up, soil C sequestration potential of 39.3 to 49.3 Tg C/y (mean of 43.3 Tg C/yr) can be exploited to offset the net emission from fossil fuel combustion. Carbon sequestration can be enhanced through **a**doption of recommended management practices including the use of resource conservation technologies, integrated nutrient management and manuring, location specific diversified cropping, use of low cost soil conditioners (like hydrogel) for better water use efficiency, alternate land-use systems (ALUS) – silvi-agri, horti-agri and agroforestry systems, restoration of eroded and salinized soils, and conversion of agriculturally marginal lands into restorative land uses. Integrated farming systems approach under the umbrella of conservation agriculture is the best carbon sequestering practice.

Metal Pollution and Toxicity

Metal-toxicity could lead to either biochemical (genetic) or physiological (environmental) abnormalities. In India and adjoining Bangladesh, the arsenic (As) contamination is of geogenic origin. But most serious problems of As poisoning occurred due to drinking of geogenically As-enriched groundwater in the alluvial Ganges aquifers in West Bengal (India) and Bangladesh, covering a geographic area of 0.173 million square kilometer (Mkm^2), while exposing 36 million people to risk. Similarly, geogenic-driven selenium toxicity has been reported from some pockets of Punjab where as high as 2.41 mg Se kg^{-1} of soil has been reported, a level much higher than 0.5 mg Se kg^{-1} of soil, a limit associated with production of Se-toxic fodder. Elevated levels of Cr in soil, surface water and groundwater at a few places in India are of anthropogenic origin related to tanning industry. The quantity of effluent discharged amounts to about 30 to 40 L kg^{-1} of skin/hide processed and in case of finishing units the quantity is about 50 L kg^{-1} of raw skin/hide. The most important source of fluoride in human diet is sea fish and drinking water. Around 50-100% districts are affected by fluoride toxicity in Andhra Pradesh, Tamil Nadu, Uttar Pradesh, Gujarat, and Rajasthan. Fluorotic ores occupy large areas of eastern and southeast parts of Rajasthan, in constricted synclinal bands in the central region of Aravali synchronium. Secondly, around the mica mines, groundwater is rich in fluorides and Rajasthan is a rich source of mica. Usually high Cd levels found in soils are related to anthropogenic activities like mining, Pb and Zn smelters, burning of fossil fuels and disposal of wastes (plastic, Cd-containing batteries, sewage sludge etc.).

Since food-chain contamination is one of the major routes for entry of metals into the human system, assessing bioavailability of metals in soils and their subsequent transfer to food chain is important. Among remediation options, excavation of metal-polluted soils is prohibitively expensive. One of major problems associated with phytoremediation is low metal-removal rates. Hence, in-depth evaluation of effectiveness of a range of inorganic and organic materials like lime, phosphate, organic manures, zeolites, hydrous oxides (Al, Fe and Mn) and palygorskite on the availability of toxic trace elements in contaminated soils is required.

Harnessing the Potential of Rice-fallows

The country has close to 12 mha of fallow lands after rice harvests as excessive wetness does not allow normal tillage and timely planting. These lands are located in the flood prone eastern agro-climatic regions of the country. These lands can be put to use (producing additional few million tonnes of food, particularly pulses and oilseeds) through surface seeding and minimum tillage practices. There is a need for research on seeding practices (crop establishment, choice of crop cultivars, nutrient, water and weed management). Research is also needed to prevent germination of grains in the panicle due to untimely rains in *kharif* and *rabi*.

Issues in the Natural Resource Management

1. Soil, water and biodiversity are our national wealth and heritage. Majority of our resources have been over-exploited and are in an advanced stage of degradation due to loss of organic matter, depletion of nutrients, over-exploitation of ground water and depletion of carrying capacity of pastures, grazing land and other open access or common property resources.

2. The growth in total and partial factor productivity in agriculture has declined and even become negative in the Indo-Gangetic plains and other agro-ecologies. Enhancing input use efficiency for cost competitiveness and reducing pollution possibilities is urgent.

3. Enhancing water productivity by integrated management of its multiple use cycling/ recycling and farming systems is the highest priority of maximizing returns per drop of water.

4. About 50% of Indian agriculture is likely to remain rain-dependent even after having developed all water resources. Improving productivity in rainfed agro-ecologies through participatory integrated watershed management needs immediate scaling up.

5. A comprehensive diversification in terms of varieties, crops, farming systems, inputs, agricultural practices and marketing strategies is necessary to meet emerging challenges.

6. Soil organic matter (SOM) is the mainstay of soil quality. While balanced fertilization may meet crop productivity and maintain SOM, it is an urgent imperative to improve the sequestration of carbon in all the soils by all available means including recycling of crop residues, green-manuring, composting, reduced tillage etc. We must realize that the **"grains belong to humans but the residues belong to the soil"**. So carbon sequestration should be an urgent priority, irrespective of its effect on climate change. Enhanced use of bio-fertilizers, soil microbes, bio-pesticides and bio-control of weeds may be given high priority.

7. Increasing urbanization and industrialization will generate large quantities of solid wastes and effluents beyond the capacity of natural systems to assimilate. This is posing severe health hazards due to load of heavy metals, detergent, pharmaceutical compounds and pathogens. Some of the water aquifers are likely to be contaminated with nitrates, fluorides, agro-chemical residues, selenium and arsenic triggered by geogenic (natural) and anthropogenic processes. While the search for cost-effective chemical and bioremediation options are on, refinement of agronomic options is called upon. River water quality monitoring showed that more than 90% of the contamination was due to point-source of urban and industrial effluents. Pre-treatment of effluents to meet the criteria for discharge into rivers and canals is necessary. Adoption of "**polluter must pay**" principle needs to be strictly adopted.

8. Productivity of wastelands may be restored with inputs of social capital for removing poverty by enhancing self-employment, income generation and livelihood opportunities for small/marginal farmers and landless communities.

9. Enabling reforms, regulations, contracting and leasing systems of land, water and machinery require legislative initiatives.

SRI Up-scaling

SRI has the larger area coverage with several institutional innovations across different states. It has engaged formal government systems, financial institutions and civil society organizations, involving of research systems in partnership with civil society. The proven benefit of SRI (SCI in general) is multifarious and of larger dimension to the society. The technology provides both the institutional architecture and the potential of agro-ecological innovations in meeting food (and income) security needs in a unified approach. Current strategies to enhance productivity in rice such as NFSM seek to augment production by 10 million tonnes with enhanced poverty and livelihood focus including resource conservation strategies. With an added emphasis on scientific approval, SRI can be extended to about 10 million hectares covering the niche areas of both irrigated ecosystem and rainfed ecosystem (approx @ 20% of irrigated, 25% rainfed). Assuming 1 to 1.5 ton/ha advantage in productivity, an additional production of 10-15 million tonnes of rice can easily be achieved.

7.4 Animal Sciences

Animal science research is capital and skill intensive and has a longer gestation period to come up with newer technologies. There is acute shortage of manpower in the area of veterinary and dairy science research and academics. Research and training facilities are inadequate to produce quality human resource and support technology needs. More financial and human resource support is needed to address emerging livestock research, technology and human resource agenda.

Genetic Resource Management and Improvement:

Focus of research and development while maintaining diversity of genetic resources should be to identify polymorphisms and genes of importance and integrate them in breed improvement including conserving them for future use. The unique characteristics of indigenous livestock in terms of heat tolerance, prolificacy, disease resistance and capacity to utilize poor feed resources need to be explored at gene level, so that these could be harnessed in combating the impacts of climate/environmental change. Conserving and improving lesser known populations of sheep and goat with unique traits (Garole, Kendrapada, Chegu, Changthangi, Gurez, Nicobari, Hillgoats etc.) should receive priority.

Breed improvement programs in livestock and poultry have been going on at various institutional hubs. More herds of indigenous breeds of cattle (especially Gir, Kankrej, Rathi) and buffaloes (Nili-Ravi and Jaffrabadi) should be established and networked as a common National Gene Pool for young bull production and evaluation. High producing animals with the farmers should also be identified and included in breed improvement program. Embryo transfer and sexed semen should be integrated in the progeny testing program to enhance genetic gains. Focus should be to identify markers linked to lactation, reproduction, and disease resistance. Rural poultry besides characterization and conservation of Indigenous germplasm should receive higher research priorities. CARI and PD (P) should be merged to provide necessary research and training support for rural poultry.

Increasing Efficiency of Feed and Fodder:

Animal nutrition research has centered on nutritional evaluation of newer feed resources, improving digestibility and adding value to low quality roughages. Research work on Rumen Microbiology should be strengthened to understand the mechanism of feed degradation and energy extraction, studying rumen microbial diversity in domesticated and wild ruminants and to identify the consortium of microbes required to maximize extraction of nutrients from poor quality crop residues. Role of probiotics (as substitute for antibiotics) in different species of animals should also be studied.

Unfortunately fodder research has all along received low priority. The only option is to strengthen fodder research and seed production. Since fodder and pasture management specialists are not available in sufficient numbers, PG programs in these areas need to be initiated.

Enhancing Reproductive Efficiency:

Basic techniques of ETT are well in place. These should be integrated in livestock improvement programs. Dependence on import of Gonadotropin hormones for super-ovulation and estrus synchronization has been one of the major limitations in furthering use of ETT. Indigenous production of these hormones using rDNA technology and other consumables is need of the hour.

Advances in diagnosis and therapeutic management of anestrous and repeat breeding are central to sustainable and rapid growth of livestock sector. A systemic mapping of reproductive disorders/diseases of dairy animals in different agro-climatic zones would help to develop strategies as well as package of practices for prevention and control of the reproductive problems. Suitable biomarker(s), kits and protocols for determination of male fertility/infertility also need to be developed.

Improving semen freezability, sexing of spermatozoa and managing reproduction are the other concerns. About 50% crossbred bulls do not produce semen of freezable quality. Suitable techniques for ultra-low preservation of spermatozoa without affecting the fertilizing potential should be developed. More research and better equipments are required to improve efficiency in sorting of spermatozoa and fertility of sorted sperms particularly in buffalo. Developing appropriate contraceptive/ sterilization strategies for population control of Nilgai and monkey should form priority.

Climate Change and Livestock:

Increased temperature and humidity adversely affect growth rate, reproduction and production. Climate change also affects rate of transmission of many infectious and vector-borne diseases. Research and strategy focus should be to reduce methane emission from livestock, providing comfortable housing to reduce stress and studying effects of rising temperatures and humidity on reproduction, diseases and fodder quality and quantity both in temperate and tropical environments.

Diagnostics and Vaccines:

Molecular and immunological tests have been standardized for various infectious diseases and drug residues in livestock and poultry. Majority of these tests are used only at the laboratory level. It is essential to subject them to proper validation as per the OIE protocols and transfer these to industry for large scale production and marketing.

National control program on FMD, PPR and brucellosis are in existence. Except FMD, diagnostic tests which can differentiate vaccinated animals from the naturally infected ones are not available. There is a need to develop novel platforms for rapid and efficient pathogen isolation, characterization, diagnosis and developing rapid detection kits for efficient disease management. Biosensor and nanotechnology based diagnostics are important areas for investment in research. Developing thermostable & multivalent vaccines should receive high research focus.

Imaging is another way to accurately diagnose various disease conditions. Advanced imaging procedures and techniques (radiography, endoscopy, laparoscopy, arthroscopy, MRI and CAT scan etc.) need to be standardised and routinely used for diagnosis and treatment of various disorders/lesions in small and large animals.

Disease Monitoring & Surveillance:

Programs on surveillance and epidemiology of important economic diseases need to be strengthened. Brucellosis is an important contagious bacterial disease and public health problem. Systematic surveillance of brucellosis in livestock, development of accurate and quick pen-side diagnostics and better vaccines should receive high research priority.

High Security Animal Disease Laboratory:

HSADL in Bhopal is currently involved in diagnosis and management of exotic and emerging diseases and reports about their status to ICAR and DAHD&F for decision making on policies pertaining to trade. The present administrative setup being under IVRI, Izatnagar, the functioning of HSADL is greatly impeded. ICAR may consider granting independent institute status under the direct control of the Council and name it as "Indian Institute of High Security Animal Diseases" with the mission to uphold National Security from exotic/trans-boundary animal diseases, bio-threat and biological warfare agents through bio-safety and bio-containment measures.

Companion Animals:

They play a vital role by providing company and security in the today's society and deserve quality life and welfare including comfortable microenvironment, proper nutrition and healthcare. There are also zoonosis issues concerning pets. These areas need to be addressed on priority through establishment of a Project Directorate.

Dairy and Meat Processing and Value Addition:

Indigenous milk product industry is very large, unorganized and need support for process mechanization and technology upgradation. Mapping of bioactives in milk of various species, nutrigenomics, designing functional dairy products, food safety and improvement of quality and shelf life are the priority areas.

Meat sector needs to aim at organizing Indian meat industry on scientific and modern lines with focus on developing technologies for clean meat production and processed meats with value addition. A net work program on "Development of grading in meat trade and its adoption to the benefit of producers, processors and consumer" should be taken up.

7.5 Fisheries

Enhancing fish productivity

The capture fisheries in open waters of rivers, reservoirs/wetlands and coastal areas have declined alarmingly due to ecological degradation. In addition to conserving these resources, there is a need to increase their productivity through ranching and culture based capture fisheries through commercialization of cage/pen culture technology. Also, there is a need for environmental monitoring and assessment of fish diversity and production of major river systems along with their wetlands/reservoirs for the generation relevant baseline data on ecology, productivity and biodiversity. A database should be generated and mapping done on frequently occurring diseases across different agro-climatic zones for use in disease forecasting.

Genetic enhancement

Moderate progress has been made in this area except producing Jyanti Rohu which has 17% higher growth. More work should be taken up on genetic enhancement of other edible species like *Catlacatla*, *Cirrhinamrigala*, *Clariasbatrachus* and *Macrobrachium rosenbergii* for higher growth, disease resistance and reproductive potential. Shrimp is a valuable foreign exchange commodity. Hatchery produced seed is more prone to viral diseases. In order to produce disease free seed, there is a need to strengthen improvement program for this species through selective breeding.

Wasteland and watersheds for aquaculture

India has 7.0 million ha of saline affected soils in the Indo-Gangetic Plains of North Western India. These lands are unfit for agriculture (partially or totally), but hold great potential for acquaculture development. Although work on the development of technologies for aquaculture in salt affected/waterlogged lands is being done, there is need for initiating a network for aquaculture in salt affected lands. Commercialization of the developed technologies should be taken up on priority. Integration of aquaculture with watershed projects in semi-arid zones (foot hills) needs attention as the harvested rain water (reservoir) in these areas can also be used for fish production besides fulfilling the irrigation needs. Although work in this direction has been done in Eastern region of the country, it needs to be extended to other parts through collaborative research.

Cold water fisheries: In order to harness the potential of cold water fisheries resources, the available technologies for breeding and culture of some economically important cold water fishes should be standardized and commercialized.

Harvest and Post-harvest technologies

Although some work on fishing vessels/gears and implements/machinery designs has been carried out, these are in no way close to the actual requirement. ICAR should seek collaboration of industry in design and fabrication of machinery and efficient fishing vessels. For deboning of carps, there is a need to enhance efficiency of meat bone separator with respect to different size groups of carps. Cost effective meat bone separator of small size should also be developed for fish processing at small scale. Many value added products have been produced from fin fish/shell fish. In view of concern for food safety, more emphasis should be laid on microbial quality of these products both for domestic and export market.

Marine Fisheries

The marine environment provides an immense biodiversity that is being catalogued for commercial uses. These include several microorganisms, algal forms, invertebrates, that could serve as potential sources of bioactive substances including antimicrobials, anaesthetics, anti-carcinogens, etc. as well a wealth of valuable genetic material for transgenics and thus presents a huge opportunity for both food and drugs from the seas. Identification of suitable sites along the Indian coastline of over 8000 km, hatcheries and grow-out systems for finfish, shelfish and other organisms, possibilities of cage culture in island eco-systems are the strategies for realizing these potential.

Research thrusts should be given to the studies in the shelf, slope and oceanic realms to assess and map the resource potential, upgradation and species diversification of mariculture technologies, socio-techno-economic aspects of marine fisheries and brackishwater aquaculture, design and fabrication of modern fuel-efficient fishing vessels, development of cost-effective and responsible fish harvesting systems, diversification and value addition for utilization of low value fish, quality assurance and management systems.

Mariculure: Mariculture is expected to be a major activity in the coastal areas in the years to come. Given the wide spectrum of cultivable species and technologies available, the long coastline and the favourable climate, mariculture is likely to generate considerable interest amongst the coastal population. At a time when we speak of over-exploitation in the near-shore waters, limited access to capture fisheries and the need for diversification, mariculture can be one of the most appropriate alternatives. Technologies for a couple of species are presently available in the country and there is an urgent need for developing package of practices for many more commercially important species.

National Seed Project in Fisheries

A project on national seed production in agricultural crops and fisheries with particular reference to seed production in fisheries has been initiated in 2005. For fish seed programme, 36 nodal points have been selected involving ICAR Institutes, SAUs and conventional Universities. The main objective of the project is to produce quality seed carps, catfishes, freshwater prawn, shrimp, seabass and ornamental fishes. The infrastructure involves hatchery establishment and other operational facilities for seed production. The infrastructure should be strengthened with focus on the following: (a) Setting up of tissue culture laboratory, (b) Procurement of research vessel for making onsite studies in the sea, (c) Hatchery for seed production and farm facility for culture of coldwater fishes, (d) Quarantine facility for research purpose, and (e) Development of nursery ponds and sea farms for onsite testing of mariculture technologies.

7.6 Agricultural Engineering

Based on the present status and future needs of mechanization of Indian agriculture, the following areas of R&D have been identified to work on during the XII Plan.

Precision farming technologies

- Development and adoption of variability based applicators for seeds, water, fertilizer and plant protection chemicals for enhanced input use efficiency.
- Development of Remote Sensing and GIS based decision support systems (DSS) and gadgets for variability assessment and application of inputs and yield monitoring.

Mechanization of horticultural and fodder crops

- Pneumatic and mechanical planters for small seeds
- Transplanter for onion and selected vegetables
- Harvesting and canopy management equipment for fruit trees
- Harvesting machines for root crops
- High-tech nursery raising technology for horticultural crops
- Equipment for feed, fodder and by-products handling related to live-stock/fisheries

Specific purpose machinery

- Harvesting machines for cotton and sugarcane crops
- High capacity energy efficient machines for custom hiring

- Tractor operated combination tillage equipment
- Equipment for in-situ and ex-situ bio-mass management
- Equipment for feed, fodder and by-products handling related to livestock/fisheries
- Direct paddy seeder for SRI
- Tractor operated sorghum harvester

Ergonomics and safety in agriculture

- Development of agricultural tools and equipment using anthropometric and strength data of agricultural workers for better productivity, efficiency, safety and reduced drudgery.
- Refinement/ development of women friendly tools and equipment for reducing drudgery and occupational health problems.
- Mitigation of occupational health and safety problems in agro industries

R&D on Energy in Agriculture

- Farm machinery management for enhanced energy use efficiency
- Development of processes and technology for cost effective alcohol production from agro residues through enzymatic route
- Decentralised power generation through gasification of agro residues
- Thermal and photovoltaic application of solar energy for cold chain and other uses in rural sector

Farm Equipment Manufacturing and Supply Centres

Making the need-based farm equipment and services available is very critical to ensure that benefits of farm mechanization reach all categories of the farmers. This is proposed to be achieved in the following modes:

- Development of business models and entrepreneurship for custom hiring of crop and location-specific package of farm equipment
- Establishment of 4 farm equipment manufacturing and incubation centres in different parts of the country. These Centres will be established in areas where availability of farm tools and equipment is restricted due to various reasons. The centres will not only manufacture and trade farm equipment but will also train local artisans to undertake manufacturing activity.

Post-Harvest Technology and Value Addition

Post Harvest Technology and Value Addition can reverse this trend and add 2 to 3 fold value to the production agriculture. This is appropriate time to focus on Post-Harvest Technology and Value Addition and infrastructure facilities to empower the farming sector and community in India. The present infrastructure facilities for pursuing research and development programmes in the area of Post-Harvest Technology and Value Addition should be strengthened and following the thrust areas are identified for XII FYP:

Development of technology for reduction of post-harvest losses

- Handling and transportation systems for perishables fruits and vegetables (fruits, vegetables, livestock and aqua products)
- Cost-effective cool chain systems for perishables

- Novel techniques for storage of food grains and perishables (balloon storage for food grains, cold storage using solar energy, etc.)
- Advanced packaging technology for raw and processed products (smart/intelligent packaging, bulk MAP/CAP systems, etc.)

Development of health foods

- Formulation of ingredients for health foods (minor millets, pulses, fruits and vegetables); Fortified/formulated foods using extrusion and baking techniques; Processing machinery for health foods; Micro and nano encapsulation techniques; probiotic and symbiotic foods

Application of cutting edge technologies for high-end processing

- Non-thermal and non-chemical techniques (high pressure processing, pulse electric field, etc.)
- Ohmic heating technique
- Supercritical fluid extraction technique (for extraction of high value compounds, flavouring compounds, etc.)
- Cryogenic processing for grinding of spices and freezing of perishable foods
- Image processing for grading/sorting and quality evaluation

Processing of fibre and by-products

- Development of suitable machinery for extraction, cleaning and segregation of hard natural fibres
- Natural fibre-based technical textiles for agricultural and medical applications
- Development of natural fibre reinforced composites
- Processing and functional finishing of cotton and blended textiles using eco-friendly agents including nano materials and effluent treatment
- Use of plasma and supercritical carbon dioxide technologies for conservation of water and energy
- Bio-mechanical process for preparation of lignocellulose in nano-form for application as fillers in composites
- Development of Diversified Value Added Products from Jute and Allied Fibres and Agro Residue

7.7 Agricultural Extension

Recent advancements in science facilitate generation and flow of knowledge in several forms, namely technology, intermediate products, or information. This provides an opportunity for various kinds of interactions, partnerships and integration of research-extension and education activities. Partnership and networking in R&D, especially with the private sector, assumes prime importance in view of their growing presence in agri input and output markets, especially in high value commodities. Hence, dissemination of knowledge and technology to non-traditional clients like small and medium entrepreneurs (SMEs) and corporate sector, besides farmers, should also be given due attention by the ICAR. The new strategy should entail development of research consortia around value chain, sharing of resources for cost reduction, facilitate exchange of knowledge and experience, technology up-scaling and commercialization etc. ICAR could use these institutional arrangements for resource generation and integration of research efforts in the NARS.

The strategy to reduce costs and increase efficiency may also involve change in organization of various operations. The institutions may find it more economical to shift to outsourcing of non-core operations from in-sourcing, and to virtual integration from vertical integration. Partnership with the CGIAR and other international organizations, farmers and farmers' organizations, nongovernmental organizations need preparedness and further strengthening to harness research synergies and accelerate the rate of flow of technologies to farmers. In order to make these partnerships more effective and build "critical scientific mass" in frontier areas like biotechnology, innovative models of technical collaboration, coordination or co-partnership would be useful especially in area of commercialization of technologies.

Validation of ITKs and integration with technology recommendations

It is encouraging to note that Indian farmers have outclassed the best firms in tractor technology business in US. Farmers' varieties are being used as standard for measuring thinness by none other than PPVR&FRA. However, in want of venture fund in agriculture, many useful innovations fail to take off at a large scale. Therefore, there is a need to have provision of venture fund as well as risk capital for agriculture so that farmers could come forward for taking initiatives. Traditional food system has a vital role in health management, so emphasis of documentation and validation efforts should be broadened to include functional food and value addition. Stress should be laid upon testing and verification of ITKs at a large scale. What is important for revival of ITKs is not just their documentation and testing but add value to them for use on a wider scale. A special budget for ITK testing and verification experiments at research institutes and universities should be recommended. Creation of Technology Acquisition Fund is the need of the hour to facilitate making of public goods from farmers' innovations. It has been observed that due to lack of resources with small innovators, many a good innovations are not up-scaled and society is denied the desired benefits. A Technology Acquisition Fund will provide impetus to local innovations and their upscaling for benefits to a larger mass.

Outreach programme of SAUs/ICAR Institutes

Extension programmes have to be strengthened to address the present agrarian constraints and the challenge of food security. Innovative extension approaches and concerted efforts are required to arrest the problems of rising cost of cultivation, bridging farm level yield gaps; disseminate technological knowledge and impart skills; improve input use efficiency; conserve natural resource base; promote collective actions and encourage entrepreneurial orientation among farmers.

A Network Project in Extension Education may be started for giving a boost to research in the field of Extension, whereby innovative extension methodologies of reaching and empowering farmers could be developed. Participatory and ICT-based extension initiatives have to be analyzed and operational models have to be devised. Emphasis should also be laid upon regular and longitudinal studies on socio-economic constraints of small and marginal farmers and other action research studies on capacity building and entrepreneurship development. Farmer participatory approaches hold immense potential in development of appropriate technologies, fostering greater uptake and enhancing impact. The philosophy and principles of Farmers' First approaches need to be promoted in research organization. It is recommended that each scientist will get engaged in Farmers' First based research and extension activities.

The number of Agricultural Technology Information Centre (ATIC) as working in various SAUs and ICAR institutes need to be further increased to cover all the SAUs and institutes. The mandate of the ATIC should be broadened so that these could be used for providing specialized subject matter trainings to SMSs of State departments and KVKs and other NGOs.

Further, at least 10% of the budget of the SAUs/ICAR institutes may be spent on front line extension work. Besides the existing demonstration programmes, the Directorate may also take up extension works related to farmers scientist forums, farmers' clubs, mobile extension, media support, etc. SAUs' presence at the district level is very important. Special funds should be provided for organization at least two seasons based "TECHNOLOGY WEEK" fair every year at all SAUs and ICAR institutes. Programmes like "Krishi Mahotsava" should be promoted in all states during pre-Kharif and Pre-Rabi seasons.

Strengthening of KVKs

Keeping in view the increased quantum of work at the zonal level, it was felt that the number of ZPDs may be increased from eight to at least twelve. The ZPD units may also be further strengthened by increasing the number of scientists up to 12. There is a strong case for adding scientific manpower so that technology delivery gets impetus and proper feedback could be obtained, analyzed and used in research and technology development.

KVKs are the major players in strengthening out-reach programmes of the SAUs and institutes. However, they are overburdened with activities given to them as per their mandate. There is a need for improving the staff strength and other infrastructural facilities and working budget to make them more viable institutions. More KVKs should be established in difficult areas with scattered inhabitation pattern. Since there is a strong emphasis on secondary agriculture and livelihood, the KVKs may prepare themselves to provide training and demonstration support to the activities related to livelihood. The technologies that are cost – effective, less risky and can work with less resource may be demonstrated. KVKs may maintain database of KVK farmers. It was suggested that the existing staff- strength of KVK with 16 staff may be increased to 20 in order to accommodate more specialization. Inter-disciplinary approach may be promoted. Staff with specialization in agribusiness management and meteorology is required to carry out the tasks of market-led interventions and weather-based agro-advisory services.

Action research on development of small and marginal farmers

There is a need for development of a framework and operational methodology for ensuring family livelihood security of small and marginal farmers. A series of pilot projects are suggested in which small and marginal farmers families will be selected in adopted villages by the SAUs and institutes for undertaking intensive work involving study of basic resources, selection of appropriate technologies, introduction of integrated farming system, water management, climate resilience etc for family-centric livelihood security. Successful pragmatic models of extension suitable for small production system could be analyzed and promoted. Micro-production system based socio-economically viable models (for example one acre model etc.) could be standardized and promoted.

Integrated Farming Systems (IFS) model with proper back-up by scientific validation of technologies on socio – economic dimensions will be highly useful in strengthening livelihood security. Suitable guidelines on IFS may be developed by SAUs / ICAR institutes that could be used under local conditions. Efforts should also be made to introduce secondary agriculture including value addition, processing etc. to help families improve their livelihood security. This will be a science based programme in which scientists and extension workers will develop family based plans for each family and implement the same. This project will involve most of the specializations available in the SAUs and institutes and also give scientists opportunities to introduce suitable technologies for small and marginal farmers.

The research and extension system may develop appropriate technology testing methods so that more and more on-farm testing could be done on the fields of small and marginal farmers. While issuing recommendations it should specifically mentioned whether these have been tested on small and marginal farms and are suitable for adoption. Operational research projects could be initiated for location specific technology generation. The small and marginal farmers should be provided with combo-packages consisting of seeds of newly developed varieties and other critical inputs for fast dissemination of new varieties and technologies. It is proposed to establish commercial window in each SAUs and selected ICAR institutes with the purpose of providing technological services, commercialization of ideas and training programmes, sale of products, consultancies, etc.

Institutional linkages and technology commercialization

Besides forging new partnerships with public and private R&D institutions, joint PhD research need to be encouraged in the Industry, general university or other R&D institution by providing assistantship to students where the receiving institution is not able to provide support to the student. Scientists from ICAR Institutes located in the area of jurisdictions of a particular SAU could be involved in research and education programmes as SAUs are 40-50 per cent short of faculty strength. There are several successful people in private sector (agripreneurs, progressive farmers, producers etc.) with proven records, who could be used as resource persons. There should be a linkage between NARS and international institutes for skill development particularly on joint educational programmes, hands-on-training, vocational trainings, technology generation, evaluation and demonstration etc. International Centers for Faculty Development should be established at IARI, IVRI, NDRI, and CIFE in public-private partnership mode. Focusing the market driven demand, the research, industry and academia linkage should be developed under Public-Private Partnership. They may mutually support the research and education system and the private sector may sponsor faculty chairs in the SAUs.

Linkages with development departments

Gaps in research–extension linkage have been one of the major limiting factors to faster sustainable agricultural development and rural livelihood security. Dissemination and accessibility of quality information, partnership based action intervention, kind and intensity of linkages, monitoring of linkages and accountability among the research, extension and development partners, and methodology of convergence are the key areas of concern. Though innovative initiatives in form of Operational Project (ORP) and Institute Village linkage Programme (IVLP) have made notable contributions in bridging such gaps, novel mechanisms have to be defined and operationalized to ensure productive and accountable linkages.

Agricultural Technology Management Agency (ATMA) has provided a platform for confluence of various partners involved in extension and technology delivery. However, active participation, accountability and ownership of partners in programme formulation and implementation need improvement for better performance. Linkage with line department, NGOs and farmers groups needs to be strengthened.

Livestock extension:

There is a need to develop appropriate models of livestock extension systems emphasizing public-private partnership, cyber extension, and expert systems including regular updating of location-specific contents in different areas of animal husbandry and livestock products. Village Knowledge or Information Centres may be established and maintained by Panchayats with technology content support of NARS. Veterinary Colleges and Universities should be encouraged and financially supported to strengthen extension education facilities including degree programmes in Animal Husbandry Extension Education. Specialized livestock KVK's should be established in major regions of each state.

Technology commercialization

Commercialisation enhances the reach of academic results into new products and services for public and economic development of a country. The public-private partnerships in the NARS have traditionally been perceived as a major vehicle to enhance technology commercialization. The ICAR has tried to realize this objective through developing a system, both at the Institute-level and by initiating a middle -tier of five Zonal Technology Management & Business Planning and Development (ZTM&BPD) Units, which are also being ably supported by the Central Intellectual property and Technology Management Unit at ICAR Hqrs. Business Planning and Development Units have also been supported in five State Agricultural Universities. The Government has approved the proposal of Department of Agricultural Research & Education (DARE) for setting up of a new company, called AGRINDIA. The AGRINDIA will be a registered company under the Companies Act, fully owned by Government of India in the Department of Agricultural Research and Education (DARE) with a share capital of Rs.100 crore and initial paid up capital of Rs.50 crore. AGRINDIA would promote spread of R&D outcomes through IPR protection, commercialization and forging partnerships both in the country and outside.

7.8 Agricultural Education

The country can be proud that we have developed extensive higher agricultural education system for meeting the new challenges of agriculture. However, the stark reality is that presently the state agricultural universities are not adequately funded. Presently, all universities without exceptions have serious faculty shortage. The present faculty strength varies from 50-60 % of the sanctioned strength in most universities. Many universities are not allowed to fill up the faculty positions falling vacant due to retirement. Even this is true of the scientific positions for which ICAR provides 75-100% support. Under this milieu, the casualty is the quality of the human resource developed and also decreased capacity for development of research and technology for different agro-eco systems. Drastic measures are needed to have assured financial support for the growth of agricultural universities. Universities need to be further insulated from the erosion of their autonomy.

Deemed universities of ICAR over the years have also witnessed serious shortfall in the cadre strength and actual faculty positions. During 80-90, IARI had a cadre strength of over 700. As against this present faculty strength in IARI is around 400. This is even when Oversight Committee's recommendations have been implemented so far as admission of OBC students is concerned, but without increase in faculty strength and financial resources. IARI, IVRI, NDRI and CIFE's contributions towards human resource development have been enormous and these institutions need to be supported much more than being done at present.

Need for integrating agricultural education with entrepreneurship and job creation:

Currently, almost every graduate looks for a white-collar job preferably in public sector. With government resolve to phase out non-performing assets, job opportunities in government sector are shrinking faster than the number of graduates coming out of SAUs and other institutions. Currently, 43% of the graduates and 23% of postgraduates (M.Sc.) find difficulty in accessing gainful employment. Hence, in order to ward off rising unemployment because of excessive dependence on public sector jobs, there is need to develop graduates/postgraduates who create their own enterprise and provide work to others also. In this pursuit, futuristic Agricultural Education will need to build entrepreneurial skills and enriched with real life subjects and their delivery through project work rather than through mere classroom lecture alone. Presently, there is too much emphasis on theory and routine subjects much divorced from market needs and experiential learning.

Price tag on S&T output:

With greater inflow of funds for S&T from the private sector and non-public institutions, the output is likely to bear a price tag. Besides, advice/consultancy on new innovations will not be available for free. Government of India Scheme on setting up of privately owned Agri-clinics and Agri-business Centers across the length and breadth of the country is a step towards paid extension. With that perspective, graduates who come out of universities will be required to be professionals cum technology agents and not mere degree holders. A radical change in the existing course curricula by infusing more management related courses and practice sessions to apply the knowledge thus acquired would become necessary to churn out professional service providers.

Demand-driven research and education: Along with sustainable development, agricultural education will need to be harmonized with existing and emerging issues related to WTO and free market economies. Worldwide, agriculture will become competitive price-wise and its produce acceptable quality-wise. Price and brand equity will become more prominent than before. Indian agriculture will be no exception and its objectives will have to align with stakeholders' needs, clients' perspective, peer concerns and market vibes. Greater infusion of frontier science subjects (biotechnology and information and communication technology), legal aspects, good practices of trade, ethics of IPR and GMO, market intelligence and modern information and communication techniques will become more important to promote efficiency, awareness, equity, and competitiveness in agriculture. In pursuance of that, development and institutionalization of easily accessible and user-friendly knowledge systems to support decision making by various client groups will become necessary.

SAUs are also expected to cater to research needs of the state and therefore research agenda should be arrived through wider consultation with the stakeholders. The mechanisms are already in place for consultations, especially with state agencies, but these need to be made for effective for the agencies of the central government like ICAR institutes, DAC, DBT, CSIR, and private organizations. At state-level, stronger linkages with the Departments of horticulture, animal husbandry, soil and water conservation and fisheries should be maintained.

Lack of adequate resources with educational institutions:

Presently, most of the SAUs are facing financial crises. New universities and colleges are opened in total disregard of the faculty strength, infrastructure and financial needs. This has seriously affecting quality education. Presently the support provided by state governments meets largely the establishment cost with practically no support for repair, renovation, modernisation and curriculum delivery. Many of the buildings in old SAUs are in a dilapidated condition. These need substantial support for renovation and modernization. The same is true for equipments. *There need to be a stop to bifurcation of existing universities and creation of new institutions without adequate financial, faculty and infrastructure support.* New institutions should receive developmental support only after due process of accreditation, and fulfilling minimum norms and standards as specified by the Accreditation Board. This will prevent further proliferation of institutions and universities to a large extent.

Faculty recruitment:

Quality of education in most of the agricultural universities is adversely affected due to shortage and competence of teaching faculty. Lifting the ban on recruitment of teachers and allowing universities to select competitive faculty is the dire necessity which need to be addressed urgently. Also, as discussed in the recently held Conference of Vice Chancellors of agricultural universities, selection of the faculty at the national level to the extent of at least 25% would go a long way in reducing inbreeding and enhancing faculty competence.

End-to-End approach:

Farm graduates need be empowered to link production and post harvest technologies in a mutually reinforcing manner. For this, the agricultural universities should set up Agricultural Technology Parks. These parks could promote technology incubation and dissemination. They will also establish economic viability of new technologies. Such parks linked to appropriate public and private sector enterprises from the point of view of marketing arrangements to enhance self-confidence of farm graduates and stimulate them to take a career of self-employment.

Uniformity in governance and structure of agricultural universities:

In order to achieve uniformity in structure and functioning of the universities for enhanced efficiency and inter-institutional acceptability, it is desired that all SAUs may adopt the Model Act for Agricultural Universities in India (2009) developed by the ICAR in consultation with all Vice Chancellors of the AUs. Adherence to the provisions of the Act related to uniform tenure and retirement age of Vice Chancellors of all AUs; selection and tenure of university officers; constitution, powers and functions of the statutory bodies; integration of education, research and extension, and coordination committee at State level deserve consideration.

Enhanced collaboration between the AUs and ICAR institutes:

The present era of plurality and breadth calls for collaboration and partnership. Many ICAR institutes have well-qualified scientific staff who can serve as faculty, deliver lectures, guide/co-guide for thesis work of PG students etc. AU need to encourage this particularly by formally recognizing the scientists of the ICAR institutes as faculty members. The laboratory and farm facilities of both the ICAR Units and the AUs should be mutually utilized for research particularly through collaborative projects.

Non-formal education and vocational training:

The AU's need to introduce non-formal education and vocational training for the farmers and rural youth for enhancing the off-farm employment opportunities and income. Presently, AUs are concentrating on formal education; they need to move to non-formal education by organizing need based diploma and certificate courses. There is also need to have strong distance education programme for technological empowerment of the practitioner of agriculture. Capacity building of the faculty for e-content development need to receive high priority.

8. Funding, Organization and Management

8.1 Research Funding

The national level R&D expenditure is a good indicator of technological capabilities of the national innovation system. India's agricultural R&D landscape is being led by the government rather than private enterprises in contrast to many developed and few developing countries like Brazil. The government expenditure on agricultural research and education (both Union and all State Govts) have continued to move upward to Rs 6343 crores in 2009-10. Agricultural research intensity—the share of agricultural research and education expenditures in Ag GDP is 0.58 per cent in 2009, showing a moderate improvement from 0.45 per cent in the early nineties. The agricultural research spending grew with an impressive rate of 6 per cent during the eighties, slowed down to 3 per cent since the nineties, which is a serious concern in view of increasingly capital intensive nature of agricultural R&D. Hence, relatively lower R &D intensity ratios as compared to other developed (2.35) and developing countries like Brazil (1.04) coupled with slowing down in growth of the funding may pose serious challenges as there is a substantial gestation period between investment in technology generation and adoption. Secondly, the figure has also concealed large differences in resource allocation across commodity/resource groups and regions of the country. Commodity orientation of research resources still shows towards crop husbandry. This needs reorientation of research priorities in view of growing diversification of research agenda. State-wise research intensity indicators show a higher intensity in the hilly and the southern states as compared to the eastern and north-eastern states. Apart from the north eastern states, the three poverty- stricken agrarian states, namely Uttar Pradesh, Orissa and West Bengal spend the lowest on agri-research depicting that these states continue to rely on classic role of research supply from the national institutes or struggling still with the traditional agricultural systems. Therefore, the case to enhance public investments in agricultural research and education to the level of one percent of AgGDP gains strength on these grounds. This amounts to a total budgetary allocation of Rs 65,000 crores for XII plan as against the current expenditure of just half of the above said funds. Since ICAR envisions itself as a lead national organization with a global face in agricultural research and education, it should align all its activities and resources in the desired direction.

Public investment in agricultural research and education should be increased to one percent of AgGDP. This amounts to Rs 65,000/- crore expenditure annually. The Group however recommends an allocation of Rs 55,000/- crore for ICAR in XII Plan, which should be made available to catch up with other countries and address the research challenges. Also, an increasing share of SAU funding should be channeled through ICAR which directly transfers funds to SAUs with a provision of additional Rs 10,000/- crore for over sixty SAUs which hardly works out to Rs 30 plus crore per annum per SAU.

The Vice-Chancellors of SAUs expressed the desire to *provide a separate budget line in the state budget for SAUs* which are in very bad shape, poor financial health and dwindling faculty strength. Most of the SAUs are operating with less than 50% of the sanctioned faculty strength and therefore they should be allowed to fill vacant positions on priority basis. For financial viability, Planning Commission should provide 10-15% of agricultural budget of the states to SAUs directly. Also, an increasing share of SAUs budget should be channeled through ICAR for direct availability to SAUs. In order to strengthen infrastructural facilities in SAUs, one time catch-up grant of Rs 100 crore should be provided to SAUs. Subsequently, Rs 25 crore must flow to SAUs annually through ICAR.

The competitive research funding has been upscaled under the externally-funded projects, viz. National Agricultural Innovation Project in the XI Five Year Plan substantially. It is suggested that in view of the abolition of the AP Cess Fund, there is an increasing need for allocating nearly Rs 1000/- crore of ICAR Plan funds for competitive funding in order to reinforce the solutions of ever increasing research challenges. This funding should be open to public agricultural R&D organizations and provide support for contractual services including manpower, operating expenses and essential equipments. The funding should be managed by ICAR and proposals could be invited and evaluated by respective SMDs with the help of a specially constituted expert group. The activities and progress of the fund should be reviewed by ICAR periodically.

8.2 Organization and Management

NARS institutions should be more innovative in mobilizing resources, availing matching grant and efficiently utilizing resources thus generated. Apart from the absolute level of financial resources, there has also been growing concerns about the efficiency with which resources are being utilized. Imbalances in functional allocation (salary, capital, operational), duplication in programmes and procedural rigidities, etc. identified as the weaknesses of the public system, and these demand necessary reforms. Striking an effective balance in these aspects would bring the much needed efficiency in the agricultural innovation system. An institutionalization of research prioritization will rationalize resource allocation among types of research (basic and strategic, applied, and adaptive), extension and education. A correction in this regards has already been made to strengthen basic and strategic research by establishing the special fund, the issue of capacity building by allocating more resources to HRD should also be addressed on similar lines.

ICAR is a lead national organization with a global face in agricultural research and education. It should *align all its activities and resources to become a truly global thought leader in cutting-edge agricultural research and innovations*. ICAR should also envision a much greater role for itself in international agricultural research. It should in particular strengthen linkages with the NARS in Africa and Asia through appropriate mechanism, besides continuing partnership with the CGIAR system.

NARS should increasingly focus on research coordination, networking and partnership to increase efficiency and effectiveness of agricultural research. NARS should foster these institutional mechanisms, especially partnership with private sector in new IPR regime, and strengthen linkages between research, extension and farmers.

ICAR should develop some of its *institutions as centres of excellence in cutting-edges science which should emerge as global leaders in their respective fields*. These centres should have direct linkages with applied research programmes on the one hand, and on the other, these should attract foreign students and scientist for higher education and training. In order to encourage students from Asia and Africa, the option of offering fellowships should also be explored.

Integration of research, education and frontline extension is essential for creation, dissemination and application of new knowledge—the main source of agricultural growth in future. Science and technology institutions should effectively convert new knowledge into a usable technology and then transfer it to the clients. Farm women form a large part of end-users or clients of agricultural research and extension services. There has been noticeable increase in women participation rates in agriculture related activities in the country especially in recent years because of emerging economic opportunities and out-migration of male labor force. Also, some sectors of agriculture like livestock are largely being managed by women. Therefore, R&D system should cater to technological needs of these farm women. There are ample evidences that women and children have been directly benefited from adoption of modern technology. So far, there has been ad-hoc attempts to mainstream gender issues in agricultural research. The focus now should be towards institutionalization of gender concerns at various stages of research planning and management. Besides, gender related course-curricula, enhancing their skills and representation in agri-research and decision making should adequately be emphasized. The Council should assume a leadership in developing such capacities in partnership with other public research systems.

There is also need to strengthen decision-support system which facilitates informed decision making and hence, accelerates the speed of response to strategic matters such as research resources, programs, research outputs etc. This database should be supplemented with an information system of recent developments in the areas like world markets, patents and protected plant varieties, technological alliances etc which directly impact research. Developments in information communication technology have created tremendous opportunities for online data management system and exchange of information. Necessary infrastructure to avail these opportunities is in place which now should more productively be used for day-today management functions for better efficiency.

New Institutions

Finally, the following new institutional changes are suggested by different sub-groups for focused research programs. Creation of these institutions have will have larger financial and manpower requirements. These suggestions may be looked by ICAR in view of final allocations made by the Planning Commission and scientific manpower currently available.

1. Establishment of AGRINDIA
2. New Central Agricultural University
3. Crop Health Management Division of ICAR
4. National Institute for Biotic Stress Management
5. National Research Centre on Agricultural Virology
6. Project Directorate on Pearl Millet
7. Project Directorate on Companion Animals
8. National Research Centre on Traditional Indian Dairy Foods
9. Up-gradation of Project Directorate on Animal Disease Monitoring and Surveillance to Indian Institute of Veterinary Epidemiology & Disease Informatics
10. National Research Centre on Animal Production Biotechnology at NDRI
11. National Research Centre on Animal Health Biotechnology at IVRI
12. National Genome Sequencing Facility
13. Institute for Post-Harvest Management of Perishables
14. Institute for Horticulture in Tribal Areas
15. National Centre for Public Leadership
16. National Institute of Agriculture Food Technology
17. Creation of Quality testing & referral labs, and centres of manufacturing and maintenance of farm machinery under CIAE
18. Review of AICRP under NRM and up-gradation of ICAR-RC Goa for the Western Region.
19. Merger of CARI and Project Directorate on Poultry
20. Closure of AICRP on Improvement of feed resources for raising animal production
21. Closure of AICRP on Poultry breeding for egg and meat, AICRP on Pigs and Network on HS

9. Examples of Inter-Departmental Platforms

A number of Inter-Departmental Platforms in high priority areas are suggested in the report to accelerate the pace of agricultural transformation through application of science and technologies. These Platforms should pool expertise within and outside NARS (CSIR, DBT, DST, general universities and international agricultural organizations like CGIAR, FAO, private foundations, international universities in the US, Europe and Australia). Research partnership with other economies in transition like China, Brazil, Russia, South Africa, etc will help address the common research challenges and make agriculture more competitive globally. Research objectives, activity milestones and expected outputs and outcomes should be worked out by ICAR and other implementing agencies for each platform. The list of potential research platforms and details of two of them are given below.

Genomics, seed, dryland agriculture, GM food, health foods, climate change, nanotechnology, conservation agriculture, water, feed, fodder and fibre, diagnostics and vaccines, farm mechanization, protected cultivation, precision farming, energy, and high value compounds.

Example 1. Genomics

India has been experiencing the impact of the continued research efforts on improving agricultural production systems by the scientists in the national agricultural research system (NARS) that is being efficiently guided by the ICAR following a multipronged approach that has enabled it to nearly stabilize sustainable levels of food production, despite the negative impacts of changing climate. Focused research on genomics science that detected molecular tools such as markers linked to specific genes and genetic polymorphism has led to the detection, development and adoption of technologies for productivity improvement, both in irrigated and rainfed production system in wheat and rice over the last five years. This has empowered the farming community to face the failure and fury of monsoons or other natural calamities and assure the policy makers with multiple options to drive production targets eco-zone wise in India. The evidence is in the form of technological adoption by the farming community that enabled India to realize over 240 million tons during the 2010-11 season from about 218 million tons in 2009. Pro-active steps by national and local governments in scaling up the technological options of research results enabled achieving of record production in wheat, higher production in maize, oilseeds and pulses over the previous few years which together led to the recovery.

Direct evidence of the impact of genomics in India:

Rice

- **Pyramiding of bacterial blight genes**: Combinations of bacteriral blight resistance genes xa5, xa-13 and Xa-21 have been pyramided in Pusa Basmati-1 and Samba Masuri through back-cross breeding program that saved the crop of huge losses during 2009, 2010 and 2011 seasons preventing a loss of 8-10 million tons each year. The parental lines of the hybrid Pusa RH 10, Pusa 6A and PRR 78 are being convted into BLB resistant lines by transferring genes ***xa13*** and ***Xa21*** respectively.
- **Pyramiding of genes for resistance to bacterial blight and blast diseases in rice:** For the first time, as many as seven genes for blast resistance namely, ***Pi-Kh, Piz-5, Pi-1, Pi-5, Pi-b, Pi-ta*** **and** ***Pi-9*** are being mobilized into rice varieties and hybrids which will ensure no losses in rice due to these two predominant biotic stresses.
- **Molecular Mapping of Fertility restorer gene (*Rf*) in PRR 78 and a procedure for testing the genetic purity of the hybrids using the molecular markers:** To avoid the use of grow-out test (GOT) for testing the genetic purity of hybrid seed (which requires one full season), a strategy based on the *Rf*-gene linked markers was developed for testing the genetic purity of the hybrid seed lot of rice hybrids and found to be efficient in assuring quality seed to farmers.

Wheat

- **Leaf rust resistance genes mapped and tagged:** A unique distinction of being the single research team that has tagged and mapped most genes for disease resistance trait has been achieved by ICAR which has put Indian wheat genomics group of breeders at par with the best in the world with the tagging and mapping of six leaf rust resistance genes (Lr genes) such as Lr9, Lr19, Lr24, Lr25, Lr28, Lr32 and Lr48 (Figure 1)

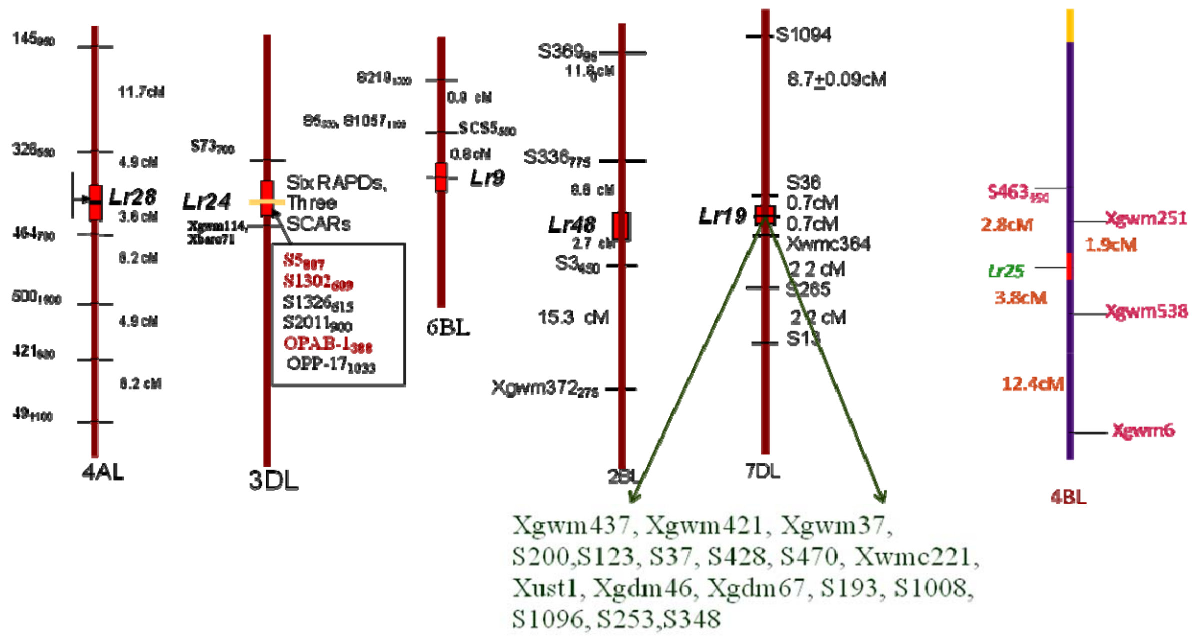

Fig. 1. Mapping leaf rust resistance genes *Lr24, Lr28, Lr9, Lr48, Lr19* and *Lr25* in wheat

- **Pyramiding genes for brown, yellow and black rust resistance:** India has achieved one of the best track records of utilizing molecular markers in breeding varieties resistant to all the three rusts through a network programme involving both Indian and international platforms for the purposes, on a competitive basis. Genes ***Lr24, Lr28, Lr9, Lr48 and Lr19*** have been mobilized for leaf rust resistance in combinations. In the case of stripe rust, genes Yr10 and Yr15 have been pyramided into eight varieties to combat yellow rust pathotypes virulent on Yr9 gene
- Another direct example of being technically prepared to face constraints is the manner in which India can stand tall to claim that there will be no impact of the globally dreaded stem rust disease of wheat **Ug99** when it eventually reaches India in near future. Genes for resistance to stem rust such as Sr24, Sr25, Sr26 and Sr27 have been mobilized in combinations into 12 popular Indian wheat varieties at the Wellington station of IARI.
- **Alien genomic introgression to transfer disease resistance:** Cytologically stable genotypes conferring resistance to either leaf, stripe and stem rusts from the backcrossed derivatives from *Aegilops markgrafii* (2n=2x=14, genome CC) and *Aegilops speltoides* (2n=2x=14, genome SS) crosses have been identified. Stable lines exhibiting seedling resistance to pathotype 117-6 of stem rust have been identified from the crosses PBW34 x PBW343, HI x PBW343. The effective gene *Yr*15 originating from *T. dicoccoides* G25 was incorporated through backcrossing into popular wheat cultivar HD2329 and an advanced wheat genotypes.
- Subsequent to the introduction of Bt cotton in India in 2002 a spectacular revolution occurred in cotton production. The area under Bt cotton increased from 29,307 hectares in 2002 to an estimated 9.5 Mha hectares in 2009. Bt cotton covered an area of 95 per cent of total cotton with more than 5 million farmers growing genetically engineered cotton. India produced 34 million bales of cotton in 2010-11 and occupied second position in global cotton production after China.

Potential of Genomics :

The science of biotechnology led advancements have been effectively utilized in mobilizing specific genes into agronomically superior varieties. However, these should not become flash in the pan and a one-time achievement. These examples need to be consolidated by extensive information generation on focused crops whose impacts can be dramatic for Indian agricultural revival for decades to come taking on priority crops like rice, wheat, pigeonpea and Indian mustard. The challenges being overcoming productivity stagnation in productive zones, impact of climate change related stresses, reduced availability of water and nutrients in the soil, increasing pest and diseases load.

Genomics science gives an analytial power to plant breeders who adopt biotechnological tools for accelerated and precise breeding programs to prioritize and schedule product development goals, trait-wise in each crop specifically for identified challenge zones in the country. Use of genomics sciences involves structural genomic information of a crop species, functional analyses of the genes for their specific functions and traits and solving a problem of a suffering crop by genetic transformation using genes from another species or organism.

The Genomics status and what can be achieved over a 5-10 years period

Rice: The 438 MB genome has been sequenced and resequenced with India having participated in the process. Some of the gains of utilizing the annotated and validated 14,000 of the about 55000 annotated loci over 31.232 genes have led to tagging these genes, assessing their functional variations (alleles) to be mobilized into different varieties. Successes have already been commercialized by IARI and DRR in high yielding disease resistant varieties. Lot more has to be achieved to use the other under explored genomic regions.

Wheat: 16,000 MB genome is too complex with three genomes A, B and D. A draft sequence has been scripted using NGS systems by Liverpool University while Indian initiative has begun in a small scale involving ICAR, Delhi University and PAU. Large number of genome specific markers have been identified and mapped with IARI, PAU, NCL, CCS Meerut University, DWR, NRCPB, etc. Need to be now integrated with intense genomic analyses, genome wise and then targeted to agronomic suitability.

Pigeon pea: 804-858 MB genome has just been sequenced separately by ICAR and ICRISAT. A crop with wide genomic diversity has now to be made farm-system friendly with suitability in the rice-wheat cropping system as an alternate option and replacement of rice in low production zones of rice. There is very low genetic variability which can only be enhanced in a programmed manner by integrating genomic analyses using the sequence information. The scope is tremendous for generating transgenic pigeon pea using the same genes as has been done in cotton successfully in India for resistance to pod borer.

Indian Mustard: 1024-1200 MB sized *Brassica juncea* genome is yet not deciphered. A complex genome again like wheat with two genomes A and B coming from two species, one of which Brassica rapa has been sequenced by Canadian initiative, representing A genome. A versatile crop that has tremendous adaptation ranging from 90 days to 150 days maturity period with least water requirement, ideally suited for rainfed agriculture through out the country. Its pungency elements from erucic acid and glucosinotate components need to be negated by genomics based options to make the oil acceptable to all. Has the potential to dramatically change oilseed production scenario in the country. IS ONLY INDIAN priority. Canada, Russia and China grow *B. napus*.

Why a platform is required and its scope:

There is sufficient expertise available in India on plant breeding and genetics areas within the NARS. Several centres have proven their internationally acclaimed expertise in genomics such as IARI, DRR, DWR, in molecular marker technology, NRCPB in structural and functional genomics including transgenic crops (GM crops). The pulse crop pigeon pea has now an Indian predominance by having sequenced the whole genome in a totally national investment by ICAR during 2011. There are several NARS centres such as TNAU, UAS-Bangalore, UAS-Dharwad, PAU, GBPUA & T., who have joined the team in a national effort to use genomics in applied crop improvement in rice, wheat and pigeonpea. Bolstered these national gains, international initiatives of ICRISAT, ICARDA, IRRI, CIMMYT, etc. have provided logistic and genomic tools support in many instances.

The need for a critical mass: The platform would be the ground for converting the merely "**exposed trained hands**" into "**experts**". The critical mass to keep the gains sustained and advanced in a fast-developing scientific area is sorely missing crop-wise, trait-wise and operation-wise in India with sporadic gains coming from mission-mode and focused grant-in-aid programmes. This needs to be converted into a system that generates and triggers consolidation of talent available within the country with the technological skills elsewhere, some times nationally in institutions of CSIR and internationally. A platform has to be created to pool the functional arms without spreading the resources thinly and provide a continued working avenue unhindered gainfully promoting creative talent to build into strong teams firmly rooted within the NARS, steered by ICAR. The platform would be effectively utilized in turning already "**exposed**"capacitated scientific work force to the status of "**experts**" with consultative and short-time skill development programmes in all key areas individually with the involvement of national and international experts.

With targeted and firm support on a medium to long-term basis, these gains can be consolidated to provide the country with huge benefits to march towards achieving the production goals of 2050 and beyond. As a starter, a multi-institutional platform to be steered by the ICAR needs to be established on four major crops, two cereals rice and wheat, a pulse crop pigeonpea and an oilseed Indian mustard.

What will the Genomics Platform Do?

The genomics platform initiatives can enable the crops to

- Overcome productivity barriers in wheat and rice to together produce 250 million tons by 2050 (A definite possibility by aggregating quantitative trait loci (QTLs) that influence yield traits which are now mapped to specific regions on the rice and wheat genomes)
- Identify genome-wide selection (GWS) based options for integrating different genomic regions and alleles in the targeted crops for improving quantitative traits like those which provide adaptation to abiotic stresses, accumulate yield contributing traits, etc.

- Breed pigeon pea for a 120 days maturity duration with a 3-4 tons/ha productivity having a crop architecture of compact and cereal-like agronomic features amenable to mechanical harvesting.
- Breed Indian mustard, one of the best suited hardy crops of India to face climate challenges to tolerate high temperatures during both planting and grain filling stages
- Breed hybrid rice, wheat, pigeon pea and Indian mustard by quick time assessment for planned heterotic pools generation and accelerated genetic conversion for parental suitability in hybrid seed production of heterotic cross products.
- Extend the "canola quality" in Indian mustard to make the crop suitable for acceptability by consumers of southern and western India thereby tremendously improving the potential of oil production by getting into non-traditional areas with low productivity during winter seasons of Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu (e.g., Gujarat in Indian mustard and rice in Punjab).
- Impart drought tolerance in rice and wheat by making these mega crops adopt to low water and low nutrition by improving water and nutrient use efficiency (WUE & NUE), durable resistance to biotic stresses under increased temperature conditions.
- Develop pest tolerance in Indian mustard (Aphid), Pigeon pea (Pod borer) and rice (brown plant hopper) through transgenic approaches.
- Identification and mapping of several novel genes and genetic factors such as transcription factors to pyramid as well as over-express by appropriate genetic modification followed by transformation.

Example 2. Diagnostics and vaccine

Rationale: Livestock and poultry sectors play an important role in the national economy and in the socio-economic development of the country. These sectors have a vital role in supplementing family incomes and generating gainful employment in the rural sector, particularly, among the landless labourers, small and marginal farmers and women, besides providing cheap nutritional food to millions of people. However, the economic losses in these sectors incurred due to devastating diseases of animals need to be minimized. The Office of international Epizootics (OIE) lists about 70 diseases of food animals of global or regional significance (http://www.oie.int/Eng/maladies/en _classification.htm). In India, around 35 animal diseases are reported to cause outbreaks and mortality (Annual report 2010-11, Department of Animal Husbandry and Dairying, Ministry of Agriculture).

Several efforts have been put forth by Government and Private sectors to control important diseases of the livestock and poultry; however, the infectious diseases still continue to pose major threat to animal production programme causing substantial economic losses. Therefore, prevention of important livestock and poultry diseases is of utmost importance and thereby provides a greatest challenge to all the researchers and professionals working in this field. One probable way of controlling these diseases is through prompt diagnosis and successful vaccination. Indeed, it has been stated that early detection of infected cases along with timely vaccination is the most cost-effective methods of reducing animal suffering and economic losses due to infectious diseases in livestock and poultry. Currently there is a short-fall in the availability of vaccines against important livestock diseases such as FMD, PPR, swine fever, brucellosis etc. The annual requirement of these vaccines is estimated to the tune of 150 million doses for PPR, 10 million doses for CSF and 600 million doses for FMD. As per the current scenario, conventional vaccines (whole killed or attenuated) and diagnostic assays (cultural or serological based) are being used against most of the important disease of livestock and poultry in the country, but they have one or another drawback(s). Professionals also find difficulty in differentiating clinically infected cases from vaccinated animals. Therefore, considering the limitations of currently available vaccines and diagnostic tests, the need of the hour demands for development of newer generation diagnostic tests which are rapid and reliable and also vaccines which are safe, economical, have better protection efficacy with immunity for longer period of time and can be differentiated from natural infections.

Trans-boundary animal diseases pose great challenge to the livestock wealth of the country. The recent emergence and re-emergence of many infectious diseases appear to be driven largely by globalization and ecological disruption. There are several exotic diseases such as Porcine Reproductive and Respiratory Syndrome which are present in the neighboring countries of India. We need to have a constant surveillance to prevent the entry of any exotic/ emerging diseases. Also, there is a lack of commercially available ready-to-use diagnostics for many of the exotic/emerging/re-emerging pathogens. This capacity needs to be urgently developed in the country so that it would help in reporting the disease status, which will assist in decision making and policies framing.

Neoplasms and non-infectious diseases of the livestock and poultry also cause significant economic loss to the farming industry. Hence it is important to properly diagnose these diseases which will help in prompt implementation of therapeutic and control measures. To achieve this, development of biomarkers-based diagnostics is need of the hour.

In recent years, viruses have emerged as important causes of foodborne diseases. However, due to lack of availability of analytical and diagnostic tools, they are rarely diagnosed and remain under reported. Virus detection in food present challenges to food-safety managers as they are not usually uniformly distributed in the foods and are present in low numbers. With increase in global food safety concerns and SPS issues in global food trade, rapid and reliable diagnostic assays for foodborne pathogens is of utmost importance.

The recent developments in the area of genomics and proteomics combined with better understanding of pathogenesis and immune responses to various pathogens has provided us with an unprecedented opportunity to develop newer generation diagnostic tests and effective genetically engineered vaccines such as marker vaccine, live attenuated vaccines, live chimeric vaccines, live replication-defective vaccines, subunit vaccines, peptide vaccines in various modifications of monovalent, multivalent, or chimeric subunit vaccines delivered as individual components or incorporated into virus-like particles for improved immunogenecity and polynucleotide vaccines.

Critical Gaps for Diagnostic test:

1. Most of the diagnostic tests that currently been used for diagnosis of livestock or poultry disease are either conventional cultural method or serological tests which are often time consuming, laborious, costly and often are cross reacting.
2. Majority of serological based diagnostic tests that are currently been used fails to discriminate vaccinated and clinically infected cases.

Critical Gaps for Vaccine:

1. Some of the conventional vaccines are lacking either in their protection efficacy or the amount and duration of immunity they impart after vaccination.
2. Most of the currently used vaccines require cold chain maintenance for effective vaccination and do not have long storage shelf life.
3. Lack of DIVA based diagnostics for currently used vaccines.

***Need for diagnostic test*:**

1. There is a need to develop newer generation diagnostic tests which are rapid and reliable, besides being highly sensitive and specific and demands for minimum laboratory facilities and technical expertise.
2. To differentiate vaccinated and infected animals, there is an urgent need to develop newer diagnostic platforms with novel antigens using DIVA strategy.

For development of newer generation diagnostic kits with DIVA capability a programme is being conceived with the following principles:

- To develop rapid and reliable newer generation diagnostic tests with DIVA capability for its use under field conditions or in regional laboratories to support clinical suspicions of diseases.
- The test developed should be sensitive enough to detect animals as soon as possible after they become infected.
- The test developed should also be highly specific, which can detect infection in an individual vaccinated animal without the need for screening whole herds.

Need of Vaccine Development:

The need of the hour is to have vaccines which are;

1. Safe and could confer broader immunity against various species or serovars of the same Genus.
2. Have better protection efficiency.
3. Can impart immunity for longer duration of time.
4. Must have better shelf life, easy to store and use under field conditions.
5. Should be economical and above all should be able to differentiate serologically vaccinated as well as clinically affected cases.

For development of genetically engineered vaccines a programme is being conceived with the following principles:

- To develop genetically engineered safe vaccines for some of the important diseases of livestock and poultry.
- The developed genetically engineered vaccines should be cost effective with better protection efficiency and ability to generate immunity for longer period of time.
- The developed genetically engineered vaccines should be able to differentiate serologically vaccinated as well as clinical affected cases.
- The developed genetically engineered vaccines should have a better shelf life and should be easy to use and store under field conditions.

Critical gaps for biomarkers for cancers and non-infectious diseases

- Non-availability of assays for quick and early stage detection of cancers and non-infectious diseases in livestock and poultry.

Need for biomarkers for cancers and non-infectious diseases

- Quick, early and accurate diagnosis of important non infectious disorders in animals using biomarkers and their assessment for prognostic value and facilitation of the early treatment
- Effective tumour markers, which have the potential to reduce cancer mortality rates by facilitating diagnosis of cancers at early stages and by helping to individualize treatments.

Objectives:

1. Development of newer generation diagnostic kits with DIVA capability, for the detection of important animal and poultry pathogens as well as foodborne pathogens.
2. Development of diagnostic biomarkers for cancers and non-infectious diseases of livestock and poultry.
3. Development of genetically engineered vaccines having better protection efficacy , longer duration immunity, longer shelf life, and DIVA capability for control of important bacterial, viral and parasitic diseases of animals and poultry origin.

Brief Technical Program for Diagnostic tests development:

- Whole/partial genome sequencing of target organism and characterization of ORFs.
- In-silico analysis of antigenic epitopes and identification of novel antigens.
- Cloning and characterization of antigenic protein coding genes.
- Expression of the immunogenic protein and production of recombinant antigens.
- Purification of the expressed proteins, micro-sequencing of protein, 3-D structure analysis
- Preparation of synthetic peptides to locate major epitopes within the identified protein.
- Development of appropriate diagnostic test by use of peptide epitopes/recombinant proteins in diagnostic platform viz : immunobiosensors/ nanoparticles/ microsphere and latex beads/ immunochromatography/ immunocombs based assay for the detection of pathogens.
- Screening of field samples by developed diagnostic tests
- Validation and commercialization of diagnostic kits developed.

Brief Technical Program for development of diagnostic biomarkers for cancer and non-infectious diseases:

- Collection of data on clinical cases of these disorders w.r.t. their occurrence, age, sex, breed in different agro-climatic zones
- Identification and evaluation of the various diagnostic markers
- Collection of samples from clinical cases and evaluation and validation of the diagnostic assays for diagnosis and prognosis.

Brief Technical Program for Vaccine studies:

- Development of genetically engineered vaccines for the targeted diseases.
- Whole genome sequencing (if required)
- Identification of candidate immunogen/antigen through genomics, proteomics and DNA approaches.

- Cloning, sequencing and expression of candidate antigen/immunogen.
- Production and purification of recombinant antigen
- Evaluation of r-DNA based candidate vaccine.
- Testing of developed genetically engineered immunogens/ candidate vaccines for their protective efficacy with immunological studies such as humoral response, cell mediated immune response, challenge studies and duration of immunity it imparts in appropriate laboratory animal models.
- Developed genetically engineered vaccines found effective above studies will be further tested for safety, clinical toxicity studies in the naturally susceptible hosts and shelf life studies, accordingly refinement/ moderation would be done.
- Testing of safe and protective vaccines for desirable parameters at large scale
- Validation and commercialization of developed vaccines.

Outcome

The current programme is expected to deliver

- Newer generation diagnostics tests with DIVA capacity for detection of bacterial, viral, parasitic and exotic diseases of animal and poultry.
- Genetically engineered vaccines with improved efficacy for important existing and emerging livestock and poultry diseases
- Diagnostic biomarkers for cancers and non-infectious diseases
- Diagnostic capabilities for foodborne pathogens

Annexure I: List of ICAR institutes and State Agricultural Universities

Deemed Universities under ICAR

1. Indian Agricultural Research Institute, New Delhi
2. National Dairy Research Institute, Karnal
3. Indian Veterinary Research Institute, Izatnagar
4. Central Institute on Fisheries Education, Mumbai

ICAR Institutions

1. Central Rice Research Institute, Cuttack
2. Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora
3. Indian Institute of Pulses Research, Kanpur
4. Central Tobacco Research Institute, Rajahmundry
5. Indian Institute of Sugarcane Research, Lucknow
6. Sugarcane Breeding Institute, Coimbatore
7. Central Institute of Cotton Research, Nagpur
8. Central Research Institute for Jute and Allied Fibres, Barrackpore
9. Indian Grassland and Fodder Research Institute, Jhansi
10. Indian Institute of Horticultural Research, Bangalore
11. Central Institute of Sub Tropical Horticulture, Lucknow
12. Central Institute of Temperate Horticulture, Srinagar
13. Central Institute of Arid Horticulture, Bikaner
14. Indian Institute of Vegetable Research, Varanasi
15. Central Potato Research Institute, Shimla
16. Central Tuber Crops Research Institute, Trivandrum
17. Central Plantation Crops Research Institute, Kasargod
18. Central Agricultural Research Institute, Port Blair
19. Indian Institute of Spices Research, Calicut
20. Central Soil and Water Conservation Research & Training Institute, Dehradun
21. Indian Institute of Soil Sciences, Bhopal
22. Central Soil Salinity Research Institute, Karnal
23. ICAR Research Complex for Eastern Region including Centre of Makhana, Patna
24. Central Research Institute of Dryland Agriculture, Hyderabad
25. Central Arid Zone Research Institute, Jodhpur
26. ICAR Research Complex Goa
27. ICAR Research Complex for NEH Region, Barapani
28. National Institute of Abiotic Stress Management, Malegaon, Maharashtra
29. Central Institute of Agricultural Engineering, Bhopal
30. Central Institute on Post harvest Engineering and Technology, Ludhiana
31. Indian Institute of Natural Resins and Gums, Ranchi
32. Central Institute of Research on Cotton Technology, Mumbai
33. National Institute of Research on Jute & Allied Fibre Technology, Kolkata
34. Indian Agricultural Statistical Research Institute, New Delhi
35. Central Sheep and Wool Research Institute, Avikanagar, Rajasthan
36. Central Institute for Research on Goats, Makhdoom

37. Central Institute for Research on Buffaloes, Hissar
38. National Institute of Animal Nutrition and Physiology, Bangalore
39. Central Avian Research Institute, Izatnagar
40. Central Marine Fisheries Research Institute, Kochi
41. Central Institute Brackishwater Aquaculture, Chennai
42. Central Inland Fisheries Research Institute, Barrackpore
43. Central Institute of Fisheries Technology, Cochin
44. Central Institute of Freshwater Aquaculture, Bhubneshwar
45. National Academy of Agricultural Research & Management, Hyderabad

National Research Centres

1. National Research Centre on Plant Biotechnology, New Delhi
2. National Centre for Integrated Pest Management, New Delhi
3. National Research Centre for Litchi, Muzaffarpur
4. National Research Centre for Citrus, Nagpur
5. National Research Centre for Grapes, Pune
6. National Research Centre for Banana, Trichi
7. National Research Centre Seed Spices, Ajmer
8. National Research Centre for Pomegranate, Solapur
9. National Research Centre on Orchids, Pakyong, Sikkim
10. National Research Centre Agroforestry, Jhansi
11. National Research Centre on Camel, Bikaner
12. National Research Centre on Equines, Hisar
13. National Research Centre on Meat, Hyderabad
14. National Research Centre on Pig, Guwahati
15. National Research Centre on Yak, West Kemang
16. National Research Centre on Mithun, Medziphema, Nagaland
17. National Centre for Agril. Economics & Policy Research, New Delhi

National Bureaux

1. National Bureau of Plant Genetics Resources, New Delhi
2. National Bureau of Agriculturally Important Micro-organisms, Mau, Pradesh
3. National Bureau of Agriculturally Important Insects, Bangalore
4. National Bureau of Soil Survey and Land Use Planning, Nagpur
5. National Bureau of Animal Genetic Resources, Karnal
6. National Bureau of Fish Genetic Resources, Lucknow

Directorates/Project Directorates

1. Directorate of Maize Research, New Delhi.
2. Directorate of Rice Research, Hyderabad
3. Directorate of Wheat Research, Karnal
4. Directorate of Oilseed Research, Hyderabad
5. Directorate of Seed Research, Mau

6. Directorate of Sorghum Research, Hyderabad
7. Directorate of Groundnut Research, Junagarh
8. Directorate of Soybean Research, Indore
9. Directorate of Rapeseed & Mustard Research, Bharatpur
10. Directorate of Mushroom Research, Solan
11. Directorate on Onion and Garlic Research, Pune
12. Directorate of Cashew Research, Puttur
13. Directorate of Oil Palm Research, Pedavegi, West Godawari
14. Directorate of Medicinal and Aromatic Plants Research, Anand
15. Directorate of Floriculture Research, Pusa, New Delhi
16. Project Directorate for Farming Systems Research, Modipuram
17. Directorate of Water Management Research, Bhubaneshwar
18. Directorate of Weed Science Research, Jabalpur
19. Project Directorate on Cattle, Meerut
20. Project Directorate on Foot & Mouth Disease, Mukteshwar
21. Project Directorate on Poultry, Hyderabad
22. Project Directorate on Animal Disease Monitoring and Surveillance, Hebbal, Bangalore
23. Directorate of Information & Publication in Agriculture (DIPA), New Delhi
24. Directorate of Cold Water Fisheries Research, Bhimtal, Nainital
25. Directorate of Research on Women in Agriculture, Bhubaneshwar

List of State Agricultural Universities

1. Acharya N G Ranga Agricultural University
   Rajendranagar, Hyderabad (Andhra Pradesh) 500 030

2. Andhra Pradesh Horticulture University
   Tadepalligudam (Andhra Pradesh) 534 101

3. Anand Agricultural University
   Anand (Gujarat) 388 110

4. Assam Agricultural University, Jorhat
   (Assam) 785 013

5. Bidhan Chandra Krishi Vishwa Vidyalaya
   Mohanpur, Nadia (West Bengal) 741 252

6. Bihar Agricultural University
   Sabour (Bihar) 813 210

7. Birsa Agricultural University
   Ranchi (Jharkhand) 834 006

8. Chandra Shekhar Azad University of Agriculture
   and Technology, Kanpur (Uttar Pradesh) 208 002

9. Chaudhary Charan Singh Haryana Agricultural
   University, Hisar (Haryana) 125 004

10. Ch Sarwan Kumar Krishi Vishwavidyalaya
    Palampur (Himachal Pradesh) 176 062

11. Dr Balaesahib Sawant Konkan Krishi Vidyapeeth
    Dapoli (Maharashtra) 415 712

12. Dr Panjabrao Deshmukh Krishi Vidyapeeth
    Akola (Maharashtra) 444 104

13. Dr Yashwant Singh Parmar University of
    Horticulture and Forestry Nauni, Distt Solan
    (Himachal Pradesh) 173 230

14. Govind Ballabh Pant University of Agriculture
    and Technology Pantnagar (Uttaranchal) 263 145

15. Guru Angad Dev Veterinary and Animal Sciences

University PAU Campus, Ludhiana, Punjab 141 004

16. Indira Gandhi Krishi Vishwavidyalaya
Raipur (Chhatisgarh) 492 012

17. Jawaharlal Nehru Krishi Vishwa Vidyalaya
Jabalpur, (Madhya Pradesh) 482 004

18. Junagarh Agricultural University
Junagarh (Gujarat) 362 001

19. Karnataka Veterinary, Animal and Fisheries
Sciences University Bidar (Karnataka) 585 401

20. Kerala Agricultural University
Vellanikara, Distt Trichur (Kerala) 680 656

21. Kerala University of Fisheries & Ocean Studies,
Papangad, Kochi -682506, Kerala

22. Lala Lajpat Rai University of Vety. And
Animal Science , Hisar

23. Kerala Veterinary & Animal Sciences University
Pookode (Kerala)

24. Madhya Pradesh Pashu Chikitsa Vigyan Vishwa Vidyalaya
Jabalpur (Madhya Pradesh)

25. Maharashtra Animal Sciences and Fisheries University, Nagpur
(Maharashtra) 440 006

26. Maharana Pratap University of Agriculture & Technology, Udaipur
(Rajasthan) 313 001

27. Mahatma Phule Krishi Vidyapeeth
Rahuri (Maharashtra) 413 722

28. Marathwada Agricultural University
Parbhani (Maharashtra) 431 402

29. Manyavar Shri Kanshiram Ji University of Agril. & Technology
Banda (U.P)

30. Narendra Dev University of Agriculture
and Technology Faizabad (Uttar Pradesh) 224 229

31. Navsari Agricultural University
    Navsari (Gujarat) 396 450

32. Orissa University of Agriculture and Technology, Bhubaneshwar
    (Orissa) 751 003

33. Punjab Agricultural University
    Ludhiana (Punjab) 141 004

34. Swami Keshavanand Rajasthan Agriculture University
    Bikaner (Rajasthan) 334 006

35. R V S Krishi Vishwa Vidyalaya
    Gwalior (Madhya Pradesh) 474 002

36. Rajasthan University of Veterinary & Animal Sciences
    Bikaner (Rajasthan)

37. Rajmata Vijayaraje Scindia
    Krishi Vishwa Vidyalaya, Gwalior (Madhya Pradesh) 474 002

38. Rajendra Agricultural University
    Samastipur, Pusa (Bihar) 848 125

39. SD Agricultural University
    Dantiwada (Gujarat) 385 506

40. Sardar Ballabh Bhai Patel University of Agriculture, and Technology
    Modipuram, Meerut (Uttar Pradesh) 250 110

41. Sher-E-Kashmir University of Agricultural Sciences and Technology
    Srinagar (Jammu and Kashmir) 191 121

42. Sher-e-Kashmir University of Agricultural
    Sciences and Technology of Jammu
    45-B, Gandhinagar, PB 37 Jammu (Jammu and Kashmir) 180 009

43. Sri Venkateswara Veterinary University
    Tirupati (Andhra Pradesh) 517 502

44. San Higginbottom Institute of Agriculture, Technology & Science
    Rewa Road, Allahabad – 211007, Uttar Pradesh

45. Tamil Nadu Agricultural University
    Coimbatore (Tamil Nadu) 641 003

46. Tamil Nadu Veterinary and Animal Sciences
University, Chennai (Tamil Nadu) 600 051

47. University of Agricultural Sciences, GKVK
Bangalore (Karnataka) 560 065

48. University of Agricultural Sciences
Dharwad (Karnataka) 580 005

49. University of Agricultural Sciences
Raichur (Karnataka) 584 101

50. University of Horticultural Sciences
Bagalkot (Karnataka) 587 102

51. UP Deen Dayal Upadhyaya Veterinary and Animal Science
University Mathura (Uttar Pradesh) 281 001

52. Uttar Banga Krishi Vishwavidyalaya
Pundibari, Cooch, Bihar (West Bengal) 736 165

53. Uttarakhand University of Horticulture & Forestry,
Bharsar (Pauri Garhwal)

54. West Bengal University of Animal and
Fishery Sciences, 68KB Sarani Kolkata (West Bengal) 700 037

55. Central Agricultural University
Imphal (Manipur) 795 004

56. Aligarh Muslim University
Aligarh (Uttar Pradesh) 202 002

57. Banaras Hindu University
Varanasi (Uttar Pradesh) 221 005

58. Upacharya, Visva Bharati
Sriniketan (West Bengal) 731 236

59. Viswa Bharti, Palli Bhavana
Shantiniketan (West Bengal) 731 236

60. Nagaland University
Medziphema (Nagaland) 797 106

Annexure II: Composition of different Sub-Groups and their terms of reference

No.M-12043/03/2011-Agri.
Planning Commission
Government of India
(Agriculture Division)

Yojana Bhawan, Parliament Street
New Delhi, the 24th May, 2011

ADDENDUM

Subject: Constitution of the Sub-Groups in the Working Group on "Agricultural Research and Education (DARE)" for the Twelfth Five Year Plan (2012-17)- Regarding.

In continuation of Planning Commission's earlier order of even No. dated 8th March, 2011 regarding **Constitution of the Working Group on " Agricultural Research and Education(DARE)for the Twelfth Five Year Plan (2012-17),** it has been decided with the approval of the Chairman and Member-Secretary to constitute the Sub-Groups under Working Group in the context of preparation of the Twelfth Five Year Plan. The theme area, Composition and Terms of Reference(TORs as per Working Group Notification & ** New TORs) of the Sub-Groups will be as follows:-

1. Sub-Group –I: Review of 11th Plan Programmes, modification – Up scaling, duplication and deletion of non-performing projects.

Composition:

1. **Dr Sudhir Bhargava** **Chairman**
2. Dr. H.S. Gupta; Director, IARI;
3. Dr. Balasubramanium, TNAU;
4. Dr. K.S. Khokkar; VC,HAU, Hisar;
5. Dr. Ravindra Kumar, ADG
6. Dr. A.K. Vashisht, ADG (PIM) **Member Convener**

Terms and reference (Specific)

I. To assess the extent by which the research projects drawn up during XI Plan have been able to meet the objectives in addressing the problems of agriculture.
II. To suggest modifications/ improvements in the on-going projects for enhancing their effectiveness in terms of impact and accountability, and also recommend winding- up schemes that could not deliver expected outcome made significant impact so far.
III. To recommend measures to synergies the efforts of SAUs and ICAR in order to avoid duplication of research.

2. Sub-Group –II: Improving production and productivities of crops and pulses, strengthening seed chain, high priority research and private investments in Research in Agriculture & Allied Sectors.

Composition:

1. **Dr. Swapan K. Datta** **Chairman**
2. Dr. K.S. Charak, Adviser, DBT;
3. Dr. C.L.L. Gowda, ICRISAT;
4. Dr. R.B. Deshmukh, ex-VC, MPKV;
5. Dr. O.P. Yadav, PC, Pearl Millet; Dr. D. Sirkar, CRIJAF;
6. Dr. B.R. Krishnaswamy;
7. Dr. K. Kranti, CICR
8. Dr. P. Ananda Kumar, NRCPB **Member Convener**

Terms and reference (Specific)

I. To study the present level of private investment in agricultural research and education, and suggest modalities for up-scaling the same through PPP mode in specific areas of animal health, agriculture entrepreneurship and agriculture education and fisheries.
II. To suggest high priority research areas and mechanism for their effective redressal in a given time frame.

3. Sub-Group –III: Improving Soil Health and Water Management.

Composition: **Dr. R.K. Gupta** **Chairman**

1. Dr. Gurbachan Singh, AC, DAC;
2. Dr. Alok Sikka, Member, NRAA; Dr. Kaushik Mazumdar, IPNI;
3. Dr. S.K. Tripathi, Professor, WRDTC, IIT, Rurkee
4. Dr. Dipak Sarkar, NBSS-LUP **Member Convener**

Terms and reference (Specific)

I. To suggest research priorities, strategies and investments for improving soil health and productivity, input use efficiency and water use efficiency.
II. Bio-mass availability for livestock productivity, shortages and new opportunities for improving health/productivity of livestock.
III. Perception on new mechanization needs if conservation agriculture is the strategy of producing more at less cost sustainability.
IV. Resource base, land degradation and land use plans, new crop acreages etc.

4. Sub-Group –IV Enhancing preparedness for climate change

Composition:

1. **Dr. Kirit Shelat** **Chairman**
2. Dr. A.K. Singh, DDG, NRM;
3. Dr. P.K. Agarwal, IWMI;
4. Dr Arbinda Mishra TERI, Director, CAZRI; Director CRIDA
5. Dr. C.S. Rathore, IMD
6. Dr. P.S. Minhas, ADG (SW&M) **Member Convener**

Terms and reference (Specific)

I. To review climate mitigation and adaptation strategies in agriculture and allied sectors and suggest new facets if any, in this critical area.
II. Carbon sequestration aspects i.e., how to follow the low carbon development pathways.
III. To propose working hypothesis for short term and long term climate variability.

5 Sub-Group –V: Higher Education to meet emerging challenges including secondary agriculture and private investment in agriculture & allied sectors

Composition:

1. **Dr. S.L. Mehta** **Chairman**
2. Dr. Dr. Arvind Kumar, DDG (Edn);
3. Dr. Dr. H.S. Nainawati Ex.ADG (Edn);
4. Dr. N.H. Rao, NAARM;
5. Dr. P. Thangraju, Ex-VC,Chennai
6. Dr. N.C. Patel, VC, Junagarh
7. Dr. R.K. Mittal, (ADG) **Member Convener**

Terms and reference (Specific)

I. To review higher education system so as to meet the current and emerging challenges.
II. To study the present level of private investment in agricultural research and education, and suggest modalities for up-scaling the same through PPP mode in specific areas of animal health, agriculture entrepreneurship and agriculture education and fisheries.
III. Capacity building & human resource development – including non-formal education and training.

6. Sub-Group –VI Institutional linkages and Technology commercialization

Composition

1. **Dr. P.L. Gautam, Chairperson, PPV&FR** **Chairman**
2. Dr. M.K. Bhan Secretary, DBT;
3. Dr. S.L. Mehta, Ex-VC, MPUA&T;
4. Dr. R.P. Singh, IAUA;
5. Dr. K Vijayraghavan (Sathguru);
6. Dr. P.G. Chengappa;

7. Dr. Uday Singh;
8. Dr. S.M. Sikka, Pantnagar
9. Dr. R.K. Mittal ADG (EQR) **Member Convener**

Terms and reference (Specific)

I. Inter-Institutional linkages for synergy

7. Sub-Group –VII Out-reach programmes linkages ITK and backstopping for small/ marginal holdings

Composition:

1. **Dr. PN Mathur** **Chairman**
2. Dr. A.M. Patnakar, Head, TTC Division, BARC, Mumbai;
3. Dr. K.D. Kokate, DDG (Extn.);
4. Dr. Sarvesh; Director, (Agri.) Karnataka
5. Dr. Ramesh Chand NCAP;
6. Dr. Arora; VC, KU Nainital
7. Dr. A.K. Mehta, ADG (Extn) **Member Convener**

Terms and reference (Specific)

I. To identify relevant and time tested ITKs, and recommend measures to put them into practice by integrating with technology recommendations.
II. To review the outreach programmes of SAUs and ICAR institutes and suggest modalities for their effective linkages with development departments.
III. To recommend short-term and long-term remedial measures for solving critical problems being faced by small and marginal farmers

8. Sub-Group –VIII Measures for financial viability of SAUs

Composition:

1. **1.Dr. S.A. Patil** **Chairman**
2. Dr. Tej Pratap;
3. Dr. Chengappa;
4. Dr.G. Kalloo, VC, JNKVV;
5. Dr. K.S. Khokhar, VC, HAU;
6. Dr. Arvind Kumar, DDG,(Edn)
7. Dr. R.P. Singh, IAUA **Member Convener**

Terms and reference (Specific)

I. To recommend measures to strengthen the financial viability of SAUs.

9. Sub-Group –*I*X Improving production and productivity and value addition in horticultural crops

Composition:

1. **Dr. H.P. Singh , DDG(Hort.), ICAR** **Chairman**
2. Dr. S.P. Ghosh, Ex-DDG (H);
3. Shri Uday Singh Chairman & MD Namdhari Seeds ;
4. Dr. N. Kumar, TNAU;
5. Dr. Karyana, Bangalore;
6. Sh. Sudhansu, Bihar
7. Dr. Umesh Srivastava, ADG (Hort); **Member Convener**

Terms and reference (Specific)

I. To suggest research priorities, strategies and investments for their effective redressal on projectized mode in a given time frame.

10. Sub-Group –X Improving production and productivity and value addition in livestock's

Composition:

1. **Vijay Kumar Tuneja, VC,** GADUVAS **Chairman**
2. Dr. S.L. Goswami, Jt. Dir, NDRI ;
3. Dr. R. Venkatraman, Jt. Director; Bangalore;
4. Dr. D.N. Kamra, Head, Animal Nutrition, IVRI, Izzatnagar;
5. Dr. G.S. Brah, Director, School of Animal Biotechnolology, GADVASU, Ludhiana;
6. Dr. Vineet Bhasin, ICAR HQ
7. Dr. Gaya Prasad, ADG (Ani.Sci) **Member Convener**

Terms and reference (Specific)

I. To follow-up research of recommendation of Bhasin's Committee Report.

II. To suggest research priorities, strategies and investments for their effective redressal on projectized mode in a given time frame.

11. Sub-Group –XI Improving production and productivity and value addition in fisheries

Composition:

1. **Dr. W.S. Lakra , Director, CIFE** **Chairman**
2. Dr. M.V. Gupta, Hyderabad;
3. Dr. K.K. Vas, Ex-Director, DCWFR, Noida;
4. Dr. Syda Rao, Director, CMFRI;
5. Dr. Sarangi, Ex. Director, CIFA
6. ADG (Fishery), ICAR **Member Convener**

Terms and reference (Specific)

I. To suggest research priorities, strategies and investments for their effective redressal on projectized mode in a given time frame.

12. Sub-Group –XII Improvising plant protection research and up scaling its application in PPP mode

Composition:

1. **Dr. C.D. Mayee, Chaiman, ASRB** **Chairman**
2. Dr. S.N. Puri, VC, CAU, Imphal;
3. Dr. Anupam Varma
4. Dr. Bombawale, NCIPM
5. Dr. T.P. Rajendran, ADG (PP), ICAR **Member Convener**

Terms and reference (Specific)

I. To suggest research priorities, strategies and private investments on PPP mode
II. To streamline product registration
III. Up scaling IPM technologies

13. Sub-Group –XIII: Improvising capabilities selected ICAR institutes for enhanced mechanization and post-harvest/ food processing through PPP mode

Composition:

1. **Dr. Anwar Alam, Ex. Vice Chancellor, SKUAST** **Chairman**
2. Dr. M.M. Pandey, DDG (Agril Extn);
3. Dr. N.P.S. Sirohi, ADG;
4. Dr. Pitam Chandra, Director, CIAE, Bhopal
5. Dr. Dipankar De, IARI
6. Dr. Surendra Singh, CIAE, Bhopal
7. Dr. R.T. Patil, former Head, CIPHET, Ludhiana; ramabhau@yahoo.com – mob. 09023334821
8. Dr. S.D. Kulkarni, Project Director, CIAE, Bhopal: email: sdk@ciae.res.in; ph.0755-2521061/2730987
9. Dr. R.K. Pal, Head, Post Harvest Technology, IARI,
10. Dr. Varadaraj, Head, CFTRI,Mysore **Member Convener**

Terms and reference (Specific)

I. To suggest strategies for enhancing Secondary Agriculture (as reflected in Verma report)
II. To promote farm equipment hubs on regional basis.

14. Sub-Group –XIV Up scaling of innovative technologies

Composition:

1. **Prof. Thyagarajan, Retd. Director Research of TNAU** **Chairman**
2. Prof. Sambhu Prasad, Ex Xavier Institute of Management, Bhubaneswar, Orissa;
3. Shri Narendra Nath, Director, NRM, PRADAN, New Delhi;
4. Dr. B.C. Barah, NABARD Chair Professor, IARI, New Delhi. **Member Convener**
   E.mail: barah48@yahoo.com

Terms and reference (Specific)

I. To address the contemporary issues of household food security in the country through the innovation.
II. Designing policy strategy and socio economic impact assessment of the novel technology (SRI)
III. Future policy planning and up scaling.

15. Sub-Group –XV Basic and Strategic Research

Composition:

1. **Dr. H.S. Gupta, Director, IARI, Pusa, New Delhi** **Chairman**
2. Dr. Swapan K Datta, DDG(CS);
3. Prof. P. Balasubramanian, CPMB, TNAU, Coimbatore;
4. Dr. R.C. Upadhyaya, NDRI, Karnal
5. Mr. Raju Barwale, MD, MAHYCO
6. Prof. Jitendra P. Khurana, UDSC, New Delhi
7. Dr. P Ananda Kumar, PD, NRCPB, Pusa,New Delhi **Member Convener**

Terms and reference (Specific)

I. To delineate roles and responsibilities between institutes/SAUs mandating them for basic and strategic research.
II. To consider manpower support and related services to take on such tasks effectively.

Terms and reference (General)

The terms and reference (General) of the Working Group and other contents of the above-mentioned Order would remain unchanged. TA/DA of the above co-opted member shall also be regulated as per Para-II.3 of the earlier Order of even No. dated 11th April, 2011.

(Vandana Dwivedi)
Joint Adviser (Agri)

Distribution

The Chairman and Members of the Working Group/Sub-Groups.

Copy also forwarded to:

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5. Sr. consultant (Agri.), Planning Commission
6. Adviser (Plan Coordination & Management Division), Planning Commission
7. Adviser (Agri)/Adviser (SS) / Joint Adviser (Agri.)/ Director (Agri.)
   Dy. Advisers / SROs/ ROs in the Agriculture Division
8. Pr. Advisers / Advisers of all Divisions
9. Account – I Section

(Vandana Dwivedi)
Joint Adviser (Agriculture)